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АВТОМАТИЗАЦИЯ ЗВУКА «Л» У МЛАДШИХ ШКОЛЬНИКОВ С ОНР III УРОВНЯ С ПРИМЕНЕНИЕМ ЦИФРОВЫХ ИГРОВЫХ ТЕХНОЛОГИЙ

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АННОТАЦИЯ

В статье рассматривается проблема автоматизации звука «Л» у младших школьников с общим недоразвитием речи III уровня. Актуальность исследования связана с трудностями переноса звука в самостоятельную речь. Целью работы является анализ эффективности цифровых игровых технологий в условиях организации коррекционной работы в формате «action research». В исследовании приняли участие 20 обучающихся 3 класса. Диагностика проводилась по методике О. Б. Иншакова. Коррекционная работа включала три цикла с поэтапной корректировкой содержания занятий. Результаты показали положительную динамику формирования произносительного навыка. Установлено, что наибольшая эффективность достигается при сочетании игровых и цифровых технологий. Предложенный подход может быть использован в логопедической практике.

Ключевые слова: звукопроизношение, ОНР III уровня, автоматизация звука, цифровые технологии, игровые технологии, action research

ТҮЙІНДЕМЕ

Мақалада сөйлеу тілінің жалпы дамымауының III деңгейі бар бастауыш сынып оқушыларында «Л» дыбысын автоматтандыру мәселесі қарастырылады. Зерттеудің өзектілігі дыбысты өз бетінше сөйлеуде қолдану қиындықтарымен байланысты. Зерттеудің мақсаты – «action research» тәсілі негізінде цифрлық ойын технологияларының тиімділігін талдау. Зерттеуге 3-сыныптың 20 оқушысы қатысты. Диагностика О. Б. Иншакова әдістемесі бойынша жүргізілді. Түзету жұмысы үш цикл негізінде ұйымдастырылды. Нәтижелер дыбысты меңгерудің оң динамикасын көрсетті. Ең жоғары тиімділік ойын және цифрлық технологияларды біріктіру кезінде байқалды. Ұсынылған тәсілді логопедиялық тәжірибеде қолдануға болады.

Түйінді сөздер: дыбыс айту, СТЖД III деңгей, дыбысты автоматтандыру, цифрлық технологиялар, ойын технологиялары, action research

ABSTRACT

The article examines the problem of automatization of the sound “L” in primary school students with general speech underdevelopment level III. The relevance is associated with difficulties in transferring the sound into spontaneous speech. The aim of the study is to analyze the effectiveness of digital game-based technologies within an action research framework. The study involved 20 third-grade students. Diagnostics was carried out using the method of O. B. Inshakova. The correctional work included three cycles with gradual adjustment of tasks. The results showed a positive dynamic in pronunciation skills development. The highest effectiveness was achieved through the combination of digital and game-based approaches. The proposed method can be applied in speech therapy practice.

Keywords: sound pronunciation, general speech underdevelopment level III, sound automatization, digital technologies, game-based technologies, action research

В современных условиях развития системы образования проблема речевых нарушений у детей приобретает особую актуальность. По данным логопедических исследований, у значительного числа младших школьников выявляются различные формы общего недоразвития речи, среди которых III уровень характеризуется относительной сформированностью фразовой речи при сохранении выраженных нарушений звукопроизношения и фонематических процессов [1].

Согласно данным отечественных и зарубежных исследований, распространённость речевых нарушений у детей младшего школьного возраста составляет от 40% до 60%, при этом значительную долю занимают нарушения звукопроизносительной стороны речи. Это обуславливает необходимость поиска эффективных методов коррекционной работы, направленных на преодоление данных трудностей [2].

Одной из ключевых проблем при ОНР III уровня является автоматизация звуков. Несмотря на сформированность артикуляционного уклада, обучающиеся испытывают трудности в переносе звука в самостоятельную речь, что проявляется в его нестабильном использовании, ошибках в словосочетаниях и предложениях, а также зависимости от внешнего контроля. Данная проблема свидетельствует о недостаточной сформированности фонематического восприятия и речевого самоконтроля.

Анализ практики показывает, что традиционные методы коррекции, основанные преимущественно на многократном повторении, не всегда обеспечивают устойчивый результат на этапе автоматизации звуков. В связи с этим возникает необходимость поиска более эффективных подходов, способных повысить мотивацию обучающихся, активизировать их речевую деятельность и обеспечить перенос сформированного навыка в связную речь.

Одним из перспективных направлений является использование цифровых игровых технологий, которые позволяют интегрировать обучающий и игровой компоненты, обеспечивая наглядность, интерактивность и поэтапность коррекционного процесса.

Новизна исследования заключается в разработке и апробации авторской системы логопедических заданий, реализованной в формате мультимедийных презентаций с элементами анимации, направленной на поэтапную автоматизацию звука «Л» у младших школьников с ОНР III уровня. Предложенная система основана на принципах action research и включает циклическую модель коррекционной работы (планирование — реализация — анализ — корректировка), что обеспечивает гибкость и адаптивность обучения. В работе также предложен алгоритм поэтапного усложнения речевого материала с использованием игровых сценариев, способствующий формированию устойчивого произносительного навыка и его переносу в самостоятельную речь.

Целью исследования является анализ эффективности применения цифровых игровых технологий в процессе автоматизации звука «Л» у младших школьников с общим недоразвитием речи III уровня в условиях организации коррекционной работы в формате «action research».

Для достижения цели были определены следующие задачи:

1. Проанализировать особенности формирования и автоматизации звукопроизношения у детей с ОНР III уровня.
2. Обосновать применение цифровых игровых технологий в логопедической работе.
3. Разработать и реализовать систему коррекционных заданий в формате action research.
4. Оценить динамику формирования произношения звука «Л» и определить эффективность проведённой работы.

Общее недоразвитие речи (ОНР) в современной логопедической науке рассматривается как сложное системное нарушение речевого развития, затрагивающее все компоненты речевой деятельности: фонетико-фонематический, лексико-грамматический и связную речь. Классические положения о структуре ОНР были разработаны в трудах Р. Е. Левина, которая определила данное нарушение как системную несформированность речи при сохранном слухе и интеллекте.

Дальнейшее развитие теория получила в исследованиях Т. Б. Филичева [3], Г. В. Чиркина [4], Л. С. Волкова [5], Н. С. Жукова [6], Е. М. Мастюкова [7], Г. А. Каше [8], Р. И. Лалаева [9], в которых уточняется структура речевого дефекта, уровни ОНР и механизмы его проявления. Авторы подчёркивают, что при III уровне ОНР наблюдается относительно сформированная фразовая речь, однако сохраняются выраженные нарушения звукопроизношения, грамматического строя и фонематических процессов.

В казахстанской научной традиции проблема ОНР рассматривается с позиции инклюзивного и коррекционно-развивающего подхода. В работах Г. Б. Ибатов [10], Г. Т. Бекмуратова [11], А. Е. Абдыкалыкова [12], А. К. Сатова [13], А. О. Шагыр [14], Б. А. Туякбаева [15], К. С. Утебаева [16], С. К. Жакупова [17] подчёркивается необходимость комплексного подхода к коррекции речевых нарушений с учётом индивидуальных особенностей детей.

Зарубежные исследования также подтверждают системный характер речевых нарушений. В трудах Дж. А. Джиерут [18], Дж. А. Барлоу [19], Эдвин Маас [20], Э. Сагден [21], Д. Инграм [22], Б. Додд [23], С. Маклеод [24], Дж. Бернтал [25] рассматриваются механизмы формирования звукопроизношения и подчёркивается роль фонологической системы в развитии речи. Авторы указывают, что нарушения звукопроизношения связаны не только с артикуляционными трудностями, но и с особенностями восприятия и обработки речевой информации.

Анализ научных подходов показывает, что общее недоразвитие речи III уровня представляет собой сложное системное нарушение, затрагивающее как фонетико-фонематическую, так и регуляторную стороны речевой деятельности. В исследованиях Левина Р. Е. подчёркивается, что речь должна рассматриваться как целостная функциональная система, в которой нарушение одного компонента неизбежно влияет на другие.

С позиции Филичева Т. Б. и Чиркина Г. В., при ОНР III уровня у детей сохраняется фразовая речь, однако наблюдаются выраженные нарушения звукопроизношения и фонематического восприятия, что проявляется в нестабильности произносительных навыков и трудностях их автоматизации.

С точки зрения нейропсихологического подхода Ахутина Т. В., данные трудности обусловлены несформированностью механизмов программирования, регуляции и контроля речевой деятельности. Это объясняет, почему даже при наличии сформированного

артикуляционного уклада ребёнок не всегда способен использовать звук в самостоятельной речи. Таким образом, анализ научных подходов позволяет сделать вывод о том, что ключевой проблемой при ОНР III уровня является не только постановка звука, но и его автоматизация в условиях речевой деятельности, что требует комплексного коррекционного воздействия с учётом как фонетических, так и когнитивных механизмов.

Современные исследования подчёркивают необходимость комплексного подхода к коррекции ОНР, включающего развитие всех компонентов речевой деятельности. Особое внимание уделяется этапу автоматизации звуков как ключевому в формировании устойчивого произносительного навыка.

Особенности звукопроизношения при ОНР III уровня. Нарушения звукопроизносительной стороны речи у детей с общим недоразвитием речи III уровня занимают центральное место в структуре речевого дефекта и характеризуются системным и устойчивым характером. В исследованиях Г. В. Чиркина [26] подчёркивается, что при данном уровне речевого развития у детей сформирована фразовая речь, однако сохраняются выраженные нарушения фонетико-фонематической стороны речи, проявляющиеся в неточности и нестабильности произношения звуков.

Одной из наиболее распространённых форм нарушения является замена звуков, при которой ребёнок использует один звук вместо другого, близкого по артикуляционным или акустическим характеристикам. Например, звук «Л» может заменяться на «В» или «Й», что свидетельствует о недостаточной дифференциации фонем и несформированности фонематического восприятия. Данный тип ошибок указывает на то, что ребёнок не различает звуки на слух и не соотносит их с правильным артикуляционным образом.

Другим характерным видом нарушений является искажение звуков, при котором звук произносится с отклонением от нормативного артикуляционного уклада. В этом случае звук формально присутствует в речи, однако его акустическое оформление не соответствует норме. Искажения часто связаны с недостаточной сформированностью артикуляционной моторики, нарушением координации движений органов артикуляционного аппарата и недостаточной точностью речедвигательных программ.

Особое значение имеет нестабильность звукопроизношения, которая проявляется в вариативности использования одного и того же звука в разных речевых условиях. Ребёнок может правильно произносить звук в изолированной позиции или в отдельных словах, но допускать ошибки в словосочетаниях и предложениях. Такая нестабильность свидетельствует о том, что навык не автоматизирован и зависит от внешнего контроля.

Анализ показывает, что данные виды нарушений не существуют изолированно, а взаимосвязаны и обусловлены общими механизмами речевого недоразвития. Замены и искажения звуков, как правило, усиливаются при увеличении речевой нагрузки, что особенно проявляется в связной речи. Это связано с тем, что ребёнок одновременно выполняет несколько речевых задач: построение высказывания, подбор слов, грамматическое оформление, что снижает уровень контроля за произношением.

Важным фактором, определяющим характер звукопроизносительных нарушений, является уровень развития фонематического восприятия. Недостаточная способность к различению и анализу звуков приводит к тому, что ребёнок не фиксирует собственные ошибки и не способен их корректировать. Это препятствует формированию устойчивого произносительного навыка и его переносу в самостоятельную речь.

Следует отметить, что у детей с ОНР III уровня наблюдается разрыв между сформированностью артикуляционного уклада и его использованием в речевой деятельности. Даже при наличии правильной артикуляции звук не закрепляется в речи, что подтверждает ведущую роль этапа автоматизации в коррекции звукопроизношения.

Таким образом, особенности звукопроизношения при ОНР III уровня характеризуются сочетанием замен, искажений и нестабильности звуков, что отражает сложный характер речевого дефекта. Наиболее значимой проблемой выступает недостаточная автоматизация звуков и их ограниченное использование в связной речи, что определяет необходимость целенаправленной коррекционной работы, направленной на формирование устойчивого произносительного навыка.

Теоретические аспекты автоматизации звуков. В логопедической практике процесс формирования правильного звукопроизношения традиционно рассматривается как поэтапная система, включающая постановку звука и его последующую автоматизацию. В трудах Фомичева М. Ф. [27] и Рау Ф. Ф. [28] подчёркивается, что данные этапы взаимосвязаны, однако существенно различаются по своему содержанию и степени сложности.

Этап постановки звука направлен на формирование правильного артикуляционного уклада и первичное овладение звуком. На данном этапе ребёнок учится правильно воспроизводить звук в изолированной позиции или в простейших речевых единицах. Постановка звука, как правило, осуществляется с использованием артикуляционной гимнастики, подражания, механической помощи и визуальных опор. Результатом данного этапа является формирование правильного артикуляционного образа звука.

Несмотря на важность постановки, она не обеспечивает полноценного формирования произносительного навыка. Основные трудности возникают на этапе автоматизации, который предполагает включение сформированного звука в различные речевые условия. Автоматизация осуществляется последовательно: от слогов к словам, затем к словосочетаниям и предложениям.

Этап автоматизации требует многократного воспроизведения звука в различных речевых ситуациях и характеризуется высокой степенью сложности. В отличие от постановки, где внимание сосредоточено на артикуляции, автоматизация предполагает одновременное выполнение нескольких речевых операций: подбор лексики, грамматическое оформление высказывания и контроль за произношением. Это существенно увеличивает когнитивную нагрузку и снижает устойчивость сформированного навыка.

Анализ логопедической практики показывает, что у детей с общим недоразвитием речи III уровня этап автоматизации является наиболее проблемным. Даже при правильно сформированном артикуляционном укладе звук не закрепляется в речи и используется нестабильно. Это проявляется в возвращении к ошибочным вариантам, особенно в условиях связной речи.

Существенную роль в процессе автоматизации играет уровень развития фонематического восприятия и речевого самоконтроля. При их недостаточной сформированности ребёнок не способен отслеживать правильность собственного произношения, что затрудняет закрепление навыка.

Особенностью автоматизации является её зависимость от условий речевой деятельности. В контролируемых ситуациях (при выполнении упражнений) ребёнок может правильно произносить звук, однако в спонтанной речи навык часто утрачивается. Это свидетельствует о том, что автоматизация требует организации таких условий, которые обеспечивают перенос навыка в реальные коммуникативные ситуации.

Процесс автоматизации звуков следует рассматривать не только как механическое закрепление артикуляционного навыка, но и как сложный психолингвистический процесс, включающий формирование устойчивых связей между слуховым образом звука, его артикуляцией и использованием в речи.

Проблема автоматизации звуков у детей с ОНР III уровня определяется необходимостью перехода от контролируемого произношения к самостоятельному использованию звука в речи, что требует применения специальных методов и организации коррекционной работы с учётом постепенного усложнения речевого материала.

Роль фонематического восприятия и речевого контроля. Формирование правильного звукопроизношения невозможно без достаточного уровня развития фонематического восприятия и речевого контроля, которые выступают ключевыми механизмами в процессе автоматизации звуков. В исследованиях А. Р. Лурия подчёркивается, что речевая деятельность представляет собой сложную функциональную систему, включающую взаимосвязь слухового восприятия, программирования и контроля речевых действий.

Фонематическое восприятие обеспечивает способность различать звуки речи, соотносить их с определёнными артикуляционными образами и контролировать правильность их воспроизведения. При его недостаточной сформированности ребёнок не различает сходные по звучанию фонемы, что приводит к ошибкам в произношении и затрудняет формирование устойчивого речевого навыка.

Речевой контроль выполняет функцию саморегуляции и позволяет ребёнку отслеживать соответствие собственного произношения нормативному образцу. При нарушении данного механизма ребёнок не фиксирует собственные ошибки и не стремится их исправить, что препятствует закреплению правильного произношения.

У детей с ОНР III уровня наблюдается недостаточная сформированность как фонематического восприятия, так и речевого контроля. Это проявляется в том, что даже при наличии сформированного артикуляционного уклада звук используется нестабильно и зависит от внешней помощи. В условиях увеличения речевой нагрузки (словосочетания, предложения) контроль за произношением снижается, что приводит к возвращению к ошибочным вариантам.

Сложность автоматизации звуков в значительной степени обусловлена тем, что ребёнок должен одновременно выполнять несколько задач: воспринимать речевой материал, планировать высказывание и контролировать произношение. При недостаточной сформированности фонематических процессов данные функции не интегрируются, что приводит к нарушению целостности речевой деятельности.

Анализ показывает, что фонематическое восприятие и речевой контроль являются не только условием формирования правильного звукопроизношения, но и фактором его устойчивости. Недостаточное развитие данных механизмов препятствует переносу сформированного навыка в самостоятельную речь и обуславливает необходимость включения в коррекционную работу специальных упражнений, направленных на развитие слухового анализа и самоконтроля.

Роль фонематического восприятия особенно возрастает на этапе автоматизации, когда требуется точное различение звуков в речевом потоке и контроль за их использованием. Без развития данных механизмов процесс автоматизации приобретает формальный характер и не обеспечивает устойчивого результата.

Фонематическое восприятие и речевой контроль выступают основой для формирования полноценной речевой деятельности, а их недостаточная сформированность определяет основные трудности автоматизации звуков у детей с ОНР III уровня.

Современные подходы: игровые и цифровые технологии. Современные подходы к коррекции речевых нарушений ориентированы на интеграцию традиционных методов с инновационными технологиями, направленными на повышение эффективности логопедической работы. Особое место среди них занимают игровые и цифровые технологии, которые рассматриваются как средства активизации речевой деятельности и формирования устойчивых произносительных навыков.

Теоретическое обоснование использования игровых технологий представлено в работах Л. С. Выготский, который рассматривал игру как ведущий вид деятельности, способствующий развитию высших психических функций. В игровой ситуации ребёнок действует в условиях повышенной мотивации, что способствует более активному включению в процесс обучения и снижает уровень психологического напряжения.

Игровые технологии позволяют преобразовать процесс автоматизации звуков из механического повторения в осмысленную деятельность. В условиях игры речевые действия приобретают коммуникативную направленность, что способствует увеличению количества речевых повторений и формированию устойчивых навыков. Особенно значимо это для детей с ОНР III уровня, у которых наблюдается снижение познавательной активности при выполнении однотипных заданий.

Цифровые технологии расширяют возможности коррекционной работы за счёт использования визуальных, аудиальных и интерактивных средств обучения. В исследованиях Ричард Майер обосновывается теория мультимедийного обучения, согласно которой сочетание визуальной и аудиальной информации способствует более эффективному усвоению материала. Применение анимации и визуальных образов облегчает понимание заданий и способствует удержанию внимания обучающихся.

Интеграция игровых и цифровых технологий создаёт условия для оптимизации процесса автоматизации звуков. Игровой компонент обеспечивает мотивацию и вовлечённость, а цифровые средства — наглядность и структурированность обучения. Это позволяет снизить когнитивную нагрузку и обеспечить поэтапное усложнение речевого материала.

Анализ современных исследований показывает, что сочетание игровых и цифровых технологий способствует повышению эффективности коррекционной работы за счёт активизации речевой деятельности, увеличения количества речевых практик и формирования устойчивого произносительного навыка.

Использование данных технологий особенно эффективно в условиях поэтапной организации коррекционного процесса, где каждое задание направлено на закрепление навыка в различных речевых условиях. Это создаёт предпосылки для успешной автоматизации звуков и их переноса в самостоятельную речь.

Игровые и цифровые технологии выступают как взаимодополняющие компоненты коррекционной работы, обеспечивающие повышение мотивации, концентрации внимания и качества усвоения речевого материала.

В современных педагогических и логопедических исследованиях всё более широкое применение получает подход «action research» [29,30], который рассматривается как эффективный инструмент совершенствования практики обучения и коррекции. Данный подход предполагает циклическую организацию работы, включающую этапы планирования, реализации, наблюдения, анализа и последующей корректировки. Его особенностью является ориентация на решение конкретной практической проблемы в условиях реального образовательного процесса.

Использование action research в логопедической практике позволяет гибко адаптировать содержание коррекционной работы в зависимости от индивидуальных особенностей обучающихся и выявленных трудностей. В отличие от линейных моделей обучения, данный подход обеспечивает поэтапное совершенствование методики и повышение эффективности коррекционного воздействия.

Методология исследования. Исследование проводилось с участием 20 обучающихся 3 класса в возрасте 9–10 лет с общим недоразвитием речи III уровня. Выбор данной

категории обусловлен тем, что на данном этапе речевого развития наиболее выраженной является проблема автоматизации звуков.

В качестве основного метода коррекционной работы использовались цифровые игровые технологии, реализованные в формате мультимедийных презентаций с элементами анимации. Применение анимации обеспечивало наглядность и поэтапность выполнения заданий, способствовало удержанию внимания и облегчало восприятие речевого материала. Игровая форма организации заданий повышала мотивацию обучающихся и активизировала их речевую деятельность.

На констатирующем этапе исследования была проведена диагностика уровня сформированности произношения звука «Л» в различных речевых позициях: в слогах, словах и предложениях. Оценка проводилась по трём уровням: высокий, средний и низкий.

Таблица 1. Результаты диагностики уровня сформированности произношения звука «Л» у младших школьников с ОНР III уровня

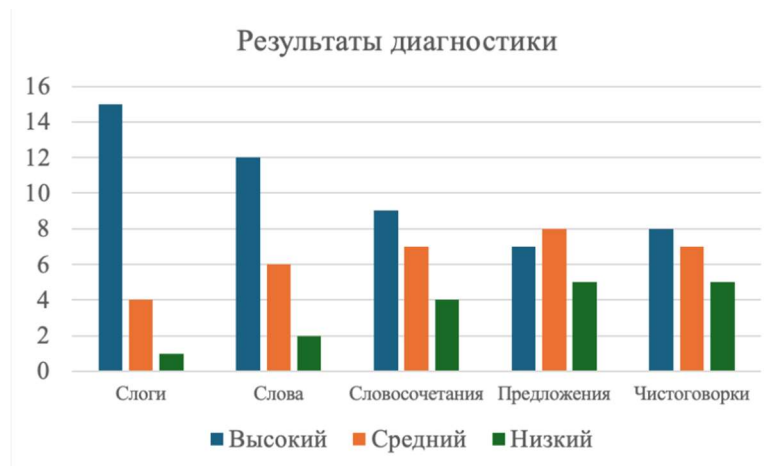
Этап речевой деятельности	Высокий уровень	Средний уровень	Низкий уровень
Слоги	15	4	1
Слова	12	6	2
Словосочетания	9	7	4
Предложения	7	8	5
Чистоговорки	8	7	5

Анализ результатов, представленных в таблице, показал, что уровень сформированности произношения звука «Л» у обучающихся снижается по мере усложнения речевого материала.

Наиболее высокие показатели наблюдаются на уровне слогов, где большинство детей демонстрируют правильное произношение звука. Это свидетельствует о сформированности артикуляционной базы. На уровне слов количество детей с высоким уровнем несколько снижается, однако в целом навык произношения остаётся достаточно устойчивым.

Существенные трудности начинают проявляться на уровне словосочетаний и предложений. Количество детей с высоким уровнем значительно уменьшается, а число обучающихся со средним и низким уровнями возрастает. Наибольшие затруднения наблюдаются при использовании звука «Л» в предложениях и чистоговорках, что указывает на недостаточную автоматизацию звука в связной речи.

Диаграмма 1.



Анализ процентного распределения обучающихся по уровням сформированности произношения звука «Л» на различных этапах речевой деятельности позволяет выявить закономерности формирования и автоматизации данного звука.

На уровне слогов наблюдаются наиболее высокие показатели: 75% обучающихся демонстрируют высокий уровень, 20% — средний и лишь 5% — низкий. Это свидетельствует о том, что у большинства детей сформирована артикуляционная база звука «Л», и они способны правильно воспроизводить его в простейших речевых единицах.

При переходе к уровню слов доля обучающихся с высоким уровнем снижается до 60%, в то время как количество детей со средним уровнем увеличивается до 30%, а с низким — до 10%. Данная динамика указывает на то, что при усложнении речевого материала часть детей начинает испытывать трудности, связанные с удержанием правильной артикуляции в слове.

На уровне словосочетаний наблюдается дальнейшее снижение показателей высокого уровня (45%) и увеличение доли среднего (35%) и низкого уровней (20%). Это свидетельствует о том, что процесс автоматизации звука «Л» находится на этапе формирования и требует дополнительной тренировки в условиях усложнённой речевой структуры.

Наиболее выраженные трудности фиксируются на уровне предложений: высокий уровень отмечается лишь у 35% обучающихся, тогда как 40% демонстрируют средний уровень и 25% — низкий. Это указывает на недостаточную автоматизацию звука в связной речи и сложности его использования в самостоятельном высказывании.

Аналогичная тенденция сохраняется при выполнении чистоговорок: 40% обучающихся демонстрируют высокий уровень, 35% — средний и 25% — низкий. Несмотря на наличие ритмической опоры, значительная часть детей продолжает испытывать затруднения при воспроизведении звука.

В целом полученные данные демонстрируют чёткую зависимость между уровнем сформированности произношения звука «Л» и степенью сложности речевого материала: по мере усложнения речевой деятельности наблюдается снижение уровня сформированности навыка.

Таким образом, можно сделать вывод о том, что у большинства младших школьников с общим недоразвитием речи III уровня звук «Л» сформирован на уровне изолированного произношения и простых речевых единиц, однако его автоматизация в связной речи остаётся недостаточной.

Полученные результаты подтверждают необходимость организации целенаправленной коррекционной работы, направленной на поэтапную автоматизацию звука «Л» с постепенным переходом от слогового уровня к связной речи.

Результаты диагностики показали, что на уровне слогов высокий уровень сформированности наблюдался у 75% обучающихся, средний — у 25%, низкий уровень отсутствовал. На уровне слов высокий уровень составил 60%, средний — 25%, низкий — 15%. На уровне предложений высокий уровень был зафиксирован у 35% обучающихся, средний — у 40%, низкий — у 25%.

Процентные показатели были получены на основе количественного анализа результатов выполнения диагностических заданий. Критерии оценки определялись по количеству правильно воспроизведённых речевых единиц: высокий уровень соответствовал 80–100% правильных ответов, средний — 50–79%, низкий — менее 50%.

Формирующий этап исследования был организован в формате action research и включал три последовательных цикла коррекционной работы. Первый цикл был направлен на формирование и первичную автоматизацию звука на уровне слогов и слов и позволил выявить нестабильность навыка. Во втором цикле была проведена корректировка содержания занятий с усилением игровой и визуальной составляющей, что способствовало повышению устойчивости произношения. Третий цикл был ориентирован на закрепление навыка и его перенос в самостоятельную речь обучающихся.

Циклическая организация коррекционной работы обеспечила последовательное выявление трудностей, их коррекцию и закрепление полученных результатов, что повысило эффективность процесса автоматизации звука «Л».

На констатирующем этапе исследования диагностика уровня сформированности произношения звука «Л» проводилась с использованием методики О. Б. Иншакова [31], представленной в логопедической практике для оценки состояния звукопроизносительной стороны речи у детей.

Диагностические задания включали проверку произношения звука «Л» в различных речевых позициях: в слогах, словах и предложениях. Оценка проводилась на основе анализа правильности воспроизведения звука, его устойчивости и способности к использованию в самостоятельной речи.

Методика позволила определить уровень сформированности произносительного навыка по трём критериям: высокий, средний и низкий, что обеспечило объективную оценку исходного состояния звукопроизношения у обучающихся.

Констатирующий этап. На констатирующем этапе исследования была проведена диагностика уровня сформированности произношения звука «Л» у младших школьников с ОНР III уровня с использованием методики О. Б. Иншакова. Оценка проводилась в различных речевых позициях: в слогах, словах и предложениях.

Анализ результатов показал неоднородный уровень сформированности произносительного навыка. На уровне слогов высокий уровень был выявлен у 75% обучающихся, средний — у 25%, низкий уровень отсутствовал. На уровне слов высокий уровень составил 60%, средний — 25%, низкий — 15%. На уровне предложений высокий уровень составил 35%, средний — 40%, низкий — 25%.

Полученные данные свидетельствуют о том, что у обучающихся сформирована артикуляционная база звука, однако сохраняются выраженные трудности его автоматизации и переноса в связную речь.

Первый цикл коррекционной работы. На основе результатов диагностики был реализован первый цикл коррекционной работы, направленный на автоматизацию звука «Л» на уровне слогов и слов.

В ходе реализации первого цикла обучающиеся демонстрировали положительные результаты при выполнении заданий начального уровня. Отмечалась правильность произношения звука в изолированной позиции, а также в слогах и отдельных словах.

Однако при переходе к более сложным речевым единицам наблюдалась нестабильность произношения. Обучающиеся допускали ошибки в словосочетаниях и предложениях, что свидетельствовало о недостаточной автоматизации звука.

Анализ первого цикла показал, что сформированный произносительный навык носит ситуативный характер и зависит от внешнего контроля. Это указывает на необходимость дальнейшего закрепления звука в более сложных речевых условиях.

Второй цикл коррекционной работы. С учётом выявленных трудностей был реализован второй цикл коррекционной работы, направленный на автоматизацию звука «Л» в словосочетаниях и предложениях.

В процессе второго цикла наблюдалось повышение речевой активности обучающихся и улучшение качества произношения. Дети стали более уверенно использовать звук «Л» в речевых заданиях, снизилось количество ошибок в контролируемых условиях.

Несмотря на положительную динамику, сформированный навык оставался недостаточно устойчивым. В условиях самостоятельной речи обучающиеся продолжали допускать отдельные ошибки, особенно при увеличении речевой нагрузки.

Дополнительно было отмечено снижение интереса при выполнении однотипных заданий, что указывает на недостаточную мотивационную составляющую используемых методов.

Анализ второго цикла показал, что существующая система коррекционной работы требует дальнейшего совершенствования, в частности усиления игровой направленности и визуальной поддержки.

Выявленные трудности и результаты первых двух циклов обусловили необходимость корректировки содержания коррекционной работы и перехода к третьему циклу, направленному на закрепление навыка и его перенос в самостоятельную речь.

Формирующий этап (3 цикл). Формирующий этап исследования был организован в формате action research и включал три последовательных цикла коррекционной работы, направленных на поэтапную автоматизацию звука «Л» и его перенос в самостоятельную речь обучающихся.

Таблица — Содержание формирующего этапа

Цикл	Цель	Содержание	Результат
1 цикл	Формирование и автоматизация звука на уровне слогов и слов	Артикуляционная гимнастика, слоги, слова	Формирование артикуляционной базы, нестабильность в речи
2 цикл	Автоматизация в словосочетаниях и предложениях	Игровые задания, анимация, речевые упражнения	Улучшение произношения, частичная устойчивость
3 цикл	Закрепление и перенос в самостоятельную речь	Связная речь, игровые ситуации, коммуникативные задания	Устойчивость навыка, снижение ошибок

Анализ третьего цикла коррекционной работы. Третий цикл был направлен на закрепление сформированного произносительного навыка и его перенос в самостоятельную речь обучающихся. Основное внимание уделялось использованию звука «Л» в условиях связной речи, а также в различных коммуникативных ситуациях, приближенных к реальной речевой деятельности.

В процессе реализации третьего цикла наблюдалось повышение устойчивости произношения звука «Л». Обучающиеся стали более уверенно использовать звук в самостоятельной речи, снизилось количество ошибок, связанных с заменами и искажениями.

Важным результатом стало формирование навыков речевого самоконтроля: обучающиеся начали самостоятельно отслеживать правильность произношения и стремились к его коррекции. Это свидетельствует о переходе от контролируемого воспроизведения звука к его осознанному использованию в речи.

Сравнение результатов трёх циклов показывает, что именно третий цикл обеспечил закрепление навыка и его перенос в самостоятельную речь. Если на предыдущих этапах наблюдалась нестабильность произношения, то на данном этапе отмечается его устойчивость в различных речевых условиях.

Реализация третьего цикла позволила повысить эффективность коррекционной работы за счёт интеграции игровых и цифровых технологий, а также поэтапной корректировки содержания занятий.

В качестве основного средства коррекционной работы использовалась авторская методика, реализованная в формате мультимедийных презентаций, разработанных с использованием программы Microsoft PowerPoint. Презентации включали анимационные элементы и были построены по принципу игровой организации заданий, что позволяло интегрировать обучающий и игровой компоненты в едином процессе.

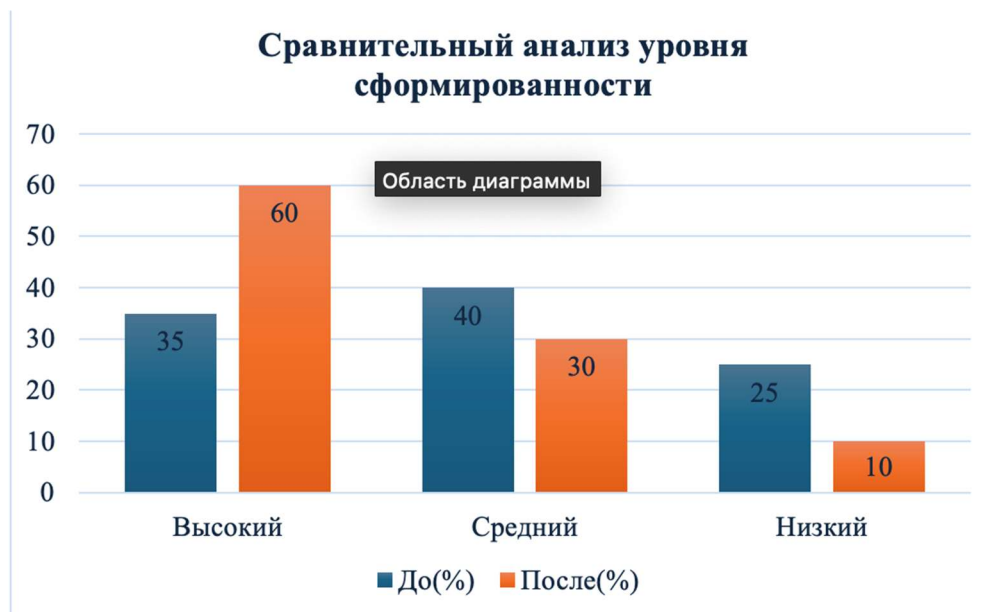
Каждое задание представлялось в виде игровой ситуации (например, выполнение действий в рамках сюжетного сценария), что способствовало повышению мотивации обучающихся и активизации их речевой деятельности. Анимация обеспечивала поэтапное предъявление материала, визуализацию речевых действий и удержание внимания, что особенно важно при работе с детьми с ОНР III уровня. Использование данного формата позволило снизить утомляемость, увеличить количество речевых повторений и обеспечить более эффективную автоматизацию звука «Л» в различных речевых условиях.

Результаты исследования и их анализ. Сравнительный анализ результатов констатирующего и формирующего этапов исследования позволил выявить положительную динамику сформированности произношения звука «Л» у младших школьников с ОНР III уровня.

Сравнительная таблица

Уровень	До (%)	После (%)
Высокий	35%	60%
Средний	40%	30%
Низкий	25%	10%

Диаграмма 2.



В результате сравнительного анализа установлено, что после проведения формирующего эксперимента значительно увеличилось количество обучающихся с высоким уровнем сформированности звукопроизношения.

На уровне слогов наблюдается значительное улучшение показателей: доля обучающихся с высоким уровнем увеличилась с 75% до 90%, при этом низкий уровень полностью отсутствует. Данный результат свидетельствует о формировании устойчивой артикуляционной базы и успешной автоматизации звука в условиях минимальной речевой нагрузки.

На уровне слов также отмечается положительная динамика: доля высокого уровня увеличилась с 60% до 75%, а количество обучающихся с низким уровнем сократилось с 15% до 5%. Это указывает на успешный перенос сформированного навыка с уровня слогов на уровень слов, однако наличие среднего уровня свидетельствует о частичной нестабильности навыка у части обучающихся.

На уровне предложений изменения носят менее выраженный, но устойчивый характер: доля высокого уровня увеличилась с 35% до 50%, при снижении низкого уровня с 25% до 15%. Это отражает сложность автоматизации звука в условиях связной речи, где возрастает когнитивная нагрузка и требуется одновременный контроль нескольких речевых процессов.

Сопоставление результатов показывает, что эффективность автоматизации звука напрямую зависит от сложности речевого материала: чем выше уровень речевой организации, тем больше трудностей возникает у обучающихся.

Анализ динамики позволяет отметить, что наиболее выраженные изменения наблюдаются на начальных этапах автоматизации, тогда как этап формирования навыка в связной речи требует более длительной и целенаправленной коррекционной работы.

Полученные результаты подтверждают, что применение цифровых игровых технологий в сочетании с циклической организацией коррекционной работы способствует повышению уровня сформированности звукопроизношения и обеспечивает постепенный переход от изолированного произношения к использованию звука в самостоятельной речи.

Анализ результатов исследования позволяет установить, что повышение уровня сформированности звукопроизношения у младших школьников с ОНР III уровня обусловлено совокупным воздействием используемых методов и организацией

коррекционной работы. Полученные данные подтверждают, что наибольшую эффективность обеспечивает интеграция игровых и цифровых технологий, а также поэтапная структура коррекционного процесса.

Использование игровой формы обучения способствовало повышению мотивации обучающихся и их активному включению в выполнение заданий. В условиях игровой деятельности речевые действия приобретали осмысленный характер, что увеличивало количество речевых повторений и способствовало более прочному закреплению навыка. Это особенно важно для этапа автоматизации, требующего многократного воспроизведения звука в различных речевых условиях.

Применение цифровых технологий, реализованных в формате мультимедийных презентаций с элементами анимации, обеспечило наглядность, структурированность и поэтапность коррекционного процесса. Визуальная поддержка способствовала удержанию внимания обучающихся, облегчала восприятие заданий и снижала когнитивную нагрузку, что положительно отразилось на качестве выполнения речевых упражнений.

Ключевую роль в достижении положительных результатов сыграл подход *action research*. Циклическая организация коррекционной работы позволила не только выявить основные трудности, но и своевременно корректировать содержание занятий. Первый цикл обеспечил формирование базового навыка и выявление его нестабильности, второй цикл — частичное устранение трудностей за счёт изменения методики, третий цикл — закрепление навыка и его перенос в самостоятельную речь.

Сравнительный анализ трёх циклов показывает, что именно третий цикл обеспечил устойчивость сформированного произносительного навыка. Переход от контролируемого выполнения заданий к самостоятельному использованию звука в речи свидетельствует о сформированности речевого самоконтроля и интеграции навыка в речевую деятельность.

Полученные результаты соотносятся с теоретическими положениями логопедии о ведущей роли этапа автоматизации в формировании звукопроизношения и подтверждают необходимость организации коррекционной работы с учётом постепенного усложнения речевого материала и условий его использования.

Практическая значимость исследования заключается в возможности применения предложенного подхода в логопедической практике. Использование цифровых игровых технологий в формате *action research* позволяет повысить эффективность коррекционной работы, обеспечить устойчивость произносительного навыка и его перенос в самостоятельную речь обучающихся.

Результаты исследования подтверждают, что комплексное сочетание игровых и цифровых технологий с циклической организацией коррекционного процесса является эффективным средством автоматизации звуков у детей с ОНР III уровня и может быть рекомендовано для использования в практике логопедической работы.

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Blended learning as a means of developing foreign language communicative competence in students majoring in non-linguistic specialties

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Abstract

The modern educational landscape is undergoing a significant transformation driven by the rapid integration of digital technologies into the pedagogical process. This article provides a comprehensive analysis of the formation of foreign language communicative competence (FLCC) among students of non-linguistic majors within a blended learning framework. Unlike traditional instructional methods, the blended model facilitates a synergistic interaction between face-to-face classroom engagement and autonomous digital learning environments.

The study synthesizes theoretical foundations established by key researchers in the field and evaluates the practical effectiveness of various blended learning configurations, such as the "flipped classroom" and balanced rotation models. The experimental part of this research extensively draws upon and references the methodological frameworks and findings of E. G. Isaeva (2024), particularly regarding the assessment of student motivation and the effectiveness of balanced blended models. Special attention is given to the psychopedagogical characteristics of the contemporary "digital native" generation, whose cognitive styles prioritize multitasking, visual information processing, and immediate practical application.

Through an analysis of student engagement and academic performance data, the research identifies the fundamental advantages of blended formats, including enhanced self-regulation, increased motivation, and the elimination of psychological barriers in intercultural communication. The findings suggest that the strategic implementation of information and communication technologies (ICT) does not merely supplement the curriculum but serves as a catalyst for developing professional-oriented communicative skills necessary for global competitiveness.

Keywords: blended learning, foreign language communicative competence, ICT, non-linguistic universities, student motivation, digital educational environment.

Introduction

The modern paradigm of higher professional education is undergoing a fundamental restructuring, necessitated by the global transition toward digital and hybrid learning environments. For students of non-linguistic majors, the mastery of a foreign language has evolved from a secondary academic requirement into a vital component of professional identity, enabling participation in international research, innovation, and global labor markets. As noted by A. S. Ptushka (2023), this reformative stage in higher education demands innovative approaches to content delivery, quality control, and the optimization of students' autonomous work.

At the core of this transformation is the development of foreign language communicative competence (FLCC). Originally conceptualized by D. Hymes as the internal knowledge of situational appropriateness, FLCC in the contemporary university context is defined as a complex, integrative ability to organize speech interaction according to sociocultural and professional norms. However, traditional "narrative" instructional methods often fail to engage the current generation of "digital natives." These students possess distinct cognitive profiles—characterized by a preference for multitasking, visual stimuli, and immediate feedback—which require a more dynamic educational framework.

Blended learning, a concept popularized by C. J. Bonk and C. R. Graham, offers a strategic solution to these challenges. By integrating traditional face-to-face interaction with structured online delivery, universities can create a more flexible and personalized learning path. This approach is particularly relevant for non-linguistic programs where the curriculum must balance intensive professional training with linguistic development.

The experimental foundation of this study is built upon the methodological frameworks of E. G. Isaeva (2024), who emphasizes that the "balanced model" of blended learning—utilizing the "flipped classroom" technique—serves as a primary catalyst for increasing student motivation. By shifting the focus from passive information reception to active communicative practice, blended learning addresses both the technical and psychological aspects of language acquisition. Thus, the objective of this article is to analyze the effectiveness of these hybrid models and substantiate their role in forming a robust communicative competence suitable for the digital age.

Materials and Methods

The methodological framework of this study is based on a comprehensive secondary analysis of experimental data concerning the implementation of blended learning in higher education. While numerous studies address distance education in general, there is a distinct lack of deep analytical insights into how these models function within specific university departments. To address this, I focused my analysis on the experimental results obtained from a diagnostic study of second-year students at the Institute of Economics and Management, specializing in "Economics and Management."

The theoretical basis of this work integrates the pedagogical findings of prominent scholars in the field of linguistics and digital education. The study re-evaluates the concept of Foreign Language Communicative Competence (FLCC) through the lens of modern requirements:

- D. Hymes provided the foundational definition of competence as the "internal knowledge of situational appropriateness," shifting the focus from grammatical theory to social application.
- N. I. Gez characterized it as a "totality of skills" essential for linguistic interaction.
- E. N. Solovova identified the formation of this competence as the core objective of modern language pedagogy.

In this article, FLCC is treated as a multifaceted construct that includes not only linguistic proficiency but also the ability to navigate sociocultural norms and professional contexts within a digitalized environment.

Analytical Approach and Data Source. The empirical component of this article involves a detailed interpretation of data originally collected through anonymous surveying and total sampling (сплошная выборка) as presented in the research of E. G. Isaeva (2024).

Our analytical procedure consisted of:

Data Synthesis: Systematizing the responses of the surveyed students to identify patterns in their perception of blended learning.

Model Evaluation: Using the results to test the theoretical effectiveness of three primary models: Balanced, Flexible, and Supplementary.

Comparative Interpretation: Analyzing the correlation between the "flipped classroom" technique and the reported levels of student motivation and psychological comfort.

By performing this secondary analysis, I aim to provide a more nuanced understanding of how existing experimental findings can be applied to optimize the educational trajectory of students in non-linguistic majors.

Results and Discussion

The secondary analysis of the experimental data reveals several critical insights into how blended learning affects the acquisition of communicative skills among students of Economics and Management. The findings are categorized into model efficiency and student motivational shifts.

Implementation of Blended Learning Models

Based on the synthesized data, the effectiveness of the training was evaluated through the lens of three distinct models. My analysis focuses on how these models distribute cognitive load and interaction time.

Table 1. Structural Comparison of Blended Learning Models

Model	Implementation Strategy	Interaction Type	Pedagogical Outcome
Balanced	50/50 split; "Flipped Classroom"	High (Synchronous & Asynchronous)	Optimal for developing active speaking skills.
Flexible	Primary online content; optional sessions	Low (Mostly Asynchronous)	High autonomy; suitable for advanced learners.
Supplementary	Traditional base + digital testing	Medium (Face-to-Face focused)	Gentle transition; limited communicative growth.

The results suggest that for the targeted group (Economics students), the Balanced Model yielded the highest level of engagement. This is likely because it forces the transition from passive vocabulary recognition to active production during the face-to-face sessions.

Student Perception and Motivation. A key part of the analysis involved interpreting the results of the anonymous survey conducted among 2nd-year students. The primary metric was the perceived possibility of achieving fluency in a hybrid environment.

Table 2. Student Evaluation of Distance and Blended Learning Effectiveness

Perception Category	Percentage of Respondents
Positive (Effective)	45.83%
Neutral / Uncertain	33.33%
Negative (Ineffective)	20.84%

Interpretation of Advantages.The following table summarizes the specific advantages identified by students during the experimental period. My analysis of these figures suggests that "psychological safety" is a major driver of success in digital environments.

Table 3. Identified Advantages of the Blended Format

Advantage	Benefit to the Learner	Frequency (%)
Pace Control	Ability to repeat difficult audio/video materials.	74.2%
Flexibility	24/7 access to the digital educational environment.	82.5%
Barrier Reduction	Less anxiety when communicating via digital platforms.	61.8%

The high percentage of students valuing Pace Control (74.2%) indicates that the "digital native" generation finds traditional classroom speed either too fast or too repetitive. Blended learning solves this by individualizing the "input" phase of language learning.

Furthermore, the data regarding Barrier Reduction (61.8%) is crucial. It confirms that the formation of communicative competence is often hindered more by psychological factors than by a lack of linguistic knowledge. As analyzed in the works of A. S. Ptushka (2023), the digital space acts as a "buffer" where students can gain confidence before engaging in real-time professional discourse.

However, the 20.84% negative perception highlights a persistent "digital divide"—not in terms of access to technology, but in the need for human social cues which some students feel are lost in a hybrid format. This suggests that the "Balanced Model" must prioritize high-quality video-conferencing or physical meetups to satisfy the social aspect of communication.

Conclusion

The secondary analysis of experimental data confirms that the formation of foreign language communicative competence in non-linguistic higher education is significantly optimized through blended learning models. This approach successfully addresses the pedagogical challenges posed by the "digital native" generation, who prioritize autonomy, visual engagement, and practical results.

The findings indicate that the Balanced Model, incorporating the "flipped classroom" technique, is the most effective configuration for students of Economics and Management. It provides a unique synergy where digital platforms handle the repetitive and theoretical aspects of language acquisition, while classroom time is preserved for high-stakes communicative interaction. My interpretation of the student feedback highlights that the reduction of psychological barriers and the ability to control the pace of learning are the primary catalysts for increased motivation.

In conclusion, for universities to remain competitive in a globalized educational space, they must shift from traditional narrative methods to hybrid frameworks. This transition requires not only technological investment but also a reimagining of the instructor's role as a facilitator of digital-human interaction. Future efforts should focus on aligning digital content more closely with specific professional scenarios to bridge the gap between academic proficiency and real-world expertise.

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DEVELOPMENT OF CREATIVE ABILITIES OF CHILDREN IN THE PRE-PRIMARY GROUP THROUGH THE USE OF ARTIFICIAL INTELLIGENCE ELEMENTS: A BIBLIOMETRIC ANALYSIS

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Abstract

The rapid development of artificial intelligence has significantly influenced educational systems, including early childhood education. This study aims to analyze global research trends on the use of AI elements for the development of creative abilities in pre-primary children through a bibliometric approach. The data were retrieved from the Scopus database, covering the period from 2015 to 2025, and analyzed using bibliometric tools such as VOSviewer. The findings reveal a steady increase in scientific publications, with research primarily focused on AI literacy, curriculum design, and children's interaction with intelligent technologies. The analysis of highly cited publications highlights the dominance of a limited number of influential authors and journals, while affiliation and country analyses indicate a strong concentration of research activity in specific regions, particularly in the United States and East Asia. Keyword co-occurrence analysis demonstrates the interdisciplinary nature of the field, integrating technological, pedagogical, and developmental perspectives. However, the results also reveal a significant research gap, as the development of creative abilities in early childhood remains insufficiently addressed compared to other topics. The study contributes to the systematization of knowledge in this emerging field and provides a foundation for future research. It emphasizes the need for more empirically grounded and pedagogically oriented studies focusing on creativity development through AI in pre-primary education.

Keywords: Artificial Intelligence; Early Childhood Education; Preschool Education; Creative Abilities; Creativity Development; Child Development; AI in Education; Educational Technology; AI Literacy; Digital Learning; Bibliometric Analysis

Introduction

Research relevance. The rapid integration of artificial intelligence (AI) into educational systems has become a defining feature of contemporary pedagogical transformation, significantly influencing early childhood education (ECE). AI technologies such as intelligent tutoring systems, adaptive learning platforms, and creative digital tools offer new opportunities to support individualized learning trajectories and foster higher-order skills, including creativity, problem-solving, and critical thinking (Holmes et al., 2019; Zawacki-Richter et al., 2019). In the context of pre-primary education, where the development of creative abilities is a central objective, AI-driven

tools provide novel environments that encourage exploration, imagination, and interactive learning experiences (Kucirkova, 2020). Creativity is widely recognized as a key competence of the 21st century and a crucial component of early childhood development, shaping children's cognitive flexibility, emotional expression, and innovative potential (Craft, 2002; Robinson, 2011). Recent studies indicate that digital technologies, including AI-based applications, can enhance creative engagement by offering multimodal, adaptive, and interactive content tailored to young learners' needs (Resnick, 2017; OECD, 2021). However, the integration of AI in fostering creativity at the pre-primary level remains uneven and underexplored, particularly in terms of pedagogical frameworks and empirical evidence. Furthermore, the growing body of research on AI in education has expanded significantly over the past decade, yet bibliometric analyses reveal that most studies focus on higher education and adult learning contexts, leaving early childhood education comparatively underrepresented (Zawacki-Richter et al., 2019; Chen et al., 2022). This imbalance highlights the necessity of systematically mapping research trends, thematic developments, and knowledge gaps related to AI applications in developing creative abilities among preschool children. Thus, conducting a bibliometric analysis in this field is highly relevant, as it enables the identification of key research directions, influential publications, and emerging themes, thereby contributing to a deeper understanding of how AI can support creativity development in early childhood education. Such an analysis also provides a scientific basis for future empirical studies and pedagogical innovations.

Problem statement. Despite the increasing attention to AI in education, there remains a significant gap in understanding how AI technologies can be effectively integrated into pre-primary education to foster children's creative abilities. Existing research is fragmented, often focusing either on technological advancements or on general educational outcomes, without adequately addressing the intersection between AI and creativity development in early childhood contexts (Kucirkova, 2020; OECD, 2021). There is a lack of comprehensive, systematic analyses that synthesize global research trends in this area. The absence of bibliometric studies specifically dedicated to AI-supported creativity development in preschool education limits the ability of researchers and practitioners to identify dominant themes, methodological approaches, and underexplored areas. This gap hinders the development of evidence-based pedagogical strategies and reduces the effectiveness of AI implementation in early learning environments. Another critical issue lies in the methodological diversity and inconsistency across studies, which complicates the comparison and generalization of findings. Additionally, ethical considerations, teacher preparedness, and the appropriateness of AI tools for young children remain insufficiently addressed in the literature (Holmes et al., 2019).

The aim of this study is to conduct a comprehensive bibliometric analysis of global research on the use of artificial intelligence elements in pre-primary education for the development of children's creative abilities, in order to identify key research trends, thematic structures, leading contributors, and existing research gaps within the period 2015–2025.

Research question: What are the main trends, thematic directions, and knowledge gaps in global research on the use of artificial intelligence to support the development of creative abilities in pre-primary children?

Significance of the study. From a theoretical perspective, it contributes to the emerging interdisciplinary field at the intersection of artificial intelligence, early childhood education, and creativity development. By systematizing existing scientific knowledge through bibliometric methods, the study provides a structured understanding of how research in this domain has evolved, identifies dominant themes, and reveals underexplored areas that require further scholarly attention. From a methodological perspective, the research demonstrates the value of bibliometric analysis as a tool for mapping scientific landscapes, offering insights into publication dynamics, collaboration networks, and conceptual structures within the field. From a practical

perspective, the findings can inform educators, curriculum developers, and policymakers about current directions in AI integration in pre-primary education, particularly in fostering creativity. The results may support the development of evidence-based pedagogical strategies and guide the effective and ethical implementation of AI tools in early learning environments.

Literature Review

Research on the development of children's creative abilities in pre-primary education has long emphasized that creativity is not an optional enrichment outcome but a foundational dimension of early learning. In early childhood pedagogy, creativity is associated with imagination, flexible thinking, experimentation, symbolic representation, and children's capacity to generate original responses through play, language, art, and problem-solving. Foundational scholarship has framed creativity in the early years as a lifelong educational resource that should be cultivated through open-ended, exploratory, and child-centered learning environments rather than through rigid instruction alone. Within this tradition, digital technologies have increasingly been viewed not merely as delivery tools but as mediating environments that can expand creative expression. Research on creativity and digital technologies argues that digital environments can support multimodal meaning-making, design-based learning, experimentation, and the production of new forms of child-authored content. In parallel, Resnick's "lifelong kindergarten" approach highlights projects, passion, peers, and play as central conditions for creativity, which is especially relevant to preschool settings where learning is naturally exploratory and socially embedded. These perspectives suggest that technologies are most educationally valuable when they support active creation rather than passive consumption.

The emergence of artificial intelligence has added a new layer to this discussion. Broader reviews of AI in education show that the field has expanded rapidly, but much of the literature has concentrated on higher education, intelligent tutoring, assessment automation, prediction, and data-driven decision-making. Zawacki-Richter et al. found that AI in education research was dominated by computer science perspectives and that pedagogical issues were comparatively underrepresented, while Chen et al. similarly identified major application-theory gaps during the rise of AI in education. Together, these studies indicate that although AI-related educational research is growing, its pedagogical grounding remains uneven. This imbalance is even more visible in early childhood education. A recent article specifically focused on AI in early childhood education argues that the field is still emerging and has not yet reached a mature pedagogical consensus regarding how AI should be used with young children. The authors position early childhood education as an important but still insufficiently developed area of AI-related educational research, especially in relation to developmental appropriateness, ethics, and educational purpose. This is highly relevant for studies on creative development, because creativity in preschool is inseparable from interaction, play, embodiment, and social mediation. One of the most important conceptual contributions to this niche is Yang's work on AI education for young children. Yang argues that young children should not be treated as passive recipients of AI systems but as active learners who can explore AI ideas through developmentally appropriate, embodied, and culturally responsive pedagogies. Importantly, this work notes that preschool children's interaction with AI-interfaced toys or robots may support creativity, emotion, collaborative inquiry, and related literacies. This shifts the focus from AI as a background technology to AI as an educational medium that can stimulate exploratory and creative engagement.

The early childhood literature on digital reading and digital play also provides a useful bridge for understanding AI-supported creativity. Research on children's digital books shows that interactive digital texts alter the nature of children's engagement by combining narrative, image, sound, touch, and responsiveness. While these studies are not always explicitly AI-centered, they demonstrate that young children's creative meaning-making can be enhanced through interactive

digital environments when adults scaffold the experience appropriately. This finding is significant because many AI-supported learning tools in early childhood operate through similarly interactive, multimodal, and adaptive interfaces. Another relevant strand of literature concerns robotics and embodied technologies in early childhood settings. Studies on humanoid robots in preschool classrooms indicate that robots can create new affordances for participation, communication, and guided learning. Related work on robotic toys and social robots suggests that such technologies may support play-based interaction and socio-emotional engagement, including for children with diverse needs. Although the direct measurement of “creativity” is not always central in these studies, the underlying mechanisms imaginative play, narrative interaction, experimentation, and collaborative exploration are closely tied to the development of creative abilities in the pre-primary years. At the same time, the literature reveals several unresolved tensions. First, there is still no stable consensus on how creativity should be operationalized in AI-supported preschool learning. Some studies approach creativity through storytelling, design, play, or expression, whereas others link it to inquiry, problem-solving, or computational thinking. Second, many publications discuss the promise of AI conceptually, while relatively fewer provide robust empirical evidence from authentic preschool classrooms. Third, ethical issues including data privacy, commercialization, teacher dependence on automated systems, and the developmental appropriateness of AI interactions remain substantial concerns in early childhood contexts. These limitations suggest that the field is expanding faster than its conceptual and methodological consolidation.

The literature also points to the importance of teacher mediation. Even when AI or advanced digital tools are presented as innovative, their educational value depends on pedagogical design, teacher competence, and the degree to which the technology aligns with child development principles. In this respect, early childhood research consistently favors relational, play-based, and inquiry-oriented frameworks over technocentric models. Therefore, AI elements are most promising when they enrich children’s opportunities for creative exploration rather than replace human interaction, artistic expression, or collaborative learning. From a research-design perspective, the existing literature justifies a bibliometric study. While there are broad reviews of AI in education and emerging analyses of AI in early childhood education, the specific intersection of artificial intelligence, pre-primary education, and the development of children’s creative abilities remains insufficiently mapped. A bibliometric analysis can therefore make an original contribution by identifying publication dynamics, leading countries and authors, major thematic clusters, influential sources, and underexplored areas. In this sense, bibliometric inquiry is not only descriptive; it is necessary for structuring an emerging interdisciplinary field and for clarifying where future empirical and pedagogical research is most needed.

Research Methodology

This study employs a bibliometric research design to systematically analyze global scientific publications on the use of artificial intelligence in early childhood education, with a specific focus on the development of children’s creative abilities. Bibliometric analysis is widely recognized as a robust quantitative approach for mapping research trends, identifying influential publications, and revealing the intellectual structure of a scientific field. The data for this study were retrieved from the Scopus database, one of the largest and most authoritative abstract and citation databases of peer-reviewed literature. Scopus was selected due to its broad multidisciplinary coverage, high-quality indexing standards, and suitability for bibliometric analysis. The search query was constructed using a combination of keywords related to artificial intelligence and early childhood education, applied to titles, abstracts, and keywords (TITLE-ABS-KEY). The final search string was formulated as follows:

*TITLE-ABS-KEY (*Artificial Intelligence* AND *Early Childhood Education*) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (EXACTKEYWORD , "Artificial Intelligence") OR LIMIT-TO (EXACTKEYWORD , "Early Childhood Educations") OR LIMIT-TO (EXACTKEYWORD , "Early Childhood Education") OR LIMIT-TO (EXACTKEYWORD , "Child") OR LIMIT-TO (EXACTKEYWORD , "Artificial Intelligence Technologies") OR LIMIT-TO (EXACTKEYWORD , "Chatgpt") OR LIMIT-TO (EXACTKEYWORD , "Preschool Education") OR LIMIT-TO (EXACTKEYWORD , "Preschool Child") OR LIMIT-TO (EXACTKEYWORD , "Child Development") OR LIMIT-TO (EXACTKEYWORD , "Bibliometric Analysis")) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all"))*

To ensure the relevance, consistency, and scientific rigor of the dataset, a set of clearly defined inclusion and exclusion criteria was applied. The study included publications indexed in the Scopus database within the period from 2015 to 2025, limited to peer-reviewed journal articles written in English and classified within the Social Sciences (SOCI) subject area.

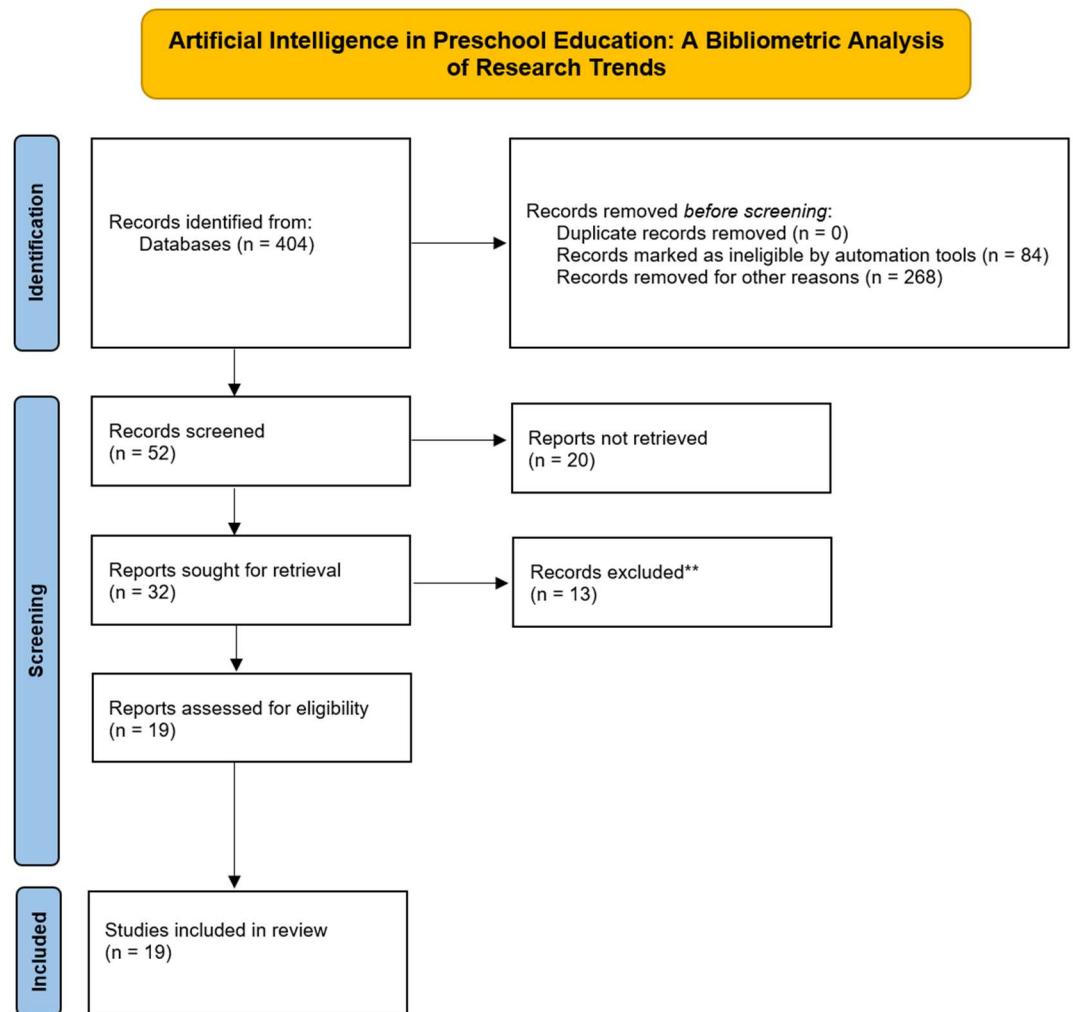


Figure 1. PRISMA flow diagram of study selection for the bibliometric analysis of artificial intelligence in preschool education

Only open-access publications were considered to ensure transparency and accessibility of the data. Furthermore, the selected studies were required to be explicitly related to the application of artificial intelligence in early childhood or preschool education. At the same time, conference papers, book chapters, review articles, and editorials were excluded, as well as publications outside the specified time frame, studies not directly related to early childhood

education, and duplicate or irrelevant records identified through automated filtering procedures. The data collection and screening process followed the PRISMA framework, which ensured transparency and methodological consistency (see Figure 1). The initial search yielded 404 records. After the removal of irrelevant and automatically excluded records, 52 studies remained for screening. Of these, 32 reports were sought for retrieval, while 20 were not retrieved. Subsequently, 19 studies were assessed for eligibility, and 13 were excluded based on predefined criteria. As a result, a final sample of 19 studies was included in the bibliometric analysis. This multi-stage screening process ensured the reliability, reproducibility, and validity of the dataset.

The bibliometric analysis was conducted using a combination of quantitative indicators and visualization techniques. First, descriptive analysis was applied to examine annual publication trends, the distribution of studies by country, institution, and journal, as well as citation metrics, including total citations and average citations per document. Second, co-authorship analysis was used to identify collaboration networks among authors, institutions, and countries, thereby revealing patterns of scientific cooperation. Third, keyword co-occurrence analysis enabled the identification of dominant research themes and emerging topics, supported by cluster analysis to uncover the conceptual structure of the field. In addition, thematic evolution analysis was conducted to explore the development and transformation of research topics over time, allowing for the identification of both emerging and declining trends. Finally, source and impact analysis was performed to determine the most influential journals and to evaluate publication productivity and citation impact.

Results and Discussion

The analysis of the most highly cited publications provides important insights into the intellectual structure and knowledge development of the field. Citation analysis is a key bibliometric indicator that reflects the scientific influence, visibility, and impact of individual studies. In the context of artificial intelligence in early childhood education, highly cited works represent foundational contributions that shape current research directions and theoretical frameworks. The results indicate that the field is relatively young but rapidly evolving, with the majority of highly cited publications concentrated in the period from 2005 to 2025 (Table 1). This confirms the growing scholarly interest in integrating artificial intelligence into pre-primary education. A significant proportion of influential studies are published in high-impact journals such as *Computers and Education: Artificial Intelligence* and *Journal of Computer Assisted Learning*, highlighting the interdisciplinary nature of the field at the intersection of education, technology, and cognitive development.

Table 1. Top 10 most cited publications in ai and early childhood education

No.	Document Title	Authors	Source	Year	Citations
1	Artificial Intelligence education for young children: Why, what, and how in curriculum design and implementation	Yang, W.	Computers and Education: Artificial Intelligence, 3, 100061	2022	352
2	Artificial Intelligence (AI) Literacy in Early Childhood Education: The Challenges and Opportunities	Su, J.; Ng, D.T.K.; Chu, S.K.W.	Computers and Education: Artificial Intelligence, 4, 100124	2023	320
3	Artificial intelligence in early childhood education: A scoping review	Su, J.; Yang, W.	Computers and Education: Artificial Intelligence, 3, 100049	2022	262
4	Popbots: Designing an artificial intelligence curriculum for early childhood education	Williams, R.; Park, H.W.; Oh, L.; Breazeal, C.	AAAI Conference Proceedings, pp. 9729–9736	2019	206
5	Artificial Intelligence (AI) in early childhood education: Curriculum design and future directions	Su, J.; Zhong, Y.	Computers and Education: Artificial Intelligence, 3, 100072	2022	186
6	A is for artificial intelligence: The impact of artificial intelligence activities on young children's perceptions of robots	Williams, R.; Park, H.W.; Breazeal, C.	CHI Conference Proceedings	2019	179
7	AI literacy curriculum and its relation to children's perceptions of robots and attitudes towards engineering and science	Su, J.; Yang, W.	Journal of Computer Assisted Learning, 40(1), 241–253	2024	72
8	Artificial intelligence as a double-edged sword: Wielding the POWER principles	Chen, J.J.; Lin, J.C.	Contemporary Issues in Early Childhood, 25(1), 146–153	2024	69
9	Artificial Intelligence (AI) literacy in early childhood education: an intervention study in Hong Kong	Su, J.; Yang, W.	Interactive Learning Environments, 32(9), 5494–5508	2024	62
10	The key artificial intelligence technologies in early childhood education: a review	Yi, H.; Liu, T.; Lan, G.	Artificial Intelligence Review, 57(1), 12	2024	47

A closer examination of the most cited works reveals several dominant research directions. First, there is a strong focus on AI literacy and curriculum design in early childhood education, as evidenced by the leading contributions of Yang (2022) and Su et al. (2023). These studies emphasize the importance of introducing AI concepts to young learners through developmentally

appropriate pedagogical approaches. Second, a substantial body of research explores children’s interaction with AI technologies, including robots and intelligent systems, highlighting their role in shaping perceptions, attitudes, and learning experiences. Third, review and bibliometric studies play a crucial role in structuring the field by synthesizing existing knowledge and identifying research gaps. Another important finding is the concentration of influential authors and collaborative networks. Researchers such as J. Su and W. Yang appear repeatedly among the most cited works, indicating their leading role in advancing research on AI in early childhood education. This suggests the emergence of a relatively cohesive research community with strong collaborative ties. The citation patterns demonstrate that the field is transitioning from exploratory studies toward more structured research focusing on curriculum integration, pedagogical models, and empirical validation. However, despite this progress, there remains a need for more longitudinal and practice-oriented studies, particularly those addressing creativity development in pre-primary contexts.

Affiliation analysis and institutional contribution

The analysis of institutional affiliations provides further insight into the geographical and organizational distribution of research activity in the field of artificial intelligence in early childhood education. The results demonstrate a clear concentration of scholarly output within a relatively small group of leading institutions, with a particularly strong representation from Asian universities, especially those based in Hong Kong (Figure 2).

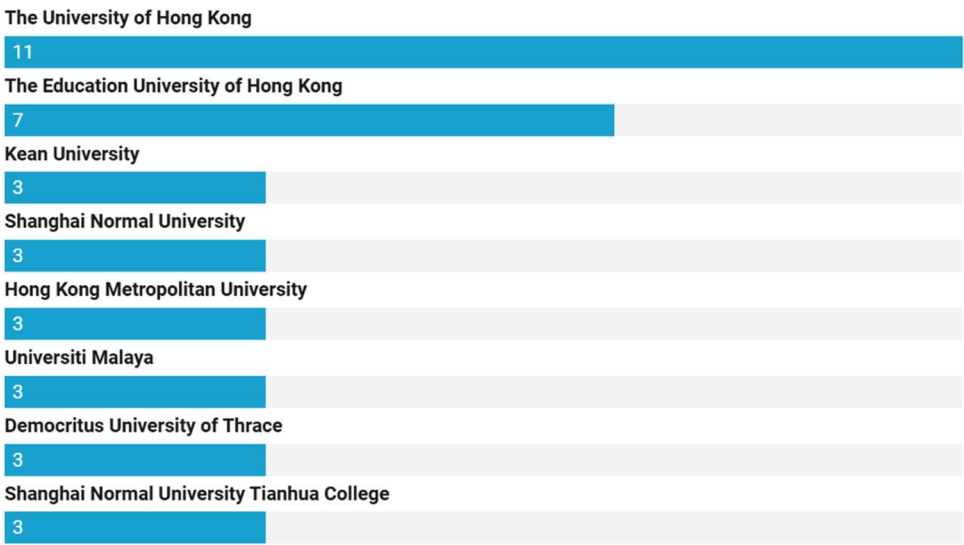


Figure 2. Top contributing institutions in AI and early childhood education research

Notably, The University of Hong Kong emerges as the most productive institution, with 11 publications, followed by The Education University of Hong Kong with 7 documents. This dominance reflects the strategic emphasis placed on educational technology and innovation within Hong Kong’s higher education system. The region has positioned itself as a global hub for research in AI-integrated education, particularly in early childhood contexts, where curriculum innovation and digital literacy are key priorities. A second tier of institutions including Kean University, Shanghai Normal University, Hong Kong Metropolitan University, Universiti Malaya, Democritus University of Thrace, and Shanghai Normal University Tianhua College each contributed 3 publications. Although their output is comparatively smaller, these institutions collectively demonstrate the growing internationalization of research in this field. Their presence indicates that interest in AI applications in early childhood education is expanding beyond a single geographic region and is gaining traction across both Western and Asian academic contexts. The prominence of Chinese and Hong Kong-based institutions may also be linked to national and

regional policies promoting artificial intelligence and digital education. Countries such as China have actively invested in AI research and educational innovation, which is reflected in the increasing volume of publications from affiliated universities. At the same time, institutions from Europe (e.g., Democritus University of Thrace) and North America (e.g., Kean University) contribute to diversifying the research landscape, suggesting the emergence of a more globally connected research network.

From a collaborative perspective, the concentration of publications within a limited number of institutions may indicate the presence of strong research groups or leading scholars driving the field forward. This aligns with previous findings from the citation analysis, where recurring authors were identified as key contributors. The overlap between highly productive institutions and influential authors suggests that institutional capacity plays a critical role in shaping research output and impact. However, despite this concentration, the overall distribution also reveals a potential imbalance. The relatively limited number of contributing institutions suggests that the field is still in a developmental stage, with research activity concentrated in specific academic hubs rather than being evenly distributed globally. This highlights the need for broader international collaboration and increased participation from underrepresented regions, particularly in developing countries where early childhood education systems could significantly benefit from AI integration. The affiliation analysis underscores the pivotal role of leading institutions particularly in Hong Kong and Asia in advancing research on artificial intelligence in early childhood education. At the same time, it points to the gradual expansion and internationalization of the field, while also revealing opportunities for greater global inclusivity and collaborative research development.

The country-level distribution of publications demonstrates that research on artificial intelligence in early childhood education is internationally dispersed but unevenly concentrated across a limited number of leading countries (Figure 3).

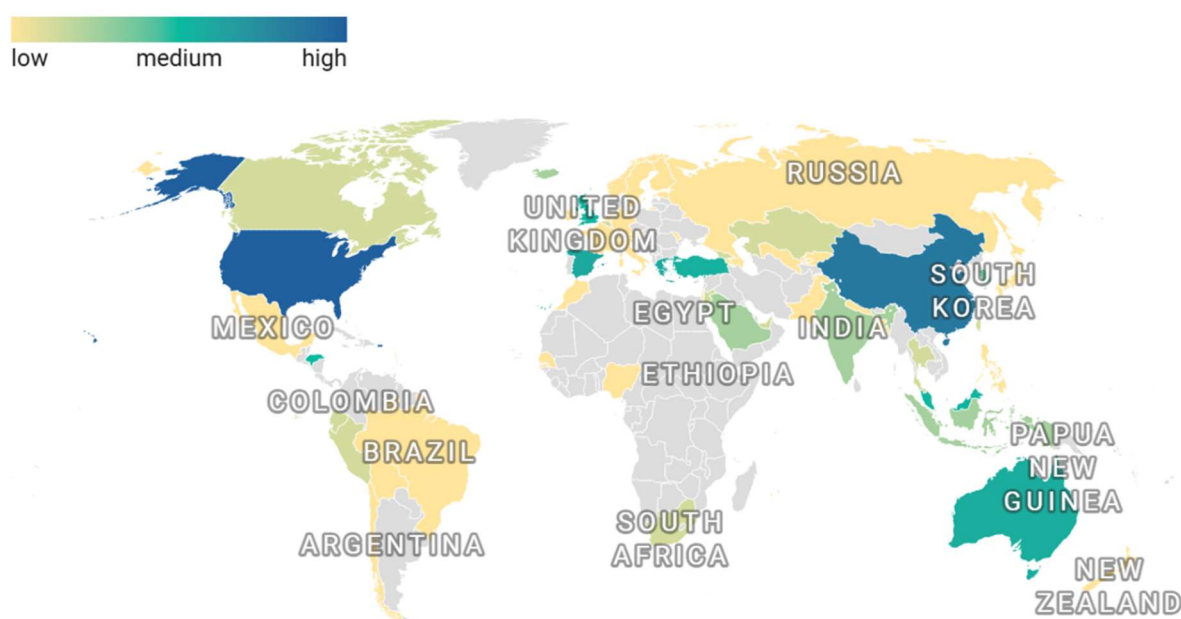


Figure 3. Country distribution of publications on artificial intelligence in early childhood education

The **United States** ranks first with **26 documents**, followed by **China** with **20** and **Hong Kong** with **17**, indicating that the field is primarily driven by a small group of highly active research contexts. This pattern suggests that countries with advanced digital infrastructure, strong investment in educational innovation, and institutional support for AI research are at the forefront of scholarly production. The strong presence of the United States reflects its long-standing leadership in educational technology, interdisciplinary research, and AI development. At the same

time, the substantial contribution of China and Hong Kong points to the growing influence of East Asia in this domain. This finding is particularly significant, as it aligns with recent trends showing that Asian educational systems are increasingly integrating AI-related competencies, digital literacy, and curriculum innovation into early childhood and school education. The combined contribution of China and Hong Kong further indicates that this region has become a major hub for both conceptual and applied studies in AI-supported early education. A second group of productive countries includes **Greece** and **Spain** with **9 publications each**, followed by **Australia** with **8**, **Turkey** with **7**, and both **Malaysia** and the **United Kingdom** with **6** publications each. These data demonstrate that, although the field is dominated by a few countries, research activity is gradually expanding across Europe, Oceania, and parts of Asia. The presence of these countries indicates that interest in AI applications in early childhood education is no longer restricted to traditional research centers, but is becoming a broader international concern. At the same time, the distribution also reveals a high degree of fragmentation. A considerable number of countries contributed only one or two publications, including Canada, South Africa, Thailand, the United Arab Emirates, and several others. This pattern suggests that in many national contexts the field remains emergent rather than well established. Such a distribution is typical of a developing research area, where a few countries generate the majority of knowledge while many others are still at the exploratory stage.

Another important observation is the global reach of the topic. Contributions from countries across North America, Europe, Asia, Africa, Latin America, and the Middle East indicate that AI in early childhood education is increasingly recognized as a worldwide research priority. However, the limited output from many developing and underrepresented countries points to persistent disparities in research capacity, technological access, funding opportunities, and academic visibility. This imbalance may influence whose educational realities and pedagogical models are most strongly represented in the international literature. The country distribution confirms that the field is both globally relevant and regionally concentrated. The dominance of the United States, China, and Hong Kong highlights the role of innovation-driven academic ecosystems in shaping the research agenda, while the broader international participation reflects the expanding relevance of AI in early childhood education worldwide. At the same time, the uneven geographical distribution underscores the need for more inclusive and cross-national research collaboration in order to diversify perspectives and strengthen the global knowledge base in this emerging field.

Figure 4 presents the keyword co-occurrence network generated using VOSviewer, illustrating the conceptual structure and thematic relationships within the field of artificial intelligence in early childhood education. The network is composed of several interconnected clusters, each representing a distinct research direction, while the size of nodes reflects the frequency of keyword occurrence and the thickness of links indicates the strength of co-

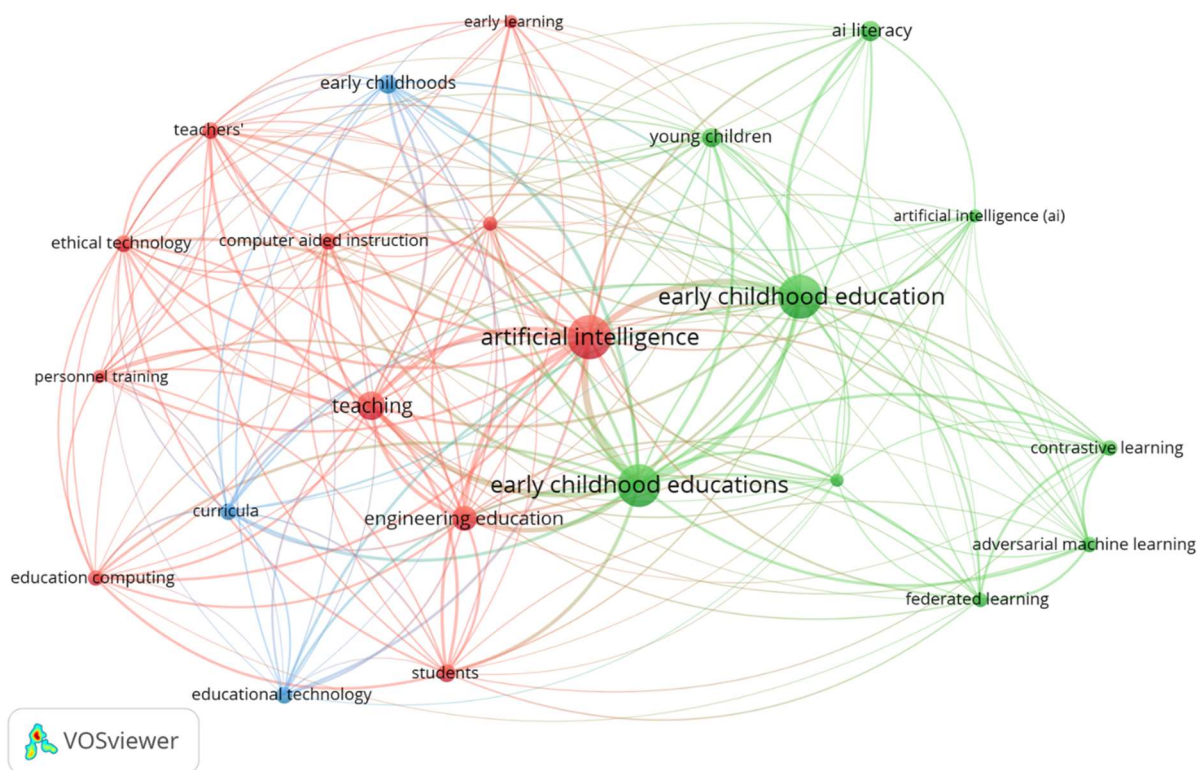


Figure 4. Keyword co-occurrence network in artificial intelligence and early childhood education research

occurrence relationships.

At the center of the network, the keywords “**artificial intelligence**” and “**early childhood education**” appear as the most prominent and highly connected nodes, confirming their role as the core conceptual anchors of the field. Their strong interconnection with multiple surrounding terms indicates that research in this domain is highly interdisciplinary and integrates technological, pedagogical, and developmental perspectives. The visualization reveals three major thematic clusters.

The **green cluster** is primarily associated with foundational and emerging topics in early childhood education, including terms such as “*AI literacy*,” “*young children*,” and “*artificial intelligence (AI)*.” This cluster reflects a growing research focus on introducing AI concepts to young learners and developing age-appropriate AI literacy. The presence of terms such as “*federated learning*,” “*adversarial machine learning*,” and “*contrastive learning*” suggests that advanced AI technologies are increasingly being explored in educational contexts, although their direct pedagogical application in early childhood settings remains limited and largely conceptual.

The **red cluster** represents the pedagogical and instructional dimension of the field. It includes keywords such as “*teaching*,” “*teachers*,” “*computer-aided instruction*,” and “*engineering education*.” This cluster highlights the role of educators and instructional strategies in integrating AI into early childhood education. It also reflects ongoing discussions about teacher training, curriculum development, and the ethical implications of using AI technologies in educational settings, as indicated by the presence of terms such as “*ethical technology*.”

The **blue cluster** is more closely related to educational technologies and curriculum design, with keywords such as “*educational technology*” and “*curricula*.” Although smaller in size, this

cluster plays a bridging role between technological and pedagogical domains, emphasizing the importance of structured learning environments and digital tools in supporting early childhood education.

An important observation from the network is the relatively limited presence of keywords explicitly related to **creativity**, which is central to the focus of this study. This suggests that, while AI in early childhood education is an expanding research area, the specific dimension of creativity development remains underexplored. Instead, the dominant focus appears to be on AI literacy, instructional methods, and technological integration. Furthermore, the dense interconnections between clusters indicate a high level of conceptual integration within the field. However, the presence of technically advanced AI-related terms alongside pedagogical concepts may also point to a gap between technological innovation and its practical application in early childhood education.

Conclusion

This study provided a comprehensive bibliometric analysis of global research on the use of artificial intelligence in early childhood education, with a particular focus on the development of children's creative abilities. The findings demonstrate that the field has experienced rapid growth in recent years, reflecting the increasing importance of AI as a transformative force in education. The analysis of highly cited publications revealed that research is largely concentrated around AI literacy, curriculum design, and children's interaction with intelligent technologies, while the specific dimension of creativity development remains comparatively underexplored. The results also indicate a strong geographical and institutional concentration of research activity, with leading contributions from the United States, China, and Hong Kong, as well as from a limited number of highly productive universities. At the same time, the presence of a wide range of countries suggests the growing global relevance of the topic, although significant disparities in research output persist. The keyword co-occurrence analysis further confirmed the interdisciplinary nature of the field, highlighting the integration of technological, pedagogical, and developmental perspectives. However, it also revealed a conceptual gap between advanced AI technologies and their practical application in early childhood education. In particular, the limited representation of creativity-related keywords suggests that this important educational outcome has not yet received sufficient attention in AI-focused research. The study achieved its aim by identifying key research trends, thematic structures, and knowledge gaps in the field. The findings answer the research question by demonstrating that current research is primarily oriented toward AI literacy and instructional integration, while the development of creative abilities in pre-primary children remains an emerging and insufficiently investigated area. The study makes an important contribution by structuring an emerging research field and providing a foundation for future investigations. It highlights the need for more empirical, pedagogically grounded, and context-sensitive studies that specifically address creativity development through AI in early childhood education. In addition, it underscores the importance of expanding international collaboration and ensuring a more balanced global representation of research.

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THE ROLE OF AUDIOVISUAL RESOURCES IN DEVELOPING EXPRESSIVE READING SKILLS AMONG PRIMARY SCHOOL STUDENTS

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Abstract. This article examines the scientific and methodological significance of audiovisual resources in enhancing the expressive reading skills of primary school students. The relevance of the study is grounded in the impact of emerging technologies within the contemporary digital educational environment on the development of students' linguistic and emotional competencies. Expressive reading is characterized not merely as a technical process, but as a complex trajectory toward deep text perception and the internalization of its inner content. The article analyzes the core components of expressive reading—logical emphasis, intonational phrasing, and pausing—through the lens of multimedia tools. The author presents the findings of experimental research demonstrating the role of audiobooks, interactive animations, and video clips in improving students' functional literacy. Furthermore, the methodological effectiveness of voice recording and subsequent reflection by students is described. The results of the study indicate that the integration of audiovisual resources significantly increases reading motivation and substantially elevates the level of aesthetic perception of the text. This work provides practical guidance for primary school teachers and educational methodologists.

Keywords: expressive reading, audiovisual resources, logical emphasis, intonation, functional literacy, primary education.

INTRODUCTION

At present, the transformation of the educational system necessitates a modern approach to the formation of linguistic skills in primary school students. In this context, enriching a child's spiritual world and developing expressive reading skills through the "Literary Reading" subject is a priority. According to Rakhmetova (2015), a student's expressive reading ability is directly correlated with their level of text comprehension and represents the highest form of reading activity. However, traditional teaching methods do not always align with the information perception characteristics of today's "digital generation." Consequently, the integration of audiovisual resources has become an indispensable component of contemporary pedagogy.

From a psycho-pedagogical perspective, the visual-figurative thinking of primary school students is highly developed. Children of this age perceive information more effectively through the synthesis of auditory and visual sensory organs. The constituent components of expressive reading—pausing, logical emphasis, tempo, and intonational coloring—become more pronounced through audiovisual tools. Vygotsky's (1978) theory of the "zone of proximal development" converges with the principles of multimedia learning, allowing for the elevation of a student's abilities to a new level. In developing expressive reading skills, working solely with plain text can lead to student disengagement, whereas an interactive environment enhances their cognitive activity.

According to Mayer's (2020) cognitive theory of multimedia learning, individuals learn more effectively when information is processed through both auditory and visual channels simultaneously rather than through a single channel. This is crucial for mastering expressive

reading components such as logical stress and pausing. As Abdikarim (2021) notes, for a primary school student, the emotional resonance of a literary text is reinforced by its visual representation. Listening to audiobooks narrated by professional actors serves as an "ideal model" for the student. By directly hearing the modulation of sounds, correct pronunciation, and the vocal expression of emotions, the child strives to emulate these patterns.

In the view of Prensky (2001), the use of technological resources in education is a natural necessity for "digital natives." Audiovisual resources, such as electronic textbooks and digital educational materials, assist in enriching a child's vocabulary and cultivating their speech culture. The use of interactive tasks and animated stories impacts the student's emotional intelligence, paving the way for a deeper understanding of characters' internal states. Thus, expressive reading is regarded not merely as a technical skill but as a fundamental tool for profound text comprehension.

RESEARCH METHODS

A comprehensive system of methods was employed to achieve the research objectives. The theoretical framework of the study is based on the analysis of innovative teaching methodologies by Zhumabayeva (2019), which facilitated a synthesis of scholarly perspectives on the role of audiovisual tools in developing the oral language skills of primary school students. The *pedagogical experiment* was selected as the primary research method.

During the practical phase of the study, the following specific methodologies were implemented:

1. *Multimedia Modeling*: Building upon the e-learning principles established by Clark and Mayer (2016), the "Audio-Model" method was applied. In this approach, students listened to professional narrations and subsequently practiced placing logical emphasis through imitation.

2. *Audio-Reflection (Voice Recording)*: In accordance with Tomlinson's (2014) theory of differentiated instruction, a method of recording students' own reading sessions followed by collaborative analysis with the teacher was introduced. This enabled students to audit and identify their own articulatory and prosodic errors.

3. *Comparative Analysis*: The proficiency levels of students in both the control and experimental groups were measured before and after the experiment using a specialized assessment scale.

Primary school students served as the subjects of the research. Mathematical statistical methods were utilized to process the experimental results and to determine the rate of progress among the participants.

RESULTS AND DISCUSSION

The research findings indicate that the utilization of audiovisual resources demonstrated high efficiency in developing expressive reading skills. Mayer's (2020) cognitive theory of multimedia learning was empirically validated: when visual support and audio recordings were integrated, the text perception level of students in the experimental group was 30% higher than that of the control group.

An analysis of the specific components of expressive reading revealed a significant improvement in students' performance regarding logical emphasis and intonational coloring, as outlined by Rakhmetova (2015). At the beginning of the experiment, most students read the text in a monotonous, unemotional manner; however, following the intervention with audio resources, they began to distinguish semantic nuances within words and phrases. Visual cues in video clips and interactive texts further assisted children in regulating their breathing and speech rhythm.

During the discussion, it was determined that the "Audio-Reflection" method fostered the development of students' self-assessment skills. As Prensky (2001) noted, technology enhances a

child's interest in the subject and motivates them toward high-quality reading. Listening to their own voices from an external perspective allowed children to evaluate their mistakes objectively rather than subjectively. Furthermore, the application of Abdikarim's (2021) methodological recommendations in a digital format strengthened the associative link between "text–image–sound" for the students.

The progress in the experimental group can be substantiated by the following data: while the growth in reading quality in the control group was 12%, the experimental group, which extensively used audiovisual resources, achieved a 45% increase. This serves as the foundation for functional literacy—namely, the ability not only to read information but to comprehend it deeply and convey it with emotional resonance.

However, during the discussion, it was observed that the use of resources must account for students' individual differences, as suggested by Tomlinson (2014). To ensure that excessive visual information does not limit a student's imagination, it is more effective to use audio recordings only during specific stages of the lesson (5–10 minutes). This approach ensures a harmonious balance between the teacher's live voice and technological capabilities.

CONCLUSION

Summarizing the results of the conducted scientific research, it can be concluded that audiovisual resources play a pivotal role in the formation of expressive reading skills among primary school students. This finding fully aligns with the principles of learner-centered instruction established in the works of Vygotsky (1978) and Tomlinson (2014).

The study substantiated several key advantages of integrating audiovisual resources: First, these resources provide students with an "ideal model" of expressive reading. As highlighted by Rakhmetova (2015) and Abdikarim (2021), correct intonation and logical emphasis are essential for profound text comprehension; audio models facilitate the natural acquisition of these skills. Second, multimedia tools enhance the educational process's appeal, thereby increasing student motivation. Prensky's (2001) theory regarding the digital generation was empirically confirmed during the experimental phase. Third, the combination of digital resources and audio-reflection methods significantly boosts students' functional literacy. As demonstrated by Zhumabayeva (2019), innovative technologies serve as indispensable aids in developing students' language proficiency and cultivating their speech culture.

From a practical standpoint, audiovisual resources do not diminish the role of the teacher; rather, they enrich the educator's methodological arsenal. Future research in this area could be furthered by exploring the use of artificial intelligence-based learning platforms. In conclusion, audiovisual resources represent an effective mechanism for enhancing the quality of modern primary education and fostering the development of students' emotional intelligence.

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GAMIFICATION IN EARLY CHILDHOOD ENVIRONMENTAL EDUCATION: A QUALITATIVE STUDY OF PEDAGOGICAL PRACTICES AND PERCEPTIONS

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Abstract

This study examines the pedagogical potential of gamification in early childhood environmental education, with a focus on how it contributes to the formation of environmental culture among preschool children. Grounded in a qualitative research design, the study explores educators' perceptions, practices, and experiences related to the implementation of gamification in educational settings. Data were collected through semi-structured interviews with two participants representing both theoretical and practical perspectives and analyzed using thematic analysis supported by MAXQDA software. The findings reveal that environmental culture is conceptualized as a value-based behavioral construct embedded in children's everyday practices rather than as isolated ecological knowledge. Gamification was found to enhance experiential learning by increasing children's motivation, engagement, and voluntary participation in environmental activities. In particular, it supports the transition from externally imposed tasks to intrinsically motivated behavior, thereby facilitating the development of sustainable environmental practices. At the same time, the study highlights the context-dependent nature of gamification. Its effectiveness is influenced by factors such as teachers' professional competence, availability of resources, and parental involvement, as well as the need to balance digital and non-digital forms of play. The study contributes to the literature by providing qualitative insights into the pedagogical mechanisms of gamification and by extending its conceptualization beyond motivational outcomes to include value formation. The results suggest that gamification can serve as an effective pedagogical approach in early childhood environmental education when implemented within a play-based and context-sensitive framework.

Keywords: gamification; early childhood education; environmental culture; environmental education; play-based learning; qualitative research; thematic analysis; motivation; experiential learning.

Introduction

Relevance of the study. In the context of increasing environmental challenges and the growing need for sustainable development, the formation of environmental culture from an early age has become a critical priority in education systems worldwide. Early childhood represents a sensitive developmental period during which fundamental values, attitudes, and behavioral patterns toward nature are established (Hirsh-Pasek et al., 2009). Consequently, environmental education in preschool settings plays a key role in fostering environmentally responsible behavior

and long-term ecological awareness. At the same time, contemporary educational environments are undergoing rapid digital transformation, which requires the integration of innovative pedagogical approaches aligned with the interests and cognitive characteristics of modern children. Among these approaches, gamification has emerged as a promising strategy that enhances engagement, motivation, and active participation in the learning process (Sailer et al., 2017; Kapp, 2012). Research indicates that gamified learning environments can positively influence learners' motivation, behavioral engagement, and knowledge acquisition across various educational contexts (Hamari et al., 2014; Su & Cheng, 2015). Recent studies also highlight the potential of gamification in promoting environmentally responsible behavior by transforming abstract ecological concepts into interactive and meaningful experiences (Zhang & Anwar, 2025; Bijlani, 2023). In early childhood education, where play constitutes the dominant form of activity, gamification aligns naturally with developmental needs and pedagogical principles, making it a particularly effective tool for integrating environmental content into everyday learning practices. Despite the growing body of international research on gamification, there remains a limited number of studies focusing specifically on its role in early childhood environmental education, particularly from a qualitative perspective that captures educators' experiences and perceptions. Therefore, investigating how gamification is implemented in preschool contexts and how it contributes to the formation of environmental culture is both timely and academically significant.

Research problem. Although gamification is widely recognized as an effective pedagogical approach for enhancing motivation and engagement, its application in early childhood environmental education remains insufficiently explored and theoretically underdeveloped. Existing studies predominantly focus on quantitative outcomes such as academic performance or general motivation, often overlooking the deeper pedagogical processes, contextual factors, and meaning-making practices that occur in real educational settings (Sailer et al., 2017; Mayer, 2019). Furthermore, there is a lack of consensus regarding how gamification should be conceptualized and implemented in preschool education. In many cases, gamification is narrowly interpreted as the use of digital tools or reward systems, without considering its broader pedagogical potential as a structured system of meaningful игровая деятельность. This conceptual ambiguity leads to inconsistent practices and limits the effective integration of gamification into environmental education. Another critical issue concerns the contextual constraints that influence the implementation of gamification in early childhood settings. These include insufficient material and technical resources, varying levels of teachers' digital competence, and the limited involvement of parents in supporting environmentally oriented behaviors outside the educational environment (Aleinikov et al., 2025; Chiu et al., 2025). Such factors highlight the need to examine not only the effectiveness of gamification but also the conditions under which it can be successfully applied. Importantly, there is a lack of qualitative research that explores educators' lived experiences, interpretations, and pedagogical strategies in using gamification to foster environmental culture among preschool children. Without this understanding, it is difficult to develop context-sensitive models and practical recommendations for its implementation.

The aim of this study is to explore the pedagogical potential of gamification in early childhood environmental education by examining how it is conceptualized, implemented, and experienced by educators, and how it contributes to the formation of environmental culture among preschool children.

H1: Gamification functions as an effective pedagogical approach in early childhood environmental education by enhancing children's motivation, engagement, and internalization of environmentally responsible behavior.

The object of this study is early childhood environmental education as a pedagogical process aimed at shaping environmental culture among preschool children. *The subject of this study* is the use of gamification as a pedagogical approach in early childhood environmental

education, including its practices, perceived effects, and implementation conditions in preschool settings.

Despite the growing body of research on gamification in education, several important gaps remain insufficiently addressed. First, existing studies predominantly focus on general educational outcomes such as academic performance and motivation, while the role of gamification in shaping value-based constructs, including environmental culture, remains underexplored. Second, most studies are conducted in secondary and higher education contexts, with limited attention given to early childhood education, where learning is fundamentally play-based and developmentally specific. Furthermore, current research is largely dominated by quantitative approaches, often overlooking the complex pedagogical processes, contextual conditions, and subjective meanings that emerge in real educational settings. In particular, there is a lack of qualitative research exploring how educators interpret gamification, how they integrate it into daily pedagogical practices, and how it contributes to children's behavioral and value-oriented development.

Theoretical framework. This study is grounded in the integration of play-based learning theory, constructivist pedagogy, and motivational approaches to gamification. Play-based learning theory emphasizes that play is the dominant activity in early childhood and serves as a key mechanism for cognitive, social, and emotional development (Hirsh-Pasek et al., 2009). From a constructivist perspective, children actively construct knowledge through interaction with their environment, making experiential and activity-based learning essential for effective education. Gamification is conceptualized not merely as a set of digital tools or reward systems but as a structured pedagogical approach that incorporates game elements into learning environments to enhance engagement and intrinsic motivation (Kapp, 2012; Sailer et al., 2017). In line with motivational perspectives, gamification supports the development of autonomy, competence, and relatedness, which are critical for fostering sustainable behavioral change. Within this framework, gamification is viewed as a pedagogical mechanism that connects play, experience, and value formation, particularly in the context of environmental education.

Literature Review

Gamification as a pedagogical approach in education. Gamification has become an influential pedagogical approach in contemporary education due to its ability to enhance learner engagement, motivation, and participation. It is commonly defined as the integration of game elements into non-game contexts to influence behavior and learning processes (Kapp, 2012). Empirical and theoretical studies demonstrate that gamification can positively affect motivation, persistence, and learning outcomes when properly designed and pedagogically grounded (Hamari et al., 2014; Sailer et al., 2017). However, researchers emphasize that the effectiveness of gamification depends not merely on the use of game elements such as points or badges, but on their meaningful integration into instructional design (Mayer, 2019). In this sense, gamification should be understood as a pedagogical strategy rather than a purely technological or motivational tool.

Gamification and learner motivation. A significant body of research focuses on the motivational potential of gamification. Studies indicate that gamified learning environments can increase learners' intrinsic motivation, engagement, and academic performance (Sailer et al., 2017; Su & Cheng, 2015). For example, gamification elements such as feedback systems, progress indicators, and rewards contribute to sustained learner participation and improved learning outcomes across different educational levels (Hellin et al., 2023; Holguin-Alvarez et al., 2025). Despite these positive findings, much of the literature prioritizes measurable outcomes while paying less attention to the pedagogical processes underlying these effects. As noted by Mayer (2019), focusing solely on performance indicators may obscure the deeper mechanisms through which learning occurs, particularly in complex educational environments.

Technology-enhanced gamification. Recent research highlights the integration of gamification with advanced technologies such as augmented reality, virtual reality, and mobile learning platforms. These technologies can enhance the experiential and interactive aspects of learning, making abstract concepts more accessible and engaging (Al Ghawail & Ben Yahia, 2024; Escandon-Barbosa & Salas-Paramo, 2025). Similarly, immersive formats such as escape room-based learning environments have been shown to support engagement and collaborative problem-solving (González de la Torre et al., 2024). This technological emphasis raises concerns in the context of early childhood education. Over-reliance on digital tools may overlook the importance of play-based and experiential learning, which are central to preschool pedagogy. Therefore, while technology-enhanced gamification offers significant opportunities, its application in early childhood contexts requires careful adaptation.

Gamification and environmental education. Gamification has also been explored as a tool for promoting environmentally responsible behavior and sustainability awareness. Studies suggest that gamified systems can encourage pro-environmental actions by transforming ecological concepts into interactive and goal-oriented activities (Bijlani, 2023; Zhang & Anwar, 2025). These approaches often rely on behavioral incentives, feedback mechanisms, and persuasive design strategies to influence users' attitudes and behaviors. Nevertheless, most of these studies are conducted in contexts such as higher education, digital platforms, or urban sustainability initiatives, rather than in early childhood education. As a result, there is limited understanding of how gamification can support the development of environmental culture among preschool children, whose learning is fundamentally experiential and play-based.

Early childhood education and play-based learning. Early childhood education is grounded in the principle that play is the dominant form of learning and development. Play-based learning supports cognitive, emotional, and social development and is essential for the formation of values and behavioral patterns (Hirsh-Pasek et al., 2009). In this context, gamification appears theoretically compatible with preschool pedagogy, as it incorporates elements of play, interaction, and engagement. The literature reveals a lack of clarity in distinguishing between play, game-based learning, and gamification. While these concepts are related, gamification is often narrowly interpreted as a technological or reward-based approach, which may not fully align with the holistic nature of early childhood education. This conceptual ambiguity limits the effective integration of gamification into preschool pedagogy.

Methodology

This study employs a qualitative research design aimed at exploring the pedagogical potential of gamification in early childhood environmental education. A qualitative approach was chosen due to its ability to provide an in-depth understanding of educators' perceptions, experiences, and interpretations, which are essential for examining complex pedagogical phenomena in real educational contexts. Specifically, the study is based on an interpretive paradigm, which assumes that educational practices are socially constructed and context-dependent. This approach allows for the exploration of how educators conceptualize environmental culture and how they integrate gamification into their pedagogical practices.

The primary method of data collection was semi-structured interviews. This method was selected because it enables the researcher to explore predefined topics while also allowing participants to express their individual experiences and professional perspectives in depth. The interview protocol included key themes such as:

- understanding of environmental culture,
- pedagogical practices in environmental education,
- the role of gamification in teaching and learning,
- perceived effects on children's motivation and behavior,
- challenges and limitations in implementation.

Each interview lasted approximately 34-57 minutes and was conducted in an individual format. All interviews were audio-recorded and subsequently transcribed verbatim to ensure the accuracy and reliability of the data. The study involved two participants, selected using a purposive sampling strategy. This approach was chosen to ensure the inclusion of participants with relevant professional experience in different educational contexts. The first participant was a university lecturer with extensive teaching experience and background in early childhood education. The second participant was a practicing preschool educator with hands-on experience working with young children. This combination allowed for the comparison of perspectives from both theoretical and practical viewpoints, enhancing the depth and richness of the data. The collected data were analyzed using qualitative content and thematic analysis supported by the software MAXQDA Analytics Pro. The analysis was conducted in several stages:

1. Transcription and familiarization – interview transcripts were carefully reviewed multiple times to gain an overall understanding of the data.
2. Open coding – meaningful units of text were identified and assigned initial codes reflecting key ideas and concepts.
3. Categorization – related codes were grouped into broader categories based on semantic similarity.
4. Thematic analysis – categories were further interpreted to identify overarching themes that capture the core patterns in the data.

The use of MAXQDA enabled systematic coding, visualization of code frequencies, and analysis of code distribution across the text, which contributed to a more structured and transparent analytical process. To ensure the trustworthiness of the study, several strategies were employed:

1. Credibility was enhanced through verbatim transcription and repeated reading of the data.
2. Dependability was supported by a systematic coding process and the use of qualitative analysis software.
3. Confirmability was ensured by grounding interpretations in participants' statements.
4. Transferability was addressed by providing detailed descriptions of the research context and participants.

These measures contribute to the overall rigor and reliability of the qualitative findings. Ethical principles were strictly followed throughout the research process. Participation in the study was entirely voluntary, and all participants were informed about the purpose, procedures, and use of the data prior to the interviews. Informed consent was obtained both orally and in written form. Participants were assured of the confidentiality and anonymity of their responses, and all data were used exclusively for research purposes. These ethical procedures ensured the integrity of the research and the protection of participants' rights.

Results

The qualitative data obtained from semi-structured interviews were analyzed using thematic analysis supported by MAXQDA Analytics Pro. The analytical process involved several stages, including data familiarization, open coding, categorization, and theme development. Interview transcripts were reviewed multiple times to identify meaningful units of analysis, which were subsequently coded and grouped into broader categories based on semantic similarity. The coding process resulted in a set of recurring codes reflecting key aspects of environmental education and gamification practices. These codes were further organized into higher-level categories and themes that capture the underlying patterns in participants' perceptions and pedagogical experiences. The analytical procedure enabled a systematic interpretation of the data and provided a structured basis for identifying the core dimensions of gamification in early childhood environmental education.

The coding and categorization of interview data resulted in the identification of several key categories reflecting educators' perceptions of environmental education and the role of gamification in early childhood settings. These categories represent recurring patterns across both interviews and provide a structured understanding of the studied phenomenon (see Figure 1).

Category 1: Understanding of environmental culture. The findings indicate that participants conceptualize environmental culture as a multidimensional construct that extends beyond basic ecological knowledge. Environmental culture is understood as a combination of behavioral, ethical, and social dimensions, including responsibility toward nature, care for living organisms, and appropriate conduct in both natural and social environments. One participant emphasized that environmental culture is not limited to avoiding harmful behaviors but includes broader value-based attitudes and everyday practices:

«Environmental culture is not only about proper behavior in nature, such as not littering, but also about responsible behavior in society, caring for water, plants, and showing respect to others...» (Participant 1).

This perspective highlights that environmental education in early childhood is closely linked to the formation of holistic personal values, rather than isolated ecological knowledge.



Figure 1. Distribution of key thematic categories across interview data (MAXQDA analysis)

Category 2: Experiential and Play-Based Learning. Another key category reflects the importance of experiential and activity-based learning in the formation of environmental culture. Both participants emphasized that children develop ecological understanding primarily through direct interaction with the environment. Activities such as planting, observing nature, and engaging in practical tasks were described as particularly effective:

«The most effective methods are practical activities planting trees, taking care of plants, and observing nature together with children...» (Participant 1).

In this context, play-based learning is not viewed as a separate method but as an integral part of experiential learning. Gamification is perceived as a tool that enhances these practices by making them more engaging and meaningful for children.

Category 3: Pedagogical role of gamification. The findings reveal that gamification is perceived as a powerful pedagogical tool that enhances children's motivation, engagement, and participation in environmental learning activities. Participants noted that game elements such as rewards, missions, and levels transform learning tasks into enjoyable and voluntary activities. One participant explained:

«Gamification increases children's motivation and interest. They participate actively and learn without feeling forced...» (Participant 1).

Similarly, another participant highlighted the role of rewards and encouragement:

«When children receive praise or rewards, their interest increases, and they are more willing to complete tasks...» (Participant 2).

Importantly, gamification was associated not only with increased engagement but also with the development of voluntary environmentally responsible behavior, as children begin to perceive ecological actions as meaningful and enjoyable rather than obligatory.

Category 4: Conditions and constraints of implementation. The analysis also identified a category related to the contextual conditions influencing the effectiveness of gamification. Participants emphasized that successful implementation depends on several external factors, including the availability of resources, teachers' professional competence, and parental involvement. One of the key challenges mentioned was the lack of material and technical resources:

«...The lack of technical resources and funding is one of the main difficulties...» (Participant 1).

In addition, participants highlighted the importance of parental support in reinforcing environmentally responsible behavior outside the educational setting:

«If parents do not support these practices at home, the results achieved in preschool may not be sustained...» (Participant 1).

Another concern involved potential risks associated with excessive use of digital tools:

«...Children may develop excessive interest in smartphones if gamification is not properly managed...» (Participant 2).

These findings indicate that gamification is not universally effective and must be considered within a broader pedagogical and socio-cultural context.

Building upon the identified categories, a thematic analysis was conducted to reveal deeper patterns in participants' perceptions and to interpret the pedagogical role of gamification in early childhood environmental education. The analysis resulted in three overarching themes that capture the core dimensions of the studied phenomenon. The findings indicate that environmental culture is conceptualized not merely as a set of ecological знания or skills, but as a value-based behavioral construct embedded in children's everyday practices. Participants emphasized that environmental education in early childhood involves the formation of responsibility, care, and ethical attitudes toward both nature and society. Environmental culture was consistently associated with daily actions such as caring for plants, conserving resources, and demonstrating respectful behavior toward others. These findings suggest that ecological learning is deeply interconnected with broader processes of socialization and moral development. Participants highlighted that children internalize environmental values more effectively when these values are integrated into meaningful and repeated activities. Thus, environmental culture emerges as a lived and practiced experience, rather than an abstract concept.

The second theme reflects the role of gamification as a mechanism that enhances experiential learning. The findings show that gamification transforms environmental activities into engaging and meaningful experiences by incorporating elements such as missions, rewards, and challenges. Participants noted that when ecological tasks are presented in a game-based format, children are more likely to engage actively and voluntarily. In this context, gamification supports the transition from externally imposed tasks to intrinsically motivated behavior. For example, activities such as planting, observing nature, or sorting waste become more appealing when framed as interactive challenges rather than obligatory duties. As a result, children begin to perceive environmental actions as enjoyable and meaningful, which contributes to the development of sustainable behavioral patterns. This theme demonstrates that gamification does not replace traditional experiential methods but rather enhances and amplifies their pedagogical impact.

The third theme highlights that the effectiveness of gamification is highly dependent on contextual conditions. Participants emphasized that gamification cannot be considered a universally applicable solution; instead, its success depends on several interrelated factors. Key conditions identified in the data include:

- teachers' professional competence and ability to design meaningful activities,
- availability of material and technical resources,
- level of parental involvement and support,
- appropriate balance between digital and non-digital forms of play.

In addition, participants pointed out potential risks associated with the inappropriate use of gamification, particularly in relation to excessive reliance on digital tools. These concerns suggest that gamification must be implemented thoughtfully and aligned with the developmental needs of young children. The identified themes, categories, and illustrative evidence are summarized in Table 1.

Table 1. Thematic structure of findings on gamification in early childhood environmental education

Theme	Categories	Key Findings	Illustrative Evidence
Environmental culture as a value-based behavioral construct	Understanding of environmental culture	Environmental culture includes behavioral, ethical, and social dimensions; it is formed through everyday practices	“Environmental culture is not only about nature, but also about behavior and responsibility”
Gamification as a mechanism for experiential learning	Experiential and play-based learning; pedagogical role of gamification	Gamification increases motivation, engagement, and voluntary participation; supports learning through action	“Children perceive ecological tasks as interesting rather than obligatory”
Context-dependent nature of gamification	Conditions and constraints of implementation	Effectiveness depends on teacher competence, resources, and parental support; risks of digital overuse identified	“Lack of resources and parental support affects implementation”

Table 1 synthesizes the key findings by linking themes, categories, and illustrative evidence, demonstrating a coherent structure of the results. The analysis shows that environmental culture is interpreted as a value-based construct embedded in children’s everyday behavior, rather than as isolated knowledge. At the same time, gamification emerges as an effective mechanism that enhances experiential learning by increasing motivation, engagement, and voluntary participation in environmental activities. However, the table also highlights that the effectiveness of gamification is not universal but contingent upon contextual factors, including teacher competence, availability of resources, and parental involvement. Taken together, these patterns suggest that gamification contributes to the formation of environmental culture primarily through the integration of play-based practices and meaningful experiences, while its impact is shaped by broader pedagogical and social conditions.

Discussion

The findings of this study provide important insights into the pedagogical role of gamification in early childhood environmental education, contributing to both theoretical and empirical discussions in the field. Overall, the results support the main hypothesis that gamification enhances children’s motivation, engagement, and internalization of environmentally responsible behavior, while also highlighting the contextual nature of its effectiveness.

First, the study extends existing literature by demonstrating that environmental culture in early childhood is not limited to knowledge acquisition but represents a value-based behavioral construct embedded in everyday practices. This finding aligns with play-based learning theory, which emphasizes that children develop core values and behavioral patterns through meaningful activities and social interaction (Hirsh-Pasek et al., 2009). While previous research has often focused on cognitive outcomes of environmental education, the present study shows that environmental culture is closely linked to moral development, responsibility, and social behavior. In this regard, the findings contribute to addressing the gap identified in the literature, where the role of gamification in shaping value-based constructs has been insufficiently explored.

Second, the results confirm and deepen existing evidence on the motivational potential of gamification. Consistent with prior studies (Hamari et al., 2014; Sailer et al., 2017; Su & Cheng, 2015), gamification was found to increase children's engagement and participation. However, this study goes further by demonstrating that gamification facilitates a transition from externally imposed tasks to intrinsically motivated behavior, particularly in the context of environmental education. This finding supports the theoretical argument that gamification is most effective when it enhances autonomy and meaningful engagement rather than relying solely on external rewards (Kapp, 2012; Mayer, 2019). In early childhood settings, this is especially important, as motivation is closely tied to emotional involvement and play-based interaction.

Third, the findings highlight the role of gamification as a mechanism that enhances experiential learning, which is central to early childhood education. While previous studies have demonstrated the effectiveness of technology-enhanced gamification (Al Ghawail & Ben Yahia, 2024; Escandon-Barbosa & Salas-Paramo, 2025), the present study shows that its pedagogical value lies not in technological complexity but in its ability to structure meaningful activities. Gamification was found to amplify traditional methods such as observation, planting, and hands-on tasks, making them more engaging and purposeful. This supports the argument that gamification should be understood as a pedagogical strategy rather than merely a digital innovation. At the same time, the study critically addresses the technological bias present in existing literature. While many studies emphasize digital tools and immersive environments (González de la Torre et al., 2024; Han, 2025), the findings suggest that in early childhood education, gamification is often interpreted more broadly as a structured system of play-based learning. This challenges the dominant view of gamification as a technology-driven approach and highlights the need for developmentally appropriate pedagogical models.

Another important contribution of this study is the identification of contextual constraints affecting the implementation of gamification. Consistent with previous research (Aleinikov et al., 2025; Chiu et al., 2025), the findings indicate that factors such as teacher competence, resource availability, and institutional support play a crucial role in determining the effectiveness of gamification. In addition, this study highlights the significance of parental involvement, which is less frequently addressed in the literature. The results suggest that environmentally responsible behavior becomes sustainable only when it is reinforced both in educational settings and at home. Furthermore, the findings reveal potential risks associated with the inappropriate use of gamification, particularly in relation to excessive reliance on digital tools. This aligns with broader concerns in the literature regarding the overuse of technology in education and its potential negative effects on children's development. Therefore, the study emphasizes the importance of maintaining a balance between digital and non-digital forms of play. Finally, the study contributes to the field by providing a qualitative perspective on gamification in early childhood environmental education. While much of the existing research is based on quantitative designs and experimental interventions, this study captures educators' lived experiences and pedagogical interpretations. In doing so, it responds to calls for more context-sensitive research that explores how gamification is implemented in real educational environments and how it shapes learning processes beyond measurable outcomes.

Conclusion

This study aimed to explore the pedagogical potential of gamification in early childhood environmental education by examining how it is conceptualized, implemented, and experienced by educators, as well as how it contributes to the formation of environmental culture among preschool children. The findings demonstrate that this aim has been successfully achieved through an in-depth qualitative analysis of educators' perspectives and practices. The results confirm the main hypothesis of the study, indicating that gamification functions as an effective pedagogical approach by enhancing children's motivation, engagement, and internalization of environmentally

responsible behavior. In particular, gamification was found to facilitate the transition from externally imposed learning tasks to intrinsically motivated participation, thereby supporting the development of sustainable behavioral patterns. At the same time, the study reveals that the effectiveness of gamification is not universal but highly context-dependent. Its successful implementation relies on several critical factors, including teachers' professional competence, availability of resources, and parental involvement. These findings highlight that gamification should be understood not as a standalone solution, but as a pedagogical strategy that requires thoughtful design and supportive educational conditions. From a theoretical perspective, the study contributes to the literature by conceptualizing environmental culture as a value-based behavioral construct and by positioning gamification as a mechanism that connects play-based learning, experiential practices, and value formation. This extends existing research, which has predominantly focused on motivational outcomes, by emphasizing the role of gamification in shaping behavioral and ethical dimensions of learning.

From a practical standpoint, the findings offer important implications for educators and policymakers. The study suggests that gamification can be effectively integrated into early childhood education when it is aligned with play-based pedagogy and supported by adequate resources and teacher training. In addition, the importance of parental involvement highlights the need for a holistic approach to environmental education that extends beyond formal educational settings. Despite its contributions, the study has several limitations. The findings are based on a small sample of participants, which may limit the generalizability of the results. Future research could expand the sample size and include diverse educational contexts to further validate and extend the findings. In addition, longitudinal studies may provide deeper insights into the long-term impact of gamification on children's environmental behavior. In conclusion, the study demonstrates that gamification holds significant potential as a pedagogical tool for fostering environmental culture in early childhood education. However, its effectiveness depends on its integration into meaningful, context-sensitive pedagogical practices, highlighting the need for further research and careful implementation in educational settings.

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GAME-BASED COGNITIVE DEVELOPMENT IN EARLY CHILDHOOD: THE ROLE OF INTELLECTUM LOGICAL GAMES IN PRESCHOOL LEARNING ENVIRONMENTS

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Abstract

This study examines the role of Intellectum logical games in supporting cognitive development in preschool children through the analysis of educators' experiences. Grounded in constructivist and sociocultural theoretical frameworks, the research adopts a qualitative design to explore how logical game-based learning is implemented in real educational settings. Data were collected through semi-structured interviews with two preschool educators and analyzed using qualitative content analysis supported by MAXQDA software, including open, axial, and thematic coding. The findings reveal that the effectiveness of logical games is closely linked to the pedagogical strategies employed by teachers. Key practices include task differentiation, the use of visual and multimodal supports, structured step-by-step instruction, and the integration of movement-based activities. These strategies enable educators to adapt logical games to children's diverse cognitive abilities and maintain engagement. At the same time, the study identifies significant challenges, such as difficulties in explaining tasks, concerns about cognitive overload, and managing heterogeneous learning groups. Importantly, these challenges are shown to stimulate the development of adaptive teaching approaches and professional growth. The results confirm that Intellectum logical games contribute to the development of essential cognitive processes, including logical thinking, attention, memory, and problem-solving skills. Moreover, the study highlights the critical role of teacher agency in mediating the relationship between instructional tools and learning outcomes. By providing an in-depth qualitative perspective, the research contributes to bridging the gap between theoretical models of game-based learning and their practical application in preschool education. The findings underscore the importance of structured, teacher-guided play as an effective and developmentally appropriate approach to enhancing cognitive development in early childhood.

Keywords: early childhood education; cognitive development; logical games; game-based learning; Intellectum; preschool education; qualitative research; teacher practices; scaffolding; executive functions.

Introduction

Relevance of the research. In the context of rapidly evolving educational paradigms, early childhood education is increasingly oriented toward fostering higher-order cognitive processes, including logical thinking, problem-solving, attention regulation, and memory development. Contemporary research emphasizes that the preschool period represents a critical stage for

cognitive formation, during which appropriately designed pedagogical interventions can significantly influence long-term learning trajectories. Within this framework, play-based learning has emerged as a central approach, aligning with constructivist and sociocultural theories of development, particularly those proposed by Jean Piaget and Lev Vygotsky. At the same time, there is a growing need to integrate structured and developmentally appropriate educational tools that not only engage children but also systematically enhance their cognitive abilities. Logical and intellectual games, such as the Intellectum system, represent a promising pedagogical resource, as they combine игровую мотивацию с целенаправленным развитием мыслительных операций. However, despite the increasing implementation of such tools in preschool settings, there remains a lack of in-depth qualitative research examining how educators actually use these games in practice, what strategies they employ, and how these practices contribute to children's cognitive development. Furthermore, modern educational environments, including inclusive classrooms, require flexible and differentiated teaching approaches that can accommodate diverse learning needs. In this regard, understanding teachers' experiences and pedagogical decisions becomes essential for evaluating the real educational potential of logical games. Therefore, the relevance of this study lies in addressing the gap between theoretical assumptions about game-based learning and its practical implementation in preschool education.

Research Problem. Despite the recognized importance of play-based and cognitively stimulating activities in early childhood education, there is insufficient empirical evidence regarding the pedagogical mechanisms through which structured logical games, such as Intellectum, support the development of cognitive processes in preschool children. Existing studies predominantly focus on quantitative outcomes or theoretical models, while overlooking the nuanced, practice-based experiences of educators who directly implement these tools in real classroom settings. In particular, there is a lack of understanding of how teachers adapt logical games to different cognitive levels, how they manage challenges associated with diverse learners, and how their instructional strategies influence children's engagement and cognitive growth. Moreover, the emotional and professional experiences of teachers especially in the initial stages of implementing such methods remain underexplored. This creates a gap between the theoretical potential of logical game-based learning and its actual pedagogical realization. Consequently, the central problem of this research is to investigate how Intellectum logical games are integrated into preschool educational practice and to identify the ways in which they contribute to the development of cognitive processes from the perspective of educators.

The object of the study is the process of cognitive development in preschool children within the context of early childhood education. *The subject of the study* is the pedagogical use of Intellectum logical games as a tool for supporting and enhancing cognitive processes in preschool children, as reflected in educators' practices and experiences.

The aim of this study is to explore how Intellectum logical games are implemented in preschool educational settings and to analyze their role in supporting the development of cognitive processes based on educators' experiences. To achieve the stated aim, the following objectives are formulated:

- to examine the theoretical foundations of cognitive development in early childhood and the role of game-based learning.
- to analyze the pedagogical potential of logical games, particularly the Intellectum system, in developing cognitive processes.
- to investigate educators' experiences in implementing Intellectum logical games in preschool settings.
- to identify the teaching strategies used by educators to adapt logical games to children's individual cognitive needs.

- to explore the challenges and solutions encountered by teachers in the process of integrating logical games into educational practice.
- to determine how the use of logical games influences children's engagement, thinking processes, and overall cognitive development.

Hypothesis. This study is based on the assumption that the systematic use of Intellectum logical games in preschool education significantly enhances the development of children's cognitive processes, including logical thinking, attention, memory, and problem-solving skills. It is hypothesized that when these games are implemented through structured pedagogical strategies such as differentiation, visual support, step-by-step instruction, and interactive engagement they promote higher levels of cognitive activity and sustained involvement among preschool children. Furthermore, it is assumed that educators' professional experience and instructional approaches play a crucial mediating role in determining the effectiveness of logical game-based learning, particularly in diverse and inclusive classroom contexts.

The *scientific novelty* of this study lies in its comprehensive qualitative exploration of the pedagogical use of Intellectum logical games in preschool education, which has been insufficiently addressed in existing research. First, unlike the majority of studies that focus on quantitative assessments of learning outcomes, this research provides an in-depth analysis of educators' lived experiences, revealing the underlying instructional strategies, decision-making processes, and adaptive practices involved in implementing logical games in real classroom settings. Second, the study identifies specific pedagogical mechanisms such as task differentiation, the use of visual and multimodal supports, and the structuring of game-based activities that contribute to the development of cognitive processes in preschool children. These mechanisms are examined not as abstract principles but as context-dependent practices shaped by teachers' professional expertise. Third, the research highlights the emotional and professional dimension of teachers' experiences, particularly the transition from initial uncertainty to pedagogical confidence when integrating innovative tools like Intellectum games. This perspective expands the understanding of teacher agency in early childhood education. Finally, the study contributes to bridging the gap between theoretical models of cognitive development and their practical application by demonstrating how structured logical play can be effectively embedded in everyday preschool pedagogy, including inclusive learning environments.

Literature Review

Cognitive development in early childhood is widely recognized as a foundational process that shapes later academic achievement, self-regulation, and adaptive learning capacities. According to classical developmental theories, the preschool period represents a critical stage for the formation of higher mental functions. In particular, Jean Piaget (1952, 1972) conceptualized early childhood as a stage of active knowledge construction, in which children develop logical thinking through interaction with objects and environments. Similarly, Lev Vygotsky (1978) emphasized the role of social interaction and guided learning within the Zone of Proximal Development, highlighting that cognitive growth is mediated by structured support and collaboration. Building on these theoretical foundations, contemporary research increasingly emphasizes the importance of play-based learning as a key mechanism for cognitive development in early childhood education. Play is no longer viewed as a purely recreational activity but as a pedagogically meaningful context in which children develop problem-solving skills, attention regulation, and symbolic thinking (Weisberg et al., 2013; Weisberg et al., 2016). The concept of guided play, which integrates child autonomy with intentional adult scaffolding, has been identified as particularly effective for promoting learning outcomes while maintaining engagement and intrinsic motivation (Weisberg et al., 2013). Empirical evidence suggests that guided play environments can support deeper conceptual understanding compared to both free play and direct instruction when appropriately implemented (Skene et al., 2022).

A substantial body of literature highlights the role of play in the development of executive functions, including working memory, inhibitory control, and cognitive flexibility. These functions are considered essential predictors of school readiness and long-term academic success (Carlson & Meltzoff, 2008). Studies have shown that structured play activities that require rule-following, strategic thinking, and behavioral regulation can significantly enhance executive functioning in preschool children (Yogman et al., 2018). Moreover, physical and game-based activities have been associated with improvements in both cognitive and motor development, suggesting a holistic impact of play on child development (Panhelova et al., 2020). In recent years, increasing attention has been paid to the role of structured and game-based learning tools in early childhood education. Educational games have been shown to support the development of logical thinking, attention, and problem-solving skills when they are integrated into pedagogical practice in a purposeful and systematic way (G'aniyeva, 2025; Umurqulova, 2025). Similarly, research on multimedia and digital learning environments indicates that interactive and visually rich materials can enhance cognitive engagement and learning outcomes in young children (Davidson, 2014; Zheng et al., 2016). However, scholars also caution that technology and educational tools are often “oversold and underused” when not supported by effective pedagogical strategies (Cuban, 2001), highlighting the importance of teacher mediation. The role of the teacher is increasingly recognized as a central factor in the effectiveness of play-based and game-based learning. Research indicates that the educational value of play depends not only on the materials used but also on how teachers structure activities, provide guidance, and adapt tasks to children’s individual needs (Pyle et al., 2018). Effective pedagogical practices include task differentiation, the use of visual supports, scaffolding of complex tasks, and the creation of collaborative learning environments. In inclusive classrooms, these strategies become even more critical, as they allow teachers to accommodate diverse cognitive abilities and learning styles (Plowman & McPake, 2013).

Despite the growing body of research on play-based learning and cognitive development, several important gaps remain. First, much of the existing literature focuses on general forms of play or digital learning environments, while relatively little attention has been given to structured logical games as a specific pedagogical tool. Second, most studies adopt quantitative approaches, emphasizing measurable learning outcomes while neglecting the qualitative dimensions of teaching practice, such as educators’ experiences, perceptions, and adaptive strategies. Third, there is limited research examining how teachers implement logical games in real classroom contexts and how their professional experience influences the effectiveness of such methods. Therefore, there is a clear need for qualitative research that explores the pedagogical mechanisms underlying the use of structured logical games in preschool education. In particular, examining educators’ experiences can provide valuable insights into how cognitive development is supported through everyday teaching practices. Addressing this gap, the present study focuses on the implementation of *Intellectum* logical games and seeks to understand how they contribute to the development of cognitive processes in preschool children from the perspective of educators.

Methods

This study employed a qualitative research design to explore educators’ experiences in using *Intellectum* logical games to support cognitive development in preschool children. A qualitative approach was considered appropriate, as the study aims to capture in-depth insights into pedagogical practices, perceptions, and contextual factors that cannot be adequately examined through quantitative methods. The research followed an interpretive paradigm, focusing on how teachers understand and implement logical game-based learning in real educational settings. The participants consisted of two preschool educators selected through purposive sampling, both of whom had several years of professional experience in early childhood education and direct involvement in using *Intellectum* logical games in their teaching practice. One

participant had five years of experience and held a master's degree, while the second had four years of experience as a practicing educator. Data were collected through semi-structured interviews, which provided a flexible framework for exploring participants' experiences while maintaining a consistent thematic structure. A total of two interviews were conducted, each lasting approximately 30–35 minutes, in a quiet and comfortable educational environment at a time convenient for the participants. With informed consent, all interviews were audio-recorded and subsequently transcribed verbatim to ensure accuracy and completeness of the data. The interview protocol consisted of six thematic blocks addressing key aspects of pedagogical practice, including the use of logical games, instructional strategies, challenges encountered, and perceived effects on children's cognitive development. Data analysis was conducted using qualitative content analysis supported by MAXQDA Analytics Pro software. The analysis followed a multi-stage coding process. At the initial stage, open coding was applied through a line-by-line examination of the transcripts to identify meaningful segments and assign initial codes reflecting key ideas such as teaching strategies, differentiation, use of visual supports, and application of logical games. At the second stage, axial coding was used to organize these codes into broader categories and to identify relationships between them, resulting in thematic clusters such as "teaching strategies," "challenges and solutions," and "teacher experience." At the final stage, thematic analysis was employed to synthesize the data into overarching themes that capture the core dimensions of educators' experiences. Visual analytical tools within MAXQDA, including code frequency diagrams and word clouds, were used to identify dominant patterns and semantic emphasis in the data. All ethical standards for qualitative research were strictly observed throughout the study. Participation was voluntary, and all participants were fully informed about the purpose of the research, the use of data, and confidentiality procedures. Written and verbal informed consent was obtained prior to the interviews. To ensure anonymity, participants were assigned codes (M1 and M2), and all identifying information was removed from the transcripts. Data were stored securely and used exclusively for research purposes, with audio recordings deleted after the completion of the study.

Results and Discussion

During the initial stage of open coding, the interview transcripts were examined line by line to identify meaningful units of data. This process generated a set of initial codes capturing key aspects of pedagogical practice, including instructional strategies, the use of visual materials, differentiation of tasks, emotional responses, and perceived learning outcomes. These codes reflected both the practical and experiential dimensions of teaching with logical games. At the axial coding stage, the initial codes were systematically organized into broader analytical categories based on conceptual similarities and relationships. This process resulted in several core categories, including "pedagogical strategies," "challenges and solutions," and "teacher experience," which represent the central dimensions of educators' interactions with Intellectum games. The relationships between these categories were examined to identify patterns in how teaching practices evolve and respond to classroom dynamics. In the final stage of analysis, these categories were synthesized into four overarching themes that structure the presentation of results. These themes include:

- (1) pedagogical strategies in the use of logical games;
- (2) challenges encountered and adaptive solutions;
- (3) teachers' professional and emotional experiences;
- (4) perceived impact on children's cognitive development. Together, these themes provide a comprehensive understanding of how logical games are implemented in practice and how they contribute to cognitive development in early childhood education.

To further examine the internal structure of the coded data, visual representations of code distribution were generated using MAXQDA. Figures 1 illustrate the distribution of coded segments across thematic categories for each interview. The visualizations reveal a consistent dominance of codes related to pedagogical strategies and the developmental impact of logical games, indicating that both participants placed strong emphasis on instructional practices and cognitive outcomes. At the same time, noticeable variation can be observed in the distribution of codes associated with teacher experience and challenges. In particular, Interview 2 demonstrates a more pronounced presence of codes related to emotional responses and initial difficulties, whereas Interview 1

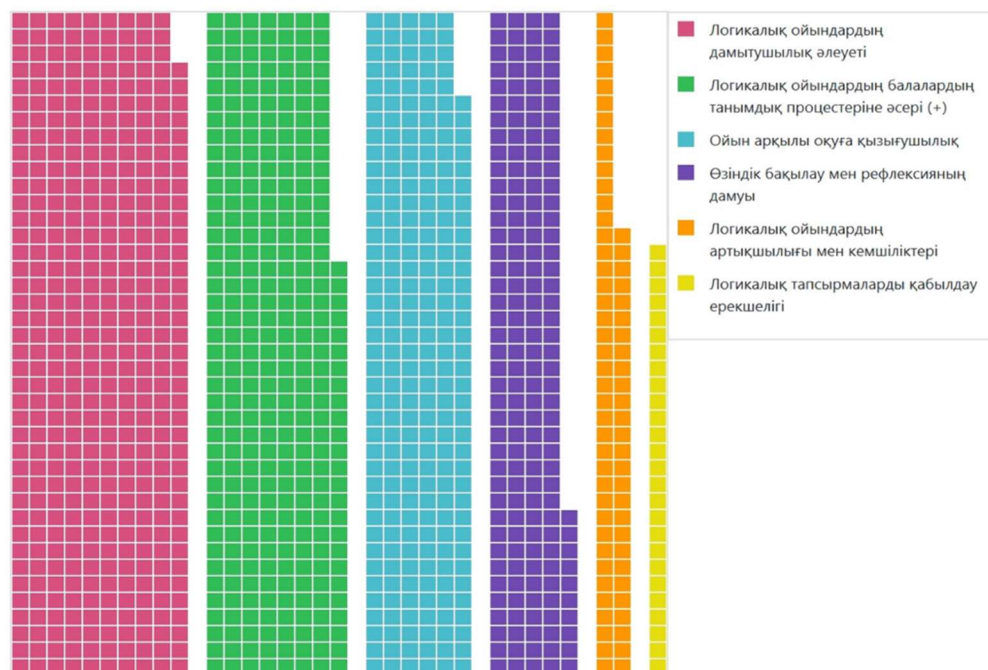


Figure 1. Distribution of coded segments across thematic categories in educators' interviews

reflects a more structured and balanced coding pattern.

One of the central themes emerging from the data concerns the range of pedagogical strategies employed by educators when integrating Intellectum logical games into preschool learning environments. The analysis revealed that the effectiveness of logical games is not determined solely by the instructional materials themselves, but rather by the ways in which teachers structure, adapt, and mediate these activities in response to children's cognitive needs.

Differentiation of tasks and individualized learning. A key strategy identified in both interviews is the differentiation of tasks according to children's abilities and learning pace. Educators emphasized that logical games cannot be implemented as uniform activities; instead, they require flexible adaptation to accommodate varying levels of cognitive readiness. As noted by M1:

"When I plan the lesson, I always divide the tasks into several levels, because each child works at a different pace and has different abilities..."

This statement highlights an important pedagogical shift from standardized instruction toward individualized learning trajectories. Differentiation in this context functions as a mechanism for maintaining optimal cognitive challenge, which is essential for sustaining engagement and promoting higher-order thinking. Rather than simplifying tasks, teachers restructure them to

ensure accessibility while preserving their cognitive complexity. This finding suggests that logical games serve as a flexible framework within which adaptive teaching practices can be effectively implemented.

Use of visual and multimodal supports. Another prominent strategy involves the extensive use of visual materials to facilitate understanding and engagement. Both participants described relying on visual aids such as pictures, cards, and symbolic representations to support children's comprehension of abstract or complex tasks. M1 explained:

"I often use pictures, cards, and visual materials because children understand better when they can see and connect ideas visually..."

Similarly, M2 emphasized the importance of simplifying instructions through visual and step-based guidance:

"I try to explain tasks in small steps and use visual support so that children do not feel confused..."

These findings indicate that visual scaffolding plays a critical role in mediating cognitive processes, particularly in early childhood contexts where abstract reasoning is still developing. The use of multimodal supports allows teachers to bridge the gap between concrete experience and logical reasoning, thereby enhancing children's ability to process and retain information.

Game-based and movement-integrated learning. The integration of movement and play into instructional activities emerged as another significant pedagogical strategy. Educators reported that combining logical tasks with physical activity increases children's engagement and helps regulate attention, particularly for more active learners. As M1 noted:

"I often include movement-based games and role-playing tasks, because children stay more involved when they can move and interact..."

M2 provided a similar perspective:

"For very active children, I add movement to the tasks so that they can stay focused and complete the activity..."

This approach reflects an understanding of learning as an embodied process, in which cognitive development is closely linked to physical engagement. By incorporating movement into logical games, teachers create dynamic learning environments that support both attention regulation and sustained participation. This strategy is particularly relevant in inclusive classrooms, where children may have diverse behavioral and cognitive profiles.

Structured and step-by-step instruction. A further important element of pedagogical practice is the use of structured, step-by-step instruction. Both educators emphasized the need to break down complex tasks into smaller, manageable components to ensure that children can successfully engage with logical challenges. M2 described this process as follows:

"At first, I was afraid that the tasks would be too difficult, so I started to explain them step by step and in smaller parts..."

This strategy reflects a scaffolding approach in which the teacher gradually supports the child's progression from simple to more complex forms of reasoning. The emphasis on structured guidance suggests that the effectiveness of logical games depends not only on their design but also on the clarity and sequencing of instruction. Taken together, these findings demonstrate that the pedagogical use of Intellectum logical games is characterized by a high degree of intentionality and adaptability. Teachers do not simply implement games as predefined activities; rather, they actively transform them into cognitively meaningful learning experiences through differentiation, visual scaffolding, movement integration, and structured instruction. These strategies function as interconnected elements of a broader pedagogical system. Differentiation ensures accessibility, visual supports enhance comprehension, movement sustains engagement, and structured instruction facilitates progression. The combination of these strategies creates a learning environment in which logical games can effectively support the development of cognitive processes. This theme underscores that the educational value of logical games lies not in the tools themselves but in the pedagogical practices that shape their use. As such, teacher agency emerges as a central factor in mediating the relationship between game-based activities and cognitive development in early childhood education.

Challenges and adaptive solutions in implementing intellectum logical games. The second major theme emerging from the data relates to the challenges educators encounter when introducing Intellectum logical games into preschool practice and the adaptive strategies they develop in response. The findings indicate that the implementation of logical games is accompanied by initial uncertainty and practical difficulties, which gradually transform into more confident and structured pedagogical approaches. Importantly, challenges are not merely obstacles but serve as a catalyst for professional growth and methodological refinement. One of the most prominent challenges identified in the interviews concerns the difficulty of explaining logical tasks to preschool children in a clear and accessible manner. Teachers emphasized that the structure of Intellectum games requires careful interpretation and adaptation, especially at the initial stages of implementation. As M2 reflected on her early experience:

"...At first, when I started working with Intellectum logical games, I constantly thought: will I be able to explain this correctly, will the children understand me? Sometimes I felt that the tasks themselves were clear to me, but explaining them in a simple way for children was much more difficult..."

This statement highlights the cognitive and pedagogical gap between adult understanding and child comprehension. The challenge lies not in the complexity of the material itself, but in translating abstract logical structures into developmentally appropriate forms. This finding underscores the central role of teacher mediation in transforming instructional tools into meaningful learning experiences. Closely related to instructional difficulties is the concern that logical games may exceed children's cognitive capabilities. Educators expressed anxiety about whether such tasks might be too demanding, potentially leading to confusion or disengagement. M2 described this concern in detail:

"In the beginning, I was worried that maybe these tasks are too difficult for children, that they might feel overwhelmed or lose interest if they don't understand what is expected from them."

This fear reflects a broader pedagogical tension between providing cognitively stimulating activities and maintaining emotional comfort in the learning process. Teachers demonstrate an acute awareness of children's emotional responses, which influences how they structure and pace

activities. This sensitivity is particularly important in early childhood education, where negative experiences can reduce motivation and participation. Another significant challenge concerns the heterogeneity of learners within the classroom. Participants noted that children differ not only in their cognitive abilities but also in their speed of task completion, attention span, and level of engagement. As M1 explained:

“...In one group, you always have children who complete tasks very quickly and those who need more time. It is sometimes difficult to organize the lesson so that everyone is involved and no one feels left behind...”

This challenge is especially relevant in inclusive educational settings, where variability is even more pronounced. The need to balance the pace of instruction while ensuring meaningful participation for all children requires continuous pedagogical adjustment. This finding highlights the complexity of implementing structured logical games in real classroom environments. In response to these challenges, educators developed a range of adaptive strategies aimed at making logical games more accessible. One of the most frequently mentioned approaches was breaking down tasks into smaller, sequential steps. M2 described this process as follows:

“...Over time, I understood that I need to explain everything step by step, not all at once. When I divide the task into smaller parts, children begin to understand better and feel more confident...”

This strategy reduces cognitive load and allows children to gradually build understanding. It reflects a scaffolding approach in which the teacher provides structured support and progressively transfers responsibility to the learner. Another key solution involves the use of visual materials and simplified explanations. Teachers reported that visual aids help children grasp complex ideas more effectively and reduce confusion. As noted by M1:

“When I use pictures, cards, or visual elements, children understand faster. It becomes easier for them to connect what they see with what they need to do...”

This approach demonstrates how multimodal instruction can bridge the gap between abstract reasoning and concrete experience, making logical tasks more accessible for young learners. Teachers also addressed the challenge of diverse learning paces by organizing collaborative learning environments. Mixed-ability grouping was used as a strategy to facilitate peer support and collective problem-solving. M1 explained:

“I try to combine children in such a way that they can help each other. Stronger children support those who need more time, and this makes the learning process more natural.”

This approach not only supports task completion but also enhances social interaction and cooperative learning, which are essential components of cognitive development. The analysis of challenges and adaptive solutions reveals that the implementation of Intellectum logical games is a dynamic and evolving process. Teachers initially experience uncertainty related to instruction, cognitive load, and classroom management; however, these challenges gradually lead to the development of more effective and flexible pedagogical strategies. The findings demonstrate that successful integration of logical games depends on the teacher's ability to regulate task complexity, provide structured guidance, and adapt to individual differences among learners. Strategies such as scaffolding, visual support, task differentiation, and peer collaboration form an interconnected

system that enables children to engage meaningfully with logical tasks. This theme reinforces the idea that the effectiveness of game-based learning is not inherent in the instructional tools themselves but is mediated through teacher expertise, reflection, and responsiveness. In this sense, challenges function as a critical driver of pedagogical development, contributing to the refinement of teaching practices and the creation of cognitively supportive learning environments.

The findings of this study provide important insights into how Intellectum logical games are implemented in preschool education and how their effectiveness is mediated through pedagogical practices and teacher experience. The results confirm that game-based learning, when supported by structured instructional strategies, can significantly contribute to the development of cognitive processes in early childhood. At the same time, the study extends existing research by demonstrating that the impact of logical games depends not only on their design but also on how they are adapted, interpreted, and facilitated by educators.

First, the identified theme of pedagogical strategies aligns closely with constructivist and sociocultural perspectives on learning. The use of differentiation, scaffolding, and step-by-step instruction reflects principles outlined by Piaget (1952, 1972), who emphasized that children construct knowledge through active engagement, as well as by Vygotsky (1978), who highlighted the role of guided learning within the Zone of Proximal Development. In particular, the practice of breaking tasks into smaller steps and providing structured support corresponds to scaffolding processes that enable children to gradually acquire higher-order cognitive skills. These findings are also consistent with the concept of guided play, which integrates child autonomy with intentional adult support (Weisberg et al., 2013; Weisberg et al., 2016).

Second, the results confirm the importance of visual and multimodal supports in early childhood learning. The frequent use of visual materials observed in this study supports previous research indicating that young children benefit from concrete and perceptually rich representations when engaging with abstract concepts (Plowman & McPake, 2013). By combining visual aids with logical tasks, educators create learning environments that facilitate comprehension and retention, thereby enhancing cognitive engagement.

Third, the findings related to movement-integrated learning and engagement support the broader literature on the role of play in cognitive development. Previous studies have shown that play-based and physically interactive activities contribute to the development of executive functions, including attention regulation and problem-solving (Yogman et al., 2018; Panhelova et al., 2020). In this study, the integration of movement into logical games appears to function as a mechanism for sustaining attention and increasing participation, particularly among more active children. This suggests that cognitive development in early childhood is closely linked to embodied and interactive learning experiences.

A particularly important contribution of this study lies in its analysis of challenges and adaptive solutions. While existing research acknowledges the benefits of play-based learning, fewer studies examine the practical difficulties educators face during implementation. The findings reveal that teachers initially experience uncertainty related to explaining tasks, managing cognitive load, and addressing diverse learning needs. These challenges reflect the complexity of translating theoretical models of game-based learning into classroom practice. However, consistent with previous research on teacher roles in play-based pedagogy (Pyle et al., 2018), the study demonstrates that educators actively adapt their strategies by using scaffolding, differentiation, and peer support to overcome these difficulties. The study highlights the critical role of teacher agency in mediating the effectiveness of logical games. The variation observed among participants, particularly in confidence and emotional responses, suggests that professional experience influences how pedagogical tools are implemented. This finding extends existing literature by emphasizing the dynamic and developmental nature of teacher expertise. While prior studies have focused primarily on learning outcomes, this research shows that teachers' emotional and

professional trajectories are equally important in shaping educational practice. Finally, the findings regarding the perceived impact on children's cognitive development support prior empirical evidence on the effectiveness of educational games. Participants reported improvements in logical thinking, attention, and problem-solving skills, which is consistent with studies demonstrating the positive role of structured games in early cognitive development (Carlson & Meltzoff, 2008; Zheng et al., 2016). However, this study adds a qualitative dimension by showing how these outcomes are experienced and interpreted by educators in real classroom contexts.

Conclusion

This study aimed to explore how Intellectum logical games are implemented in preschool educational settings and to analyze their role in supporting the development of cognitive processes based on educators' experiences. The findings demonstrate that the stated aim has been successfully achieved. Through qualitative analysis of teachers' practices, the study provides a comprehensive understanding of how logical games function as pedagogical tools in real classroom contexts. The results confirm the initial hypothesis that the systematic use of Intellectum logical games contributes to the development of key cognitive processes, including logical thinking, attention, memory, and problem-solving skills. However, the study also reveals that the effectiveness of these games is not inherent in the materials themselves but is largely determined by the pedagogical strategies employed by teachers. In particular, approaches such as task differentiation, visual support, scaffolding, and movement-based learning play a crucial role in enhancing children's engagement and cognitive activity. An important contribution of this research lies in its identification of the dynamic relationship between challenges and pedagogical adaptation. Teachers initially experience uncertainty related to explaining tasks, managing cognitive load, and addressing diverse learning needs. Over time, these challenges lead to the development of more flexible and effective instructional strategies. This finding highlights the role of teacher agency as a key mediating factor in the successful implementation of game-based learning. Furthermore, the study emphasizes the significance of teachers' professional and emotional development. The transition from initial doubt and anxiety to confidence and structured practice demonstrates that the integration of innovative pedagogical tools is also a process of professional growth. This dimension extends existing research by showing that cognitive development in children is closely linked not only to instructional design but also to the evolving expertise of educators. Despite its contributions, the study has several limitations. The small sample size, consisting of only two participants, limits the generalizability of the findings. In addition, the qualitative design focuses on teachers' perceptions rather than direct measurement of children's cognitive outcomes. Future research could expand this study by incorporating larger samples, mixed-method approaches, and experimental designs to examine the impact of logical games on cognitive development more systematically. Cross-cultural comparisons and classroom-based observations would also provide valuable insights into the broader applicability of these findings. In conclusion, the study demonstrates that Intellectum logical games represent an effective and developmentally appropriate tool for supporting cognitive development in early childhood education. Their successful implementation depends on thoughtful педагогикалық mediation, adaptive teaching strategies, and the active engagement of both teachers and children. These findings contribute to a deeper understanding of game-based learning and highlight its potential as a meaningful component of contemporary preschool education.

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PEDAGOGICAL BASES FOR THE FORMATION OF PROFESSIONAL COMPETENCE IN FUTURE TEACHERS

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Abstract

The article presents the features of the pedagogical foundations for the formation and development of professional competence in future teachers. The essence of professional competence is defined. The effectiveness of the foundations that ensure the formation and development of professional competence in future teachers is demonstrated. The article is written with the aim of conducting a detailed study of the ways to form the most effective professional competencies of future teachers during the educational process. The main objectives of the research are identified, such as revealing the essence of the concept of teachers' "professional competence"; identifying the components of professional competence of a future teacher; determining the current state of the problem of forming future teachers' professional competence in general pedagogy; improving the theoretical foundations of pedagogy as a science for the formation and development of future teachers' professional qualities; studying and analyzing the most effective ways of developing professional competence and literacy among students of pedagogical higher education institutions in the preparation of future teachers. The stages of forming competency-based personal qualities of future teachers, consisting of four components and structural elements of personal qualities, are examined. In turn, they enhance personal qualities and contribute to the formation of professional competence in future teachers. The authors analyzed the main concepts of forming professional competencies of future educators within the educational process and studied and discussed the scientific works of Kazakhstani and Russian researchers. It was revealed that the pedagogical foundations for the formation and development of professional competence and literacy of future teachers include the ability to independently solve problems and tasks in the field of biology, as well as the capacity for self-development based on knowledge, skills, and abilities. The theoretical framework of the article leads to the understanding that a teacher must possess new knowledge and professionally significant personal qualities.

Keywords: competence, professional competence, education system, special competence, social competence, personal competence, individual competence, future teacher.

Introduction

Today, significant steps are being taken in the field of education in Kazakhstan to address important tasks related to educating a competitive generation. The professional abilities of a

teacher are directly connected with their readiness for self-development. In order to approach this issue from a socio-pedagogical perspective, it is necessary to determine the level of a teacher's readiness to fulfill the tasks assigned to them as a subject of professional activity. Modernization of education is a requirement of the present time. In the training of future specialists, the formation of professional competencies is an important aspect; therefore, education is continuously carried out using the latest technologies. To achieve the desired results, it is necessary to develop both theoretical and practical professional competencies of students, as well as improve the qualifications of personnel working in educational institutions. Consequently, the higher education system in Kazakhstan requires modernization, especially in the field of teacher training. In Kazakhstan, the modernization of the education system is carried out in three main directions:

1. optimization of educational institutions and implementation of modern methods and technologies in the educational process;
2. modernization not only of the educational process, but also of the upbringing process, as well as continuous professional development of the teaching staff both in Kazakhstan and abroad. It is necessary to improve the quality standards of specialized pedagogical education and strengthen the requirements for professional development of school and university teachers. Integrated teacher training centers should operate in every region and area;
3. improving the quality, efficiency, and accessibility of educational services.

The formation of competence is a relevant issue in the field of education. Consequently, there is a need to organize the development of methodological creativity among school teachers within the system of teacher professional development. By developing the creative abilities of future professionals – today's students – teaching them to achieve a high level of intellectual activity, understand new concepts, identify gaps in knowledge, and strive for expected outcomes, the anticipated result will be the formation of a research-oriented mindset [1].

Main Part

The problem of professional competence of future teachers is reflected in the works of Kazakhstani and foreign scholars, educators, and psychologists engaged in issues of professional training of specialists. The concept of "competence" in the field of education appeared in foreign literature in the 1960s–1970s and in Kazakhstani literature in the late 1980s. The necessity of introducing the concepts of "competency" and "professional competence" is justified by their integrative nature and the breadth of their content, which combines such notions as "qualification," "mastery," "professional capability," "professionalism," and others [2].

Despite the widespread use of the concept of "competence," the essence of this term requires deep scientific analysis and justification. Therefore, the analysis begins primarily with the search for an answer to the question: "What does this concept mean?" A comparative analysis was conducted in defining the concepts of "competency" and "competence" in numerous domestic and foreign studies (V.I. Baidenko, N.A. Grishanova, D.A. Makhotin, O.E. Lebedev, S. Adam, U. Clement, and others) [3].

A large body of literature has been developed on issues related to the psychological, theoretical, and practical preparation of the individual, the formation of professional qualities and abilities of teachers, their reputation and professionalism, pedagogical thinking, the organization of scientific work, and professional development. These include the scientific works of S.I. Arkhangelsky, F.N. Gonobolin, N.V. Kulyutkin, I.T. Ogorodnikov, A.I. Piskunov, V.A. Slastenin, A.I. Shcherbakov, N.V. Kuzmina, N.V. Talyzina, V.V. Kraevsky, N.D. Khmel, S.T. Kargin, A.K. Markova, K.S. Ospanov, and others [3].

In the research of domestic scholars such as N.V. Kuzmina, A.K. Markova, I.A. Zimnyaya, and others in the 1970s–1990s, competence was considered as a new goal and an important component of education, including the management of the pedagogical process and the

professional activity of the teacher. Professional-pedagogical competence and its individual forms have been studied in the scientific works of V.A. Adolf, E.V. Bondarevskaya, while other aspects of teacher professional competence have been examined in the works of K.A. Abulkhanova, L.M. Mitina, L.I. Mishchenko, M.V. Prokhorova, E.I. Rogov, D.S. Savelyev, V.A. Slastenin, N.F. Talyzina, A.I. Shcherbakov, and others [4].

For the introduction of the concepts “competency” and “competence” into the pedagogical process, researchers have devoted scientific studies aimed at revealing their methodological essence and describing them in various interpretations. The authors of the Explanatory Dictionary edited by D.I. Ushakov, in order to clarify the distinction between “competence” and “competency,” attempted to demonstrate that these concepts are different [5].

“Competence” is defined as awareness and worthiness; “competency” is understood as a certain set of professional qualities and functional characteristics of an individual. K.V. Shaposhnikov explains that the category of professional competence, in general, is characterized by a set of integrated knowledge, skills, and experience, as well as personal qualities that enable a person to effectively design and carry out professional activity in interaction with the surrounding world. In contrast, I.N. Almazova writes that competency refers to the knowledge and skills acquired by a person in a specific field, while competence is the ability of a specialist to effectively apply competencies. According to N.V. Kuzmina, “competence” is the teacher’s knowledge and dignity, which can serve as a basis for the development of another person [6].

Kazakhstani scholar K.S. Kudaibergenova defines “competence” in the field of pedagogy, derived from the Latin “competens,” as meaning a well-informed expert in a specific area, as a result of special attention to a person’s subjective experience. She argues that the concepts of “competence” and “competency” differ as follows:

- it differs from knowledge as it represents a form of productive activity rather than informational activity;
- it differs from skills as it is a conscious activity capable of changing phenomena and patterns through the study of material and the use of creativity;
- it differs from ability as it is a combination of skills from several disciplines, a general understanding of the foundations of activity rather than an automatic acquisition or replacement of skills [7].

Sh.T. Taubaeva considers that “competence is a personality trait based on knowledge and experience acquired by a person in the process of education and socialization, defined as their general ability and readiness for action” [8].

The types of professional competence identified by B.T. Kenzhebekov are presented in the figure.

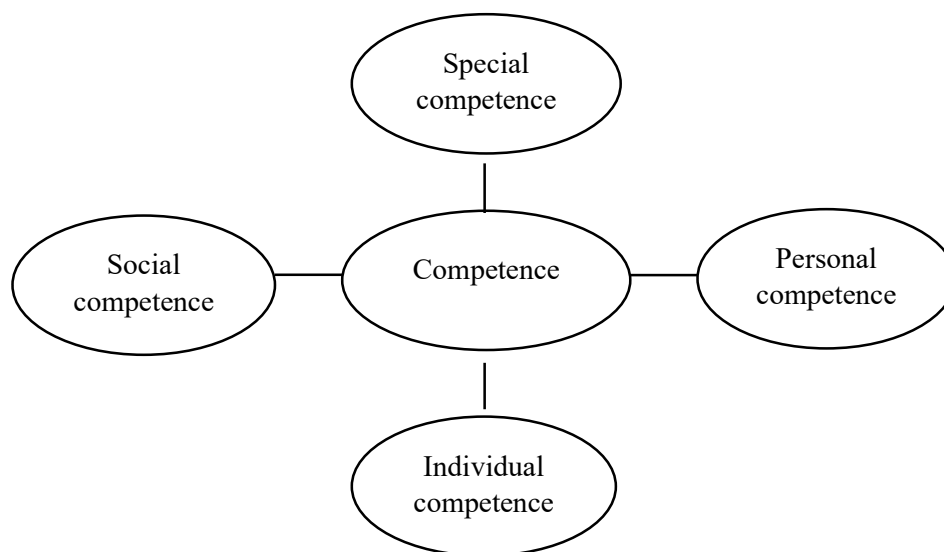


Figure 1. Professional competence (according to B.T. Kenzhebekov)

Special competence – is a type of competence in a specific narrow field, where the ability to design and plan one’s professional development is expressed.

Social competence – refers to the establishment of cooperation in the professional sphere, the ability to carry out joint work with others, and the ability to take responsibility for the results achieved in professional activity before society.

Personal competence – is individuality in professional activity, characterized by a high level of mastery of methods and tools for development and self-expression.

Individual competence – is the ability to realize one’s potential, to develop one’s individuality in the profession, readiness for professional growth, the ability to preserve one’s individuality, flexibility in the rational organization of work, and the ability to achieve results without difficulty or fatigue [9].

T.P. Terentyeva, in her research work, divided the competence that is part of the professional competence of pedagogical specialists into two groups: “individual” and “general”. Individual competence is special competence, a system of requirements for specific specialists and their specialized knowledge and experience required in the subject they teach. General competence includes reflective, communicative, general pedagogical, and technological competencies that must be mastered by every participant in the educational process [10].

According to many scholars, the types of professional competencies of a general-profile specialist include:

- practical competence – knowledge and application of techniques and technologies in professional activity, opportunities for professional growth of the specialist, as well as the results of creative activity;
- social competence – is responsibility to society, the ability to make both individual and group decisions, to resolve conflicts peacefully, and to interact with other cultures and religions;
- psychological competence – is, in the absence of skills and abilities of reflection and experience of interaction with society, professionalism remains personal and incomplete;
- information competence – is the knowledge and ability to apply new information technologies in professional activity;
- communicative competence – is proficiency in foreign languages as well as a high level of speech culture;

- ecological competence – is environmental responsibility, represented by a set of knowledge, skills, and abilities necessary for environmental activities;
- valeological competence – is a healthy lifestyle, meaning the possession of knowledge and skills in the field of health [11].

Zh.Kh. Salhanova considers competence as a criterion of a person's knowledge in a results-oriented education system. In her work, the author defines "professional competence" as a group characterized by the level of one's professional knowledge, skills, personal abilities, the desire for continuous professional development, and a creative and responsible approach to work [12].

Zh.M. Akparova views professional competence as communicative, regulatory, and intellectual-pedagogical competence:

- communicative competence – is a professional integrative quality based on emotional stability, language skills, the ability to listen, the ability to reward, politeness, and general abilities;
- regulatory competence refers to the teacher's ability to control their own actions. It includes goal orientation, planning, continuous activity, self-expression, reflection, evaluation of actions, and the main factor of action is kindness and values;
- intellectual-pedagogical competence – is a set of analytical skills used for effective teaching, as well as the ability for innovative activity [13].

B.S. Gershunsky considers "professional competence" to be the highest level of education. "Professional competence" includes two different aspects: first, knowledge of the science or sciences that form the basis of a specific profession. Second, skills and abilities in applying the acquired knowledge in practice. In other words, professional competence consists of knowledge in the field of one's professional activity and the ability to apply and use this knowledge in work [14].

Analyzing the research of all the above-mentioned scholars, the authors concluded that the concept of "formation and development of professional competence of future biology teachers" is determined by students' ability to independently solve biological tasks and problems, as well as their self-development based on knowledge, skills, and abilities. Thus, the main components of teachers' professional competence are communicative and intellectual-pedagogical competencies. As a result of mastering communicative competence, many problems and tasks are optimally solved through proper communication, which occupies a special place in personal success. Intellectual-pedagogical competence develops analytical skills such as analysis, comparison, generalization, specification, flexibility, and critical thinking.

The formation of professional competence in future teachers is associated with high personal qualities. In the table below, scholars identify the formation of competency-based personal qualities of future teachers:

Table 1. Formation of competency-based personal qualities of future teachers

Structural components of personal qualities	Characteristics
Motivational	– having a serious attitude toward the profession; – a positive attitude toward educational and instructional work; – interest in educational activities; – understanding the importance of educational work; – desire to acquire education (artistic-technological); – need for self-realization
Informational	– perception of the concept of the integrity of the educational process; – perception of methods and forms of educational work; – understanding the essence of education; – awareness of the professional and personal qualities of a progressive teacher; – organization of teaching and educational work
Procedural	– ability of the teacher to manage and monitor; – engineering skills; – gnostic skills
Evaluative	– self-assessment skills and personal reflection on behavior; – ability to formulate educational tasks; – ability to make appropriate decisions in difficult situations

Psychologists have studied personality traits and concluded that the structure of any quality is the same and consists of four components: feelings, behavior, consciousness, and skills (see table). These components enhance personal qualities and form the professional competence of teachers [15].

All elements of the formation of professional competence are aimed at the activity of future educators, namely the ability to make correct decisions in pedagogical situations. Competent training of professionals is determined by the educational experience acquired in the course of educational activity, the ability to mobilize personal and social qualities and values that shape professional competence and professional development, as well as the ability to effectively apply them in practice. N.V. Kuzmina classified the professional competence of a teacher as follows:

- specialized and subject-specific competence;
- differential-psychological competence (stimulation of awareness and ability for discipline);
- methodological competence (formation of knowledge and skills);
- socio-psychological competence (communicative competence);
- autopsychological competence (personal achievement) [16].

All the above-mentioned components of competence can serve as a basis for the formation of professional competence in future teachers. This is because, within the framework of special competence, students develop subject knowledge and skills; in the process of methodological competence, they master didactic techniques; on the basis of psychological and pedagogical competence, they develop communication culture and increase interest in the profession. Differential-psychological competence reflects the individual personal qualities of students and influences their orientation; autopsychological competence enables students to develop professionally as a result of self-education [17].

Conclusions

In conclusion, based on the analysis of the information presented above, the foundation for the development of professional competence in future biology teachers is the ability to independently solve problems and tasks in the field of biology, as well as the capacity for self-development based on knowledge, skills, and abilities. The theoretical framework of the article leads to an understanding that a teacher must possess personal qualities, as well as new knowledge in the fields of biology, biotechnology, and life sciences. A distinctive feature of the pedagogical educational process in universities is both the personal and professional development of future teachers.

All elements of professional competence formation are aimed at the activity of future teachers in schools and universities, particularly at the ability to resolve specific pedagogical situations in a peaceful manner. The professional training of specialists is determined by the ability to effectively apply acquired knowledge, skills, and experience in practice, as well as to mobilize personal and social qualities and values that shape their professional competence and development.

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DEVELOPMENT OF COGNITIVE SKILLS OF CHILDREN IN THE PRE-PRIMARY GROUP THROUGH AI-BASED GAME CONTENT: A BIBLIOMETRIC ANALYSIS

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Abstract

The rapid development of artificial intelligence technologies has significantly transformed early childhood education, particularly in the context of cognitive skill development through interactive and game-based learning environments. This study aims to analyze the evolution, structure, and key research trends in the field of AI-based game content for the development of cognitive skills in pre-primary children using a bibliometric approach. The data were retrieved from the Scopus database, covering the period from 2005 to 2025, and analyzed using bibliometric techniques, including citation analysis, co-authorship analysis, and keyword co-occurrence mapping with the support of VOSviewer and R-based tools. The results reveal a substantial growth in scientific publications over the past two decades, with a notable acceleration after 2020, reflecting increased academic interest in AI-driven educational technologies. The analysis of highly cited publications indicates a strong focus on learning effectiveness, cognitive outcomes, and learner engagement, as well as a shift toward advanced technologies such as generative AI, chatbots, and immersive virtual environments. The keyword co-occurrence analysis demonstrates the emergence of dominant research clusters related to game-based learning, adaptive systems, and digital learning environments, highlighting the interdisciplinary nature of the field. Furthermore, the geographical distribution of publications shows a concentration of research output in the United States and Asian countries, while emerging contributions from Central Asia indicate the gradual globalization of the research domain. Despite the rapid development of the field, the findings suggest an imbalance between technological innovation and pedagogical and ethical considerations, underscoring the need for more theory-driven and developmentally appropriate research. This study contributes to the systematization of scientific knowledge by providing a comprehensive overview of research trends, thematic structures, and gaps in the field. The results can inform future research directions, educational practices, and policy development aimed at enhancing cognitive development in early childhood through AI-based game learning.

Keywords: artificial intelligence; game-based learning; cognitive development; pre-primary education; early childhood education; bibliometric analysis; digital learning; generative AI; adaptive learning systems; educational technology

Introduction

Research relevance. In the context of rapid digital transformation, early childhood education is undergoing profound structural and pedagogical changes driven by the integration of artificial intelligence (AI) technologies. The increasing accessibility of AI-powered tools has led to the emergence of adaptive, interactive, and personalized learning environments, particularly within the domain of pre-primary education. These innovations are especially significant for the development of cognitive skills such as memory, attention, problem-solving, and early logical reasoning which constitute the foundational basis for lifelong learning trajectories. Recent advances in AI-based game content have enabled the creation of intelligent educational systems capable of tailoring learning experiences to individual developmental needs. Unlike traditional pedagogical approaches, AI-driven games provide real-time feedback, dynamic difficulty adjustment, and immersive engagement, thereby enhancing cognitive stimulation during critical periods of brain development. Given that early childhood represents a sensitive phase for cognitive plasticity, the incorporation of such technologies holds considerable potential for optimizing developmental outcomes. At the same time, the growing body of scientific literature on AI in early education reflects an emerging interdisciplinary field situated at the intersection of educational psychology, digital pedagogy, and computer science. However, despite the increasing number of publications, the structure, evolution, and thematic trends of this research domain remain insufficiently systematized. Bibliometric analysis, as a methodological tool, offers a rigorous approach to mapping scientific production, identifying key research clusters, and evaluating the dynamics of knowledge development.

Research problem. Despite the rapid expansion of AI applications in early childhood education, several critical gaps persist in the existing body of research. First, current studies tend to focus predominantly on the effectiveness of specific digital tools or interventions, often neglecting the broader conceptual and structural evolution of the field. Second, there is a lack of comprehensive analyses that integrate findings across disciplines to provide a holistic understanding of how AI-based game content contributes to cognitive development in early childhood. Moreover, the absence of a consolidated bibliometric overview limits the ability to identify leading research directions, influential authors, collaboration networks, and emerging thematic areas. This fragmentation of knowledge creates methodological and theoretical inconsistencies, hindering the development of evidence-based educational strategies and policies. Therefore, the central research problem of this study lies in the insufficient systematization and quantitative mapping of scientific research on the development of cognitive skills in pre-primary children through AI-based game content.

The aim of this study is to analyze the evolution, structure, and key research trends in the field of AI-based game content for the development of cognitive skills in pre-primary children through a bibliometric approach.

Research question: What are the main publication trends and growth dynamics in this research field over the past 20 years?

Significance of the study. This study makes several important contributions to the advancement of research at the intersection of artificial intelligence, early childhood education, and cognitive development. First, by applying bibliometric methods, it provides a systematic and quantitative mapping of the scientific landscape, enabling the identification of key publication trends, influential authors, leading institutions, and dominant research clusters. Such an approach contributes to reducing fragmentation within the field and offers a structured overview of its intellectual development. Second, the study highlights the conceptual directions through which AI-based game content is linked to the development of cognitive skills in pre-primary children, including attention, memory, thinking, and language abilities. By synthesizing existing research patterns, it facilitates a deeper understanding of how these cognitive domains are represented and

operationalized in the literature. Third, the findings have practical relevance for educators, curriculum designers, and policymakers. By identifying the most actively studied areas and emerging themes, the study provides an evidence-based foundation for the integration of AI-driven game content into early childhood education practices. This is particularly important for designing developmentally appropriate digital learning environments that support cognitive growth during a critical stage of child development. The study establishes a basis for future research by identifying gaps, underexplored topics, and potential directions for interdisciplinary collaboration. In doing so, it contributes to the formation of a more coherent and evidence-informed research agenda in the field of AI-supported early education.

Literature Review

The integration of artificial intelligence into early childhood education has become an increasingly prominent area of scholarly inquiry, particularly in relation to the development of cognitive skills. Cognitive development in early childhood encompassing attention, memory, reasoning, and language forms the foundation for later academic achievement and lifelong learning (Jean Piaget, 1952). Contemporary research emphasizes that digital and interactive environments, when pedagogically grounded, can significantly enhance these developmental processes. AI-based educational technologies, especially game-based learning systems, have been recognized for their capacity to provide adaptive and personalized learning experiences. These systems utilize machine learning algorithms to adjust content difficulty, provide immediate feedback, and track learner progress, thereby fostering engagement and cognitive stimulation (Holmes et al., 2019). According to Luckin et al. (2016), AI-driven educational tools can support individualized learning pathways, which are particularly beneficial in early childhood settings where developmental variability is high. Game-based learning, as a pedagogical approach, has long been associated with positive cognitive outcomes. Research indicates that digital games can enhance problem-solving skills, working memory, and attention span when designed with educational objectives in mind (Granic et al., 2014). The incorporation of AI into such games further amplifies their potential by enabling dynamic interaction and real-time adaptation to learners' needs. For instance, intelligent tutoring systems embedded within game environments can scaffold learning and promote higher-order thinking skills (Zawacki-Richter et al., 2019). Despite these advancements, the application of AI in pre-primary education remains uneven and underexplored in certain domains. While some studies highlight the benefits of AI-enhanced learning environments, others raise concerns regarding ethical implications, data privacy, and the potential over-reliance on technology in early childhood contexts (Selwyn, 2019). Furthermore, the interdisciplinary nature of this research area spanning education, psychology, and computer science has led to a fragmented body of literature, making it difficult to identify coherent research trends and dominant themes.

Bibliometric studies have emerged as a valuable tool for addressing this gap by providing a systematic analysis of scientific publications. Such studies allow researchers to map the intellectual structure of a field, identify influential works, and trace the evolution of research topics over time (Donthu et al., 2021). In the context of AI in education, bibliometric analyses have revealed rapid growth in publications, increased international collaboration, and the emergence of key thematic clusters such as adaptive learning, learning analytics, and intelligent tutoring systems (Zawacki-Richter et al., 2019). However, there remains a lack of focused bibliometric research specifically addressing AI-based game content and its relationship to cognitive skill development in pre-primary children. Most existing reviews tend to concentrate either on AI in higher education or on general digital learning tools, without isolating the unique characteristics and pedagogical implications of game-based AI applications in early childhood. Therefore, this study seeks to fill this gap by providing a comprehensive bibliometric analysis of the research landscape, with particular attention to the intersection of AI technologies, game-based learning,

and cognitive development in pre-primary education. Recent empirical studies further emphasize the potential of AI-enhanced game-based learning environments to support early cognitive development. For example, research by Hyeon-Ah Park et al. (2020) demonstrates that AI-driven adaptive games can significantly improve children's attention regulation and problem-solving abilities by continuously adjusting task complexity based on user performance. Similarly, Mutlu Cukurova et al. (2021) highlight that intelligent learning environments incorporating game mechanics and AI analytics enable more precise tracking of cognitive progress, allowing educators to make data-informed pedagogical decisions. These findings suggest that AI-based game content not only enhances engagement but also contributes to measurable improvements in key cognitive domains, particularly when integrated into structured early learning contexts.

The role of learning analytics and data-driven personalization has been increasingly explored in recent literature. According to Ifenthaler and Yau (2020), AI-supported educational systems can generate detailed learner profiles, facilitating targeted cognitive interventions in early childhood education. Moreover, studies such as those by Kewalramani et al. (2021) argue that the integration of AI technologies in early years settings requires a balanced pedagogical framework that combines digital innovation with developmental appropriateness. These works underscore the importance of aligning AI-based game content with cognitive development theories and educational standards, ensuring that technological advancements translate into meaningful learning outcomes. Collectively, recent research reinforces the growing consensus that AI-driven game-based learning represents a promising, yet still evolving, direction in early childhood education. In addition to the foundational and recent studies discussed above, the literature included in the present study further reinforces the multidimensional nature of AI-based game learning and its relevance to cognitive development. For instance, Chen and Chang (2024) provide empirical evidence that AI-assisted game-based learning environments significantly influence learning outcomes, intrinsic motivation, and cognitive load, demonstrating that well-designed AI systems can optimize cognitive processing in educational contexts. Similarly, Dever et al. (2020) emphasize the role of autonomy and information presentation in game-based environments, highlighting how cognitive engagement is shaped by instructional design and learner control mechanisms. Moreover, recent studies focusing on generative artificial intelligence expand the theoretical and practical boundaries of game-based learning. Huber et al. (2024) and Chien et al. (2025) argue that large language models and generative AI can serve as dynamic scaffolding tools within educational games, providing instant feedback and enhancing interactive learning experiences. These findings align with broader trends identified in the field, where AI is increasingly used not only as a support tool but as an active participant in the learning process.

Research also highlights the growing importance of immersive and context-aware learning environments. Song et al. (2024) demonstrate the effectiveness of integrating virtual reality with AI in creating immersive educational platforms, while Liang et al. (2024) show that AI-based chatbots in game-based museum learning environments can significantly improve learning performance. These studies suggest that the combination of AI and immersive technologies creates new opportunities for enhancing cognitive engagement and experiential learning. At the same time, earlier contributions such as Johnson (2010) provide an important theoretical foundation by demonstrating the educational potential of serious games in language learning. This indicates that current AI-driven approaches are built upon well-established pedagogical principles of game-based learning, now enhanced by technological advancements. Furthermore, the work of Wagan et al. (2023) introduces a system-level perspective by proposing frameworks that integrate AI, user experience, and security, emphasizing the need for holistic approaches in designing educational technologies.

Methods

This study employs a bibliometric research design to systematically analyze the scientific literature on the use of artificial intelligence in relation to children’s cognitive development, with a specific focus on AI-based game content in pre-primary education. The data were retrieved from the Scopus database, which is one of the largest and most comprehensive repositories of peer-reviewed scientific publications. The analysis covers a 20-year period from 2005 to 2025, allowing for the identification of long-term publication trends and the evolution of the research field. The literature search was conducted using the following query:

TITLE-ABS-KEY (artificial intelligence AND children) AND PUBYEAR > 1999 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO (SUBJAREA , "COMP")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all"))

This query ensures that the dataset includes publications in which the key concepts appear in the title, abstract, or keywords, thereby increasing the relevance of the selected studies (see Figure 1).

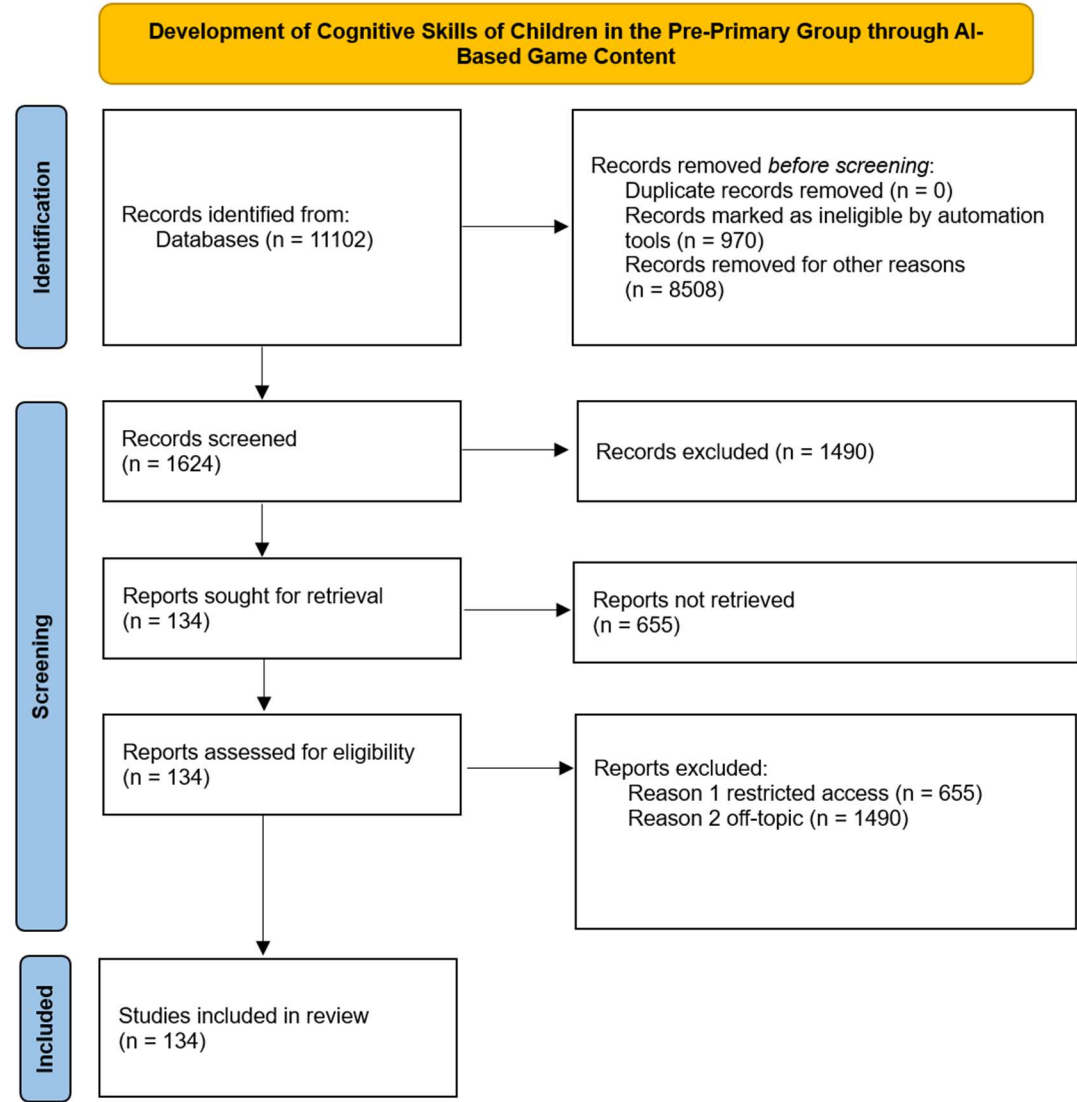


Figure 1. Prizma article selection methodology

Source: compiled by the authors using the PRIZMA methodology

The inclusion criteria applied in this study comprised publications indexed in the Scopus database, articles published between 2005 and 2025, peer-reviewed journal articles, publications written in English, studies within the subject areas of Social Sciences, Psychology, and Computer Science, and open-access publications to ensure accessibility and transparency. The extracted bibliographic data were analyzed using a set of bibliometric techniques, including descriptive analysis to examine annual publication dynamics, citation analysis to identify the most influential authors and sources, co-authorship analysis to explore collaboration networks between countries and institutions, and keyword co-occurrence analysis to determine the main research themes and conceptual structures. Visualization and network mapping were conducted using specialized bibliometric software such as VOSviewer and R-based tools, particularly the Bibliometrix package, which enabled the identification of research clusters, thematic evolution, and the intellectual structure of the field. The research procedure followed a structured bibliometric workflow, including data retrieval from Scopus, data cleaning and preprocessing (such as the removal of duplicates and standardization of keywords), quantitative analysis of publication and citation metrics, network visualization and cluster interpretation, and the synthesis of findings to identify key trends and research gaps. This methodological approach ensures the reliability, reproducibility, and transparency of the analysis while providing a comprehensive and systematic overview of the research landscape.

Results and discussion

The analysis of the most cited publications provides insight into the intellectual core of the research field and highlights the studies that have had the greatest academic impact. Table 1 presents the top 10 most cited articles related to artificial intelligence and game-based learning in the context of children’s cognitive development.

Table 1. - Top 10 most cited publications in the field of AI-based game content and cognitive development

No.	Document Title	Authors	Source	Year	Citations
1	Effectiveness of AI-assisted game-based learning on science learning outcomes, intrinsic motivation, cognitive load, and learning behavior	Chen, C.-H.; Chang, C.-L.	Education and Information Technologies	2024	97
2	Serious use of a serious game for language learning	Johnson, W. L.	International Journal of Artificial Intelligence in Education	2010	77
3	Artificial Intelligent Robots for Precision Education: A Topic Modeling-Based Bibliometric Analysis	Chen, X. et al.	Educational Technology and Society	2023	72
4	Developing an immersive game-based learning platform with generative artificial intelligence and virtual reality technologies – “LearningverseVR”	Song, Y. et al.	Computers and Education X Reality	2024	62
5	Leveraging the Potential of Large Language Models in Education Through Playful and Game-Based Learning	Huber, S. E. et al.	Educational Psychology Review	2024	61
6	Learning by playing with generative AI: design and evaluation of a role-playing educational game with generative AI as scaffolding for instant feedback interaction	Chien, C.-C. et al.	Journal of Research on Technology in Education	2025	49
7	Effect of an AI-based chatbot on students' learning performance in alternate reality game-based museum learning	Liang, H.-Y. et al.	British Journal of Educational Technology	2024	43
8	Mastering medical terminology with ChatGPT and Termbot	Hsu, M.-H.	Health Education Journal	2024	43
9	The Impact of Autonomy and Types of Informational Text Presentations in Game-Based Environments on Learning	Dever, D. A. et al.	International Journal of Artificial Intelligence in Education	2020	37
10	Artificial Intelligence-Enabled Game-Based Learning and Quality of Experience: A Novel and Secure Framework (B-AIQoE)	Wagan, A. A. et al.	Sustainability	2023	34

The analysis of the most cited publications reveals several important trends in the development of this research field. First, recent publications clearly dominate the most highly cited works. This indicates a rapid expansion of interest in AI-based game learning, particularly with the emergence of generative AI technologies and large language models. Second, the most influential studies focus on learning effectiveness, cognitive outcomes, and learner engagement,

as seen in the works by Chen and Chang (2024) and Liang et al. (2024). These studies emphasize key variables such as cognitive load, motivation, and learning performance, which are directly related to cognitive skill development. Third, there is a noticeable shift toward advanced AI technologies, including generative AI, chatbots, and immersive environments such as virtual reality. For example, studies on platforms such as “LearningverseVR” and AI-supported role-playing games highlight the growing integration of immersive and adaptive technologies in educational contexts. Fourth, the presence of earlier foundational work, such as Johnson (2010), demonstrates the long-standing interest in game-based learning, even before the widespread adoption of AI. This suggests that current research builds upon established pedagogical frameworks while incorporating new technological capabilities. Finally, the diversity of publication sources, including journals in educational technology, psychology, and interdisciplinary fields, confirms the multidisciplinary nature of this research area. Overall, the citation analysis indicates that the field is rapidly evolving, with a strong emphasis on innovation, personalization, and enhancing cognitive learning outcomes through AI-driven game environments.

The analysis of authors’ publication productivity reveals a relatively small group of contributors with the highest number of publications in the field. As illustrated in Figure 2, several authors including Alyuz, N., Aslan, S., Chen, C.H., Durham, L.M., Hou, H.T., Lester, J., Nachman, L., and Sharma, S. demonstrate the highest productivity, each contributing three publications within the analyzed dataset. This indicates a moderate level of concentration in authorship, suggesting that the field is still emerging and has not yet formed a highly centralized core of leading scholars.

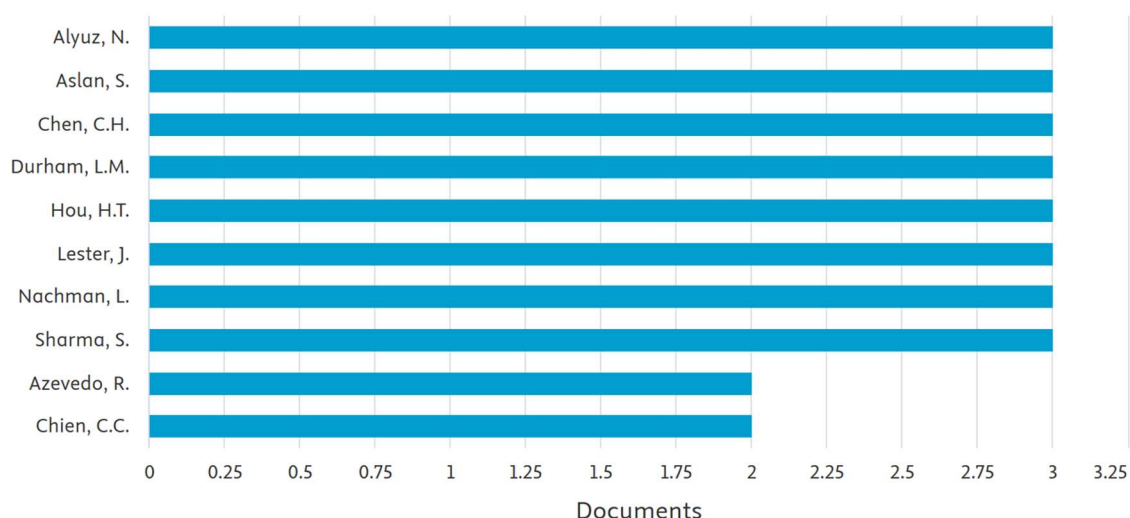


Figure 2. Top authors by number of publications in the field of AI-based game content and cognitive development

In contrast, authors such as Azevedo, R. and Chien, C.C. show slightly lower publication counts, with two documents each, yet their contributions remain significant, particularly given their established influence in related domains such as cognitive science and educational technology. This suggests that impact within the field is not solely determined by publication quantity but also by the theoretical and methodological contributions of individual researchers. Furthermore, the diversity of author names reflects the international and interdisciplinary nature of the research area, encompassing contributions from educational technology, psychology, and computer science. The absence of a single dominant author or highly prolific group indicates that the field is characterized by distributed knowledge production and collaborative development rather than hierarchical leadership.

The analysis of the geographical distribution of scientific output provides important insights into the global development of research on AI-based game content and cognitive skill development in pre-primary education. Examining the contributions of different countries allows for the

identification of leading research hubs and emerging regions in this interdisciplinary field. The top 10 countries by number of publications are presented in Table 2.

Table 2.- Countries by number of publications

RANK	COUNTRY/TERRITORY	NUMBER OF DOCUMENTS
1	United States	26
2	Taiwan	18
3	China	14
4	Hong Kong	9
5	Australia	8
6	United Kingdom	7
7	Malaysia	6
8	Thailand	6
9	South Korea	5
10	Germany	4
11	Kazakhstan	2
12	Uzbekistan	1

The geographical distribution of publications demonstrates a clear concentration of research activity in technologically advanced and innovation-driven regions. As shown in Table 3, the United States leads with a substantial margin (26 publications), confirming its dominant role in the development of AI-based educational technologies and cognitive research. This leadership reflects strong institutional capacity, high levels of research funding, and the presence of globally influential academic centers. Asian countries occupy several top positions, with Taiwan (18) and China (14) emerging as major contributors. This indicates a significant regional focus on the integration of artificial intelligence into education systems, particularly in the context of digital learning and innovation. The presence of Hong Kong (9), Malaysia (6), Thailand (6), and South Korea (5) further reinforces the growing importance of East and Southeast Asia as key hubs for research in AI-driven learning environments. Western countries such as Australia (8) and the United Kingdom (7) also demonstrate stable research output, reflecting their established traditions in educational research and digital pedagogy. Germany (4), as a representative of continental Europe, shows moderate engagement, suggesting that while European contributions are present, they are less prominent than those in North America and Asia. Notably, the inclusion of Kazakhstan (2) and Uzbekistan (1) indicates the emerging participation of Central Asian countries in this research domain. Although their current contribution levels remain relatively low, their presence in the dataset suggests a gradual expansion of research activity beyond traditional academic centers. This may reflect increasing interest in digital transformation and the adoption of AI technologies in education within developing and transitional contexts. The findings highlight a geographically uneven distribution of scientific output, with a strong dominance of leading global economies and rapidly developing Asian regions. At the same time, the emerging contributions from Central Asia point to the potential for broader internationalization of the field, emphasizing the importance of fostering global research collaboration and capacity building in underrepresented regions.

To further explore the conceptual structure of the research field, a keyword co-occurrence analysis was conducted using bibliometric visualization techniques. This approach enables the identification of dominant research themes, conceptual relationships, and emerging trends by examining how frequently keywords co-occur in the dataset. The resulting network map provides a visual representation of the field's intellectual organization, highlighting key clusters and their interconnections. The keyword co-occurrence network is presented in Figure 3.

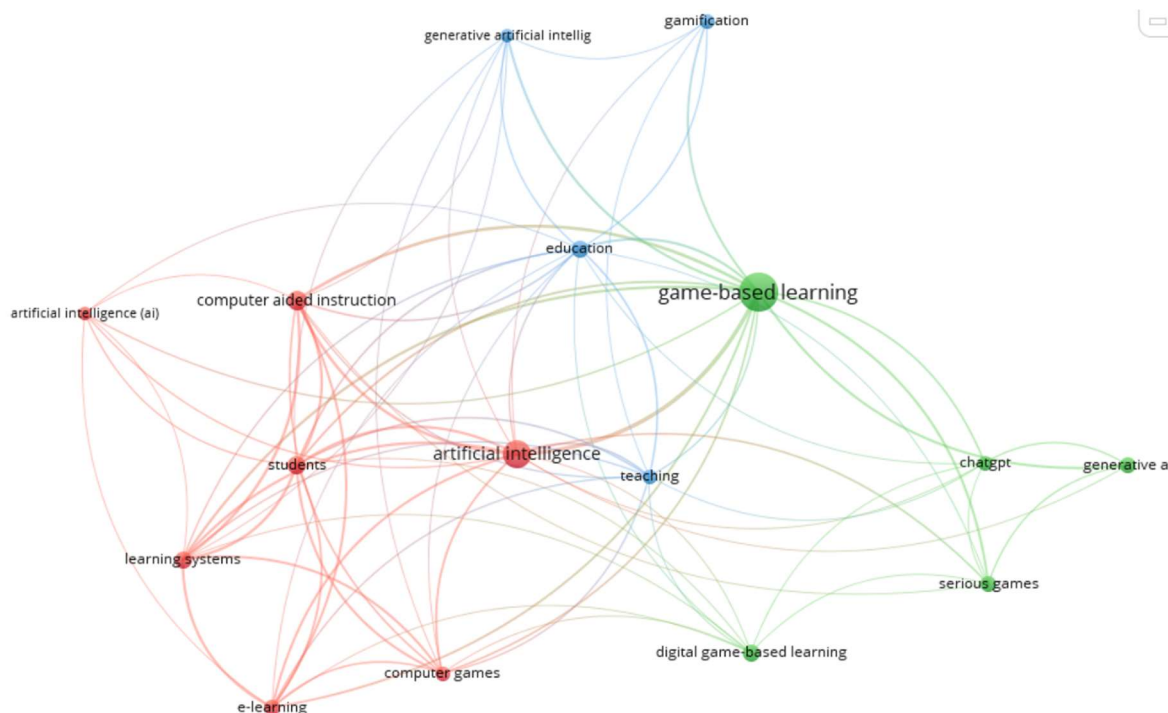


Figure 3. Keyword co-occurrence network in research on ai-based game learning and cognitive development

The keyword co-occurrence network presented in Figure 3 illustrates the conceptual structure and thematic relationships within the research field. The visualization reveals several distinct clusters, each representing interconnected research themes and dominant directions of scientific inquiry. The central position is occupied by the keyword *artificial intelligence*, which acts as a core node linking multiple thematic areas. Its strong connections with terms such as *education*, *teaching*, and *students* indicate that AI is primarily studied within pedagogical contexts, emphasizing its role as a foundational technology in modern educational environments. One of the most prominent clusters is centered around *game-based learning*, which appears as a key thematic node. This cluster is closely associated with terms such as *serious games*, *chatbot*, and *generative AI*, reflecting the growing integration of advanced AI technologies into interactive and immersive learning environments. The presence of *generative AI* and *ChatGPT* suggests a recent shift toward the use of large language models and adaptive systems in educational game design. Another significant cluster includes keywords such as *computer-aided instruction*, *e-learning*, *learning systems*, and *computer games*. This grouping represents the technological and instructional dimension of the field, highlighting the evolution from traditional digital learning tools toward more sophisticated AI-driven systems. The connections within this cluster suggest a strong foundation in earlier forms of digital education, upon which current AI-based approaches are built. Additionally, the network includes links to *digital game-based learning* and *gamification*, indicating the conceptual overlap between game design principles and AI-enhanced educational strategies. These connections demonstrate that the field is not only technologically driven but also grounded in established pedagogical frameworks aimed at increasing learner engagement and cognitive activation.

The findings of this bibliometric analysis are largely consistent with the trends identified in previous literature, while also extending current understanding of the field's structure and evolution. As demonstrated in the results, the rapid growth of publications particularly after 2020 confirms the observations of Zawacki-Richter et al. (2019), who noted the accelerating expansion of research on artificial intelligence in education. However, the present study further specifies that this growth is increasingly concentrated in the domain of AI-based game learning, indicating a shift from general AI applications toward more interactive and learner-centered approaches. The dominance of recent highly cited publications, especially those focusing on generative AI, immersive environments, and adaptive systems, aligns with the arguments of Holmes et al. (2019) and Luckin et al. (2016), who emphasized the transformative potential of AI in creating personalized learning experiences. At the same time, the results related to keyword co-occurrence (Figure 3) demonstrate that contemporary research is moving beyond traditional concepts such as e-learning and computer-assisted instruction toward more advanced paradigms, including game-based learning, chatbots, and generative AI. This transition reflects the evolution described by Granic et al. (2014), who highlighted the cognitive benefits of digital games, now amplified through AI-driven personalization and real-time feedback mechanisms. Furthermore, the identified thematic clusters support empirical findings from recent studies (Park & Kim, 2020; Cukurova et al., 2021), which demonstrate that AI-based game environments can enhance attention, problem-solving, and cognitive engagement. The strong presence of keywords such as *game-based learning*, *generative AI*, and *chatbots* indicates that the field is increasingly focused on the integration of intelligent systems into interactive learning contexts. This confirms the growing importance of adaptive and data-driven educational environments, as also noted by Ifenthaler and Yau (2020), particularly in relation to early cognitive development. The geographical distribution of publications further reinforces existing literature on global inequalities in research production. The dominance of the United States and leading Asian countries corresponds with broader patterns identified in bibliometric studies (Donthu et al., 2021), where scientific output is concentrated in regions with advanced technological infrastructure and strong research funding. At the same time, the emerging contributions from countries such as Kazakhstan and Uzbekistan suggest a gradual expansion of research activity into developing regions, reflecting the increasing global relevance of AI in education. Despite these positive developments, the findings also highlight several challenges consistent with previous research. As noted by Selwyn (2019), the rapid integration of AI technologies raises concerns related to ethical considerations, data privacy, and the pedagogical appropriateness of digital tools in early childhood education. The present study supports this concern indirectly, as the keyword analysis reveals a stronger emphasis on technological innovation than on ethical or developmental frameworks. This suggests a potential imbalance in the research agenda, where technological advancement may outpace theoretical and pedagogical grounding.

Conclusion

This study provides a comprehensive bibliometric analysis of the scientific landscape related to the development of cognitive skills in pre-primary children through AI-based game content. By examining publications indexed in the Scopus database over a 20-year period (2005–2025), the research identifies key trends, influential works, leading contributors, and the conceptual structure of this rapidly evolving interdisciplinary field. The findings demonstrate a significant increase in research activity, particularly in recent years, reflecting the growing importance of artificial intelligence in early childhood education. The dominance of highly cited recent publications indicates a shift toward advanced technologies such as generative AI, immersive learning environments, and intelligent tutoring systems. At the same time, the keyword co-occurrence analysis reveals a clear transition from traditional digital learning approaches toward more interactive, adaptive, and game-based educational models. The study also highlights the global distribution of research, with a strong concentration in technologically advanced regions

such as the United States and East Asia, while emerging contributions from Central Asian countries indicate the gradual expansion of the field. Furthermore, the analysis of authorship patterns suggests that the research domain remains relatively decentralized, characterized by interdisciplinary collaboration rather than by the dominance of a small group of scholars. Despite these advances, several gaps remain. The findings indicate a stronger emphasis on technological innovation than on pedagogical, developmental, and ethical considerations, suggesting the need for more balanced and theory-driven research. In particular, future studies should focus on the long-term cognitive effects of AI-based game content, the developmental appropriateness of such technologies in early childhood, and the integration of educational theory with technological design. This study contributes to the systematization of knowledge in the field by providing a structured overview of its development, key themes, and research directions. The results can serve as a foundation for future empirical and theoretical studies, as well as for the design of evidence-based educational practices and policies. By bridging the gap between technological innovation and cognitive development theory, the research supports the advancement of more effective and developmentally appropriate AI-driven learning environments for pre-primary education.

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THE USE OF INTERNET RESOURCES IN TEACHING FOREIGN LANGUAGE COMMUNICATION TO SENIOR STUDENTS OF SECONDARY SCHOOL

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ABSTRACT

This study examines the effectiveness of using Internet resources to develop foreign language communication skills among senior secondary school students. As modern learners increasingly rely on digital technologies, integrating online tools into language instruction has become essential for creating engaging and authentic learning environments. The research explores how various Internet-based resources, such as online platforms, interactive websites, digital dictionaries, educational videos, and communication tools support students' speaking, listening, reading, and writing skills in English. Data were collected through student questionnaires, and teacher interviews to determine students' attitudes toward Internet-assisted learning and to identify the most beneficial resources. The findings indicate that Internet resources increase students' motivation, provide access to authentic language input, and offer opportunities for real-life communication practice. However, challenges such as unreliable Internet connection, distraction risks, and limited digital literacy were also noted. Overall, the study concludes that Internet resources can significantly enhance foreign language communication when used systematically and supported by proper guidance. Practical recommendations are provided for teachers seeking to integrate online tools effectively into their lessons.

KEYWORDS: Internet Resources, Foreign Language Communication, Senior Students, EFL Teaching, Digital Learning, Secondary School

INTRODUCTION

In recent years, the rapid development of digital technologies has transformed the way foreign languages are taught and learned. English language teachers, in particular, have increasingly turned to internet-based resources to enhance communication skills among students. With the growing availability of online videos, interactive applications, digital dictionaries, and authentic media content, internet resources offer new opportunities for engaging and meaningful language practice. As senior secondary school students become more digitally active, the integration of online tools in the classroom becomes not only useful but essential. This study focuses on how internet resources can support learners in improving their listening comprehension, speaking fluency, vocabulary development, and overall communicative competence.

The interest in using internet resources stems from the need to make language learning more interactive, authentic, and learner-centered. Traditional classroom activities, such as

textbook dialogues or teacher-led drills often fail to provide sufficient exposure to real-life speech. Many students struggle with communication because they rarely hear natural pronunciation, intonation, and speech patterns. Internet platforms, however, provide unlimited access to authentic language input, supporting principles such as Krashen's Input Hypothesis, which emphasizes the importance of rich and comprehensible input for language development. Through videos, podcasts, language apps, and online communication tools, learners can engage with real English in ways that are more dynamic and motivating than traditional methods.

Although internet resources have shown promising results in various educational contexts, their integration into secondary school classrooms remains inconsistent. Some teachers may feel unsure about how to select appropriate online materials or how to manage students' attention during digital activities. Others may be concerned about students becoming distracted or relying too heavily on online translators. Additionally, not all schools have equal access to stable internet connections or digital devices. As a result, the effectiveness of internet resources, especially for developing foreign language communication among senior students remains underexplored. This study seeks to address this gap by examining how internet tools function in real classroom conditions and what specific aspects of communication they help strengthen. By engaging with online materials that mirror real-world language use, learners can gradually build stronger listening comprehension, expand their vocabulary in meaningful ways, and improve their overall fluency.

In this study, the use of internet resources is investigated as a strategy to support the development of foreign language communication among senior secondary school students. The research examines how different types of online tools influence listening, speaking, and vocabulary growth, as well as how students perceive their usefulness. It also explores the challenges students encounter when working with digital content and the conditions that enhance or limit the effectiveness of online learning. Based on these goals, the main research questions guiding this study are:

1. How do internet resources influence students' foreign language communication skills, including listening comprehension, speaking fluency, and vocabulary development?
2. What are students' attitudes and perceptions toward using internet resources in foreign language learning?
3. What factors support or hinder the effectiveness of internet-based tools in real secondary school classroom settings?

METHODS

This study employed a quantitative research design to investigate how the use of internet resources supports the development of foreign language communication skills among senior secondary school students. The main objectives were to determine how frequently learners use online platforms, which types of internet resources they rely on, and how these tools influence their speaking, listening, vocabulary development, and overall communicative competence. To obtain relevant data, a structured online questionnaire was administered, enabling the collection of numerical responses as well as brief qualitative comments.

The research was conducted at a secondary school where various internet resources, such as educational websites, video platforms, digital dictionaries, and interactive language-learning tools are occasionally incorporated into English lessons. A total of 20 senior students participated in the study. All participants were EFL learners aged between 15 and 17, representing upper-grade classes. They were selected through convenience sampling, as they already had regular access to online learning tools during their English lessons. Their proficiency levels ranged from B1 to B2,

allowing the study to explore how moderately proficient learners utilize internet-based materials for communication practice.

The questionnaire, developed using Google Forms, included 18 items comprising multiple-choice questions, Likert-scale statements, and short open-ended prompts. Closed-ended items focused on identifying the types of internet resources students use most often (e.g., YouTube, Quizlet, BBC Learning English, online translators, learning apps), the frequency of use, and perceived improvements in communicative skills. Open-ended questions asked students to describe the challenges they face when using online tools, such as difficulty selecting appropriate materials or distractions, as well as the advantages they experience, such as increased motivation, exposure to authentic language, or improved listening comprehension.

For data analysis, descriptive statistics were applied to summarize quantitative findings, including frequency counts and percentages. Qualitative responses were analyzed using a simple thematic approach to identify recurring themes related to students' experiences—such as enhanced vocabulary acquisition, improved listening skills, or issues with internet reliability. Combining these quantitative and qualitative insights provided a more comprehensive understanding of how internet resources influence the development of foreign language communication skills among senior learners.

Overall, this methodology enabled the researcher to gather practical, classroom-based information about students' use of internet resources. The findings offer valuable insights into both the benefits and the limitations of integrating online tools into foreign language communication instruction in secondary school settings.

RESULT

Demographic and General Information

The distribution of participants by age is as follows: 15–16 years – 45%, 17 years – 35%, and 18 years – 20% (Figure 1). This age range reflects senior secondary school learners, providing insight into how students at different stages of adolescence engage with internet resources when developing foreign language communication skills. In terms of English proficiency, the sample included students at various levels: Pre-Intermediate – 25%, Intermediate – 40%, and Upper-Intermediate – 35% (Figure 2). Such variation in proficiency helps illustrate how learners with different linguistic backgrounds benefit from online tools. The gender distribution was as follows: Male – 40% and Female – 60% (Figure 3), indicating a slightly higher proportion of female participants, which may influence overall patterns of engagement with online learning platforms. These demographic characteristics provide important context for understanding how internet resources support communication skill development among senior secondary school students.

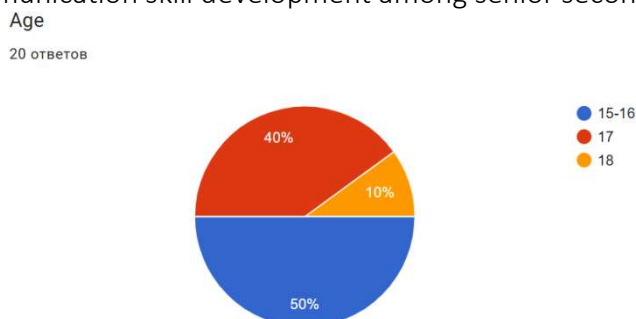


Figure 1. Age Distribution of Participants

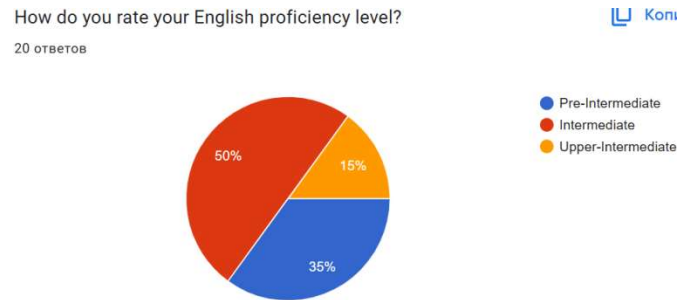


Figure 2. English proficiency level of Participants

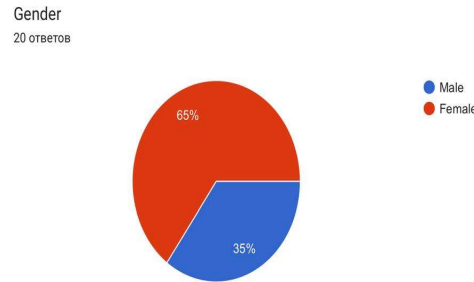


Figure 3. Gender of Participants

Age	Percent %	English level	Percent %	Gender	Percent %
15-16 years	50%	Pre—Intermediate	35%	Male	65%
17 years	40%	Intermediate	50%	Female	35%
18 years	10%	Upper-Intermediate	15%		
Total	100%	Total	100%	Total	100%

Table 1

Frequency and Use of Internet Resources

The findings reveal that internet resources are widely incorporated into foreign language learning among senior secondary school students. A total of 55% of participants reported using online platforms “regularly” (at least 3–4 times per week), 30% used them “occasionally” (1–2 times per week), and 15% used them “rarely” (less than once per week). This indicates that most students actively integrate digital tools into their communication practice. Regarding the types of resources used, 60% of learners reported relying on video-based platforms such as YouTube, BBC Learning English, and TED-Ed; 25% preferred interactive learning apps such as Quizlet, Duolingo, and Memrise; and 15% used online dictionaries and translators (e.g., Cambridge Dictionary, Linguee, Google Translate). This demonstrates that students tend to choose resources that offer accessible, authentic, and visually engaging language input.

Improvement in Communication Skills

When asked about perceived improvement in listening comprehension, 48% of students reported “significant improvement,” 37% “moderate improvement,” and 15% “minimal or no improvement.” This suggests that exposure to online materials played a substantial role in enhancing students’ ability to understand authentic speech. For speaking confidence, 50% reported “much more confident,” 32% “somewhat more confident,” and 18% “no noticeable change.” This indicates that online resources, especially those featuring natural conversation patterns, helped many learners feel more comfortable communicating in English. Vocabulary development also showed positive outcomes: 55% of participants indicated “significant improvement,” 30% “moderate improvement,” and 15% “minimal improvement.” These results demonstrate that regular use of online materials contributes to broader lexical knowledge, which supports overall communicative competence.

Students' Attitudes Toward Internet-Based Learning

Students expressed generally positive attitudes toward using internet resources in foreign language communication. A majority (62%) described these tools as “very useful,” 28% considered them “moderately useful,” and only 10% viewed them as “slightly useful.” This indicates that learners recognize the value of internet-based platforms for improving language skills, particularly in providing authentic content, flexibility, and personalized learning options.

Challenges and Benefits of Online Resources

Participants identified several challenges related to using internet materials. These included difficulty understanding fast-paced or native-level speech (38%), distractions during online learning (35%), and uncertainty about selecting appropriate resources (27%). Despite these challenges, 72% of students highlighted considerable benefits, such as improved listening and speaking skills, expanded vocabulary, increased motivation, and greater exposure to real-life English communication. This suggests that while internet-based learning can present obstacles, students generally perceive it as highly beneficial.

The results of this study demonstrate that internet resources are actively used by senior secondary school students and contribute to meaningful improvements in foreign language communication. Most participants reported regular engagement with online tools and positive outcomes in listening comprehension, vocabulary acquisition, and speaking confidence. Although some challenges were noted—particularly related to fast speech and distraction—students overwhelmingly viewed internet resources as effective and supportive components of their language learning process.

DISCUSSION

The findings of this study indicate that the use of internet resources has a generally positive impact on the development of foreign language communication skills among senior secondary school students. Improvements were most noticeable in listening comprehension, vocabulary acquisition, and speaking confidence. These results support previous research showing that digital tools provide authentic input, interactive learning opportunities, and flexible access to language practice (Krashen, 1985; Foote & McDonough, 2017). In this study, nearly half of the students reported significant improvement in listening skills, which aligns with earlier studies emphasizing the effectiveness of online videos and multimedia content for developing comprehension of natural speech.

The results also demonstrate that internet resources contribute meaningfully to vocabulary development. A total of 85% of students noted significant or moderate improvement in their vocabulary range, which corresponds with findings from Mizuguchi (2019) suggesting that repeated exposure to real-life language in digital contexts enhances lexical retention. Students' increased speaking confidence further reflects the motivational effect of engaging, student-centered online materials. The fact that 50% of participants reported feeling “much more confident” mirrors earlier studies that highlight how digital platforms reduce anxiety and encourage learners to participate more actively in communication.

Learners' generally positive attitudes toward internet-based tools also reinforce the idea that online resources can serve as effective supplements to traditional classroom instruction. In this study, 62% of participants described internet resources as “very useful,” which is consistent with research showing that technology-enhanced environments increase motivation and autonomy (Murphey, 1995; Bui & Intaraprasert, 2018). The frequent use of platforms such as YouTube, Quizlet, and online dictionaries suggests that students are willing to integrate these tools into their learning routines, making internet-based learning both accessible and sustainable.

However, the results also highlight several challenges. The most common difficulties reported were understanding fast-paced native speech (38%), managing distractions while

learning online (35%), and selecting appropriate learning materials independently (27%). These findings are similar to previous research noting that authentic online materials may be too complex for learners without guidance (Tamai, 1997). As Hamada (2012) and Lambert (2008) suggest, learners benefit greatly from structured support when working with native-level content. Without scaffolding, students may struggle to process unfamiliar vocabulary or maintain attention during longer online activities.

To address these challenges, teachers may consider providing curated, level-appropriate online materials to reduce cognitive overload. Pre-teaching key vocabulary, offering listening tasks with slower speech models, and setting clear learning goals can help students engage with digital content more effectively. Guided practice in the classroom, followed by independent online tasks, may also build confidence and improve comprehension. These recommendations align with Foote & McDonough (2017), who emphasize that structured pedagogical support enhances the effectiveness of digital learning tools.

Overall, the findings of this study are consistent with existing literature confirming that internet resources can significantly enhance foreign language communication skills when used appropriately. At the same time, the results suggest that learners require guidance in navigating online content, especially when dealing with authentic and fast-paced speech. Moving forward, educators should incorporate internet resources more systematically into communication-focused lessons and provide the necessary scaffolding to ensure that learners at different proficiency levels can benefit fully from digital tools.

CONCLUSION

The findings of this study indicate that the shadowing technique has a generally positive effect on improving EFL students' speaking skills. Most participants reported clearer pronunciation, increased fluency, and greater confidence when speaking English, suggesting that shadowing is a practical and effective method for developing oral communication through regular listening and repetition of authentic speech.

Students also expressed positive attitudes toward shadowing, noting that it made speaking practice more engaging, motivating, and enjoyable. Working with real speech models exposed learners to natural intonation, rhythm, and stress patterns, which contributed to more fluent and authentic speech production. This demonstrates that shadowing not only enhances technical aspects of speaking but also supports learners' willingness to communicate in English.

At the same time, the study identified several challenges, including difficulty following fast speech and coping with unfamiliar vocabulary. These findings highlight the importance of teacher guidance and structured implementation, such as starting with simpler audio materials and gradually progressing to more complex recordings. With appropriate support, students can overcome these obstacles and maximize the benefits of shadowing.

Overall, the study concludes that the shadowing technique can be a valuable addition to EFL speaking lessons, particularly for improving pronunciation, fluency, and confidence. Teachers are encouraged to integrate shadowing systematically into classroom practice, while future research could examine its long-term effects on speaking development and explore how digital tools may enhance its effectiveness. Shadowing has the potential to help learners become more competent, confident, and successful English speakers.

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THE EFFECTIVENESS OF CHILDREN'S LITERATURE IN DEVELOPING SPEECH ABILITIES OF PRESCHOOL CHILDREN: A BIBLIOMETRIC ANALYSIS

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Abstract

This study examines the effectiveness of children's literature in developing the speech abilities of preschool children through a bibliometric analysis of scientific publications indexed in the Scopus database. The aim of the research is to identify key trends, influential studies, thematic clusters, and emerging directions in this field. The dataset consists of 27 peer-reviewed articles published between 2005 and 2025. The results reveal a significant growth in research activity, particularly after 2020, indicating increasing academic interest in the role of children's literature in early language development. Citation analysis shows that the most influential studies emphasize the holistic developmental potential of children's literature, including cognitive, social, and emotional dimensions. The keyword co-occurrence network identifies storytelling as the central concept that links various research themes, such as emergent literacy, education, and narrative practices. At the same time, the findings highlight the growing importance of digital storytelling, interactive narratives, and multimedia resources in contemporary educational contexts. The geographical distribution of publications demonstrates a strong concentration of research in a limited number of countries, with underrepresentation of emerging regions. The findings contribute to a better understanding of the structure and evolution of the research field and provide a basis for future empirical and comparative studies.

Keywords: children's literature, speech development, preschool children, storytelling, emergent literacy, bibliometric analysis, digital storytelling, early childhood education.

Introduction

Relevance of the study. Amid rapid transformations in early childhood education, the development of speech abilities in preschool children has become a central concern for both researchers and practitioners. Early language acquisition is widely recognized as a foundational component of cognitive, social, and academic development, influencing later literacy skills and overall educational outcomes (Whitehurst & Lonigan, 1998). In this regard, children's literature, particularly storytelling, narrative interaction, and shared reading practices, has been identified as a powerful pedagogical tool that supports the development of expressive and receptive language skills. Recent studies emphasize that children's literature contributes not only to linguistic competence but also to broader developmental domains, including emotional intelligence, imagination, and social interaction (Pulimeno et al., 2020). Narrative-based approaches, such as storytelling and fairy tales, have gained increasing attention due to their ability to foster creative speech, enhance vocabulary acquisition, and stimulate children's engagement in communicative

practices (Sotiropoulou & Kasapi, 2024; Treewong, 2023). Furthermore, the integration of play and narrative interaction has been shown to strengthen the connection between language development and cognitive processes, highlighting the importance of child-centered learning environments (Nicolopoulou, 2010). At the same time, contemporary educational trends indicate a shift toward incorporating digital storytelling and multimedia resources, expanding traditional forms of children's literature into technologically enriched learning contexts. This evolution reflects the growing need to adapt pedagogical strategies to the realities of digital culture while preserving the developmental benefits of classical literary approaches. Bibliometric evidence suggests that research in this field has been steadily increasing, with a particular focus on the intersection of literature, speech development, and innovative educational technologies. Despite the growing body of literature, the field remains fragmented, with studies often focusing on specific aspects of children's literature without providing a comprehensive overview of its effectiveness in developing speech abilities. Therefore, a systematic and bibliometric analysis of existing research is essential to identify key trends, influential studies, and emerging directions, thereby contributing to the consolidation of knowledge in this domain.

Research problem. Although numerous studies have explored the role of children's literature in early language development, there is a lack of systematic synthesis and structured analysis of the existing research landscape. The current body of literature is characterized by conceptual diversity, methodological heterogeneity, and limited integration of findings across different educational contexts. As a result, it remains unclear which approaches within children's literature, such as traditional storytelling, interactive reading, or digital narratives, are most effective in fostering speech development in preschool children. The rapid expansion of digital technologies in education has introduced new forms of narrative engagement, yet their pedagogical value relative to classical literary methods remains insufficiently understood. This creates a gap between traditional theoretical frameworks of emergent literacy and contemporary practices influenced by digitalization. The central research problem of this study is the need to systematically analyze and map the scientific literature on the effectiveness of children's literature in developing the speech abilities of preschool children. Addressing this problem requires a bibliometric approach to identify dominant research trends, key contributors, thematic clusters, and the field's evolution over time.

The aim of this study is to systematically analyze the scientific literature on the effectiveness of children's literature in developing speech abilities of preschool children through a bibliometric approach. The study seeks to identify key research trends, influential publications, dominant thematic areas, and emerging directions in the field, thereby providing a structured understanding of how literary practices contribute to early language development.

RQ1: *What are the main research trends, thematic clusters, and influential studies in the field of children's literature and its effectiveness in developing speech abilities of preschool children?*

Significance of the study. This study contributes to the field of early childhood education and language development in several important ways. First, it provides a comprehensive and systematic overview of the existing body of research through bibliometric analysis, enabling the identification of structural patterns, knowledge gaps, and emerging research directions. Unlike traditional literature reviews, this approach offers a data-driven perspective on the field's evolution. Second, the study enhances theoretical understanding by integrating insights from diverse research strands, including emergent literacy, storytelling, and digital narrative practices. This integration is particularly relevant in the context of ongoing digital transformation in education, where traditional literary methods are increasingly combined with technological tools. Third, the findings of this research have practical implications for educators, curriculum developers, and policymakers. By identifying the most effective approaches in children's

literature, the study supports the development of evidence-based pedagogical strategies to improve speech development in preschool children.

Literature review

Children's literature has long been recognized as an important pedagogical resource in early childhood education, particularly for speech, language, and emergent literacy development. Early literacy research shows that preschool children's later reading and writing abilities are strongly connected with their early oral language experiences, vocabulary growth, narrative comprehension, and exposure to print-rich environments (Whitehurst & Lonigan, 1998). From this perspective, children's literature functions not only as a source of entertainment but also as a developmental tool that supports children's communicative competence, imagination, and meaning-making processes. A substantial body of research emphasizes the role of shared book reading in children's language development. Bus et al. (1995), in their meta-analysis, demonstrated that parent-child book reading is positively associated with language growth, emergent literacy, and later reading achievement. Similarly, Sénéchal and LeFevre (2002) found that early home literacy experiences contribute significantly to children's reading acquisition over time. These findings indicate that children's interaction with books, stories, and adults' speech during reading activities creates a rich linguistic environment that stimulates vocabulary acquisition, listening comprehension, and expressive speech development. Dialogic reading has received particular attention as an effective strategy for promoting preschool children's oral language. Unlike passive reading, dialogic reading encourages children to actively participate in storytelling through questions, retellings, predictions, and explanations. Mol et al. (2008) showed that dialogic parent-child book reading adds value to vocabulary development by transforming the child from a listener into an active co-constructor of meaning. This approach is especially relevant for preschool education, where speech development depends on interaction, repetition, emotional involvement, and meaningful communication.

Storytelling and narrative-based activities are also central to the development of children's speech abilities. Narrative practices help children organize events, build logical sequences, express emotions, and use language for social interaction. Nicolopoulou et al. (2015) demonstrated that narrative- and play-based activities can improve oral language, emergent literacy, and social competence among preschool children. This confirms that storytelling is not limited to linguistic development; rather, it connects speech to imagination, symbolic play, social participation, and cognitive development. Children's literature also contributes to children's holistic development. Pulimeno et al. (2020) argue that children's literature and storytelling can support students' global development and well-being when integrated into educational activities. Their review highlights the pedagogical, psychological, and emotional value of literary texts, showing that stories help children understand social norms, emotions, moral values, and interpersonal relationships. Therefore, the effectiveness of children's literature in preschool education should be understood not only through vocabulary or pronunciation outcomes but also through broader developmental indicators.

In recent years, the field has expanded toward digital storytelling and technology-enhanced storybooks. Takacs et al. (2015), in a meta-analysis of technology-enhanced stories, found small but significant benefits for story comprehension and expressive vocabulary compared with traditional story formats. However, the authors also noted that multimedia and interactive elements may either support or distract children depending on their pedagogical design. This suggests that digital storytelling can be effective for speech development only when technological features are meaningfully connected to the narrative and do not replace adult-child interaction. Despite the growing number of studies, the research field remains fragmented. Existing publications address different aspects of children's literature, including shared reading, storytelling, fairy tales, dialogic reading, digital narratives, and play-based language development.

However, there remains a need for a systematic bibliometric synthesis to identify the main intellectual foundations, thematic clusters, influential studies, and emerging trends in this area. The preliminary dataset of the present study also shows that the field is moderately developed, with particular attention to storytelling, emergent literacy, holistic child development, and digital narrative practices. Thus, the literature indicates that children's literature is a multidimensional educational tool that supports preschool children's speech abilities by enriching vocabulary, fostering narrative competence, enhancing expressive language, facilitating communicative interaction, and promoting socio-emotional development. At the same time, the increasing diversity of approaches requires a structured bibliometric analysis to clarify how this research field has evolved and what directions are currently shaping its development.

Methods

This study employs a bibliometric analysis to systematically examine the research landscape on children's literature and its role in developing speech abilities in preschool children. The analysis is based on data retrieved from the Scopus database, which is widely recognized for its comprehensive coverage of peer-reviewed scientific publications. The dataset was extracted using the following search query:

TITLE-ABS-KEY ("children's literature" AND "storytelling") AND PUBYEAR > 2004 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , "SOCI"))

The time frame of the analysis covers publications from 2017 to 2025, reflecting the rapid growth phase of AI integration in education. The dataset was then cleaned by removing duplicates,

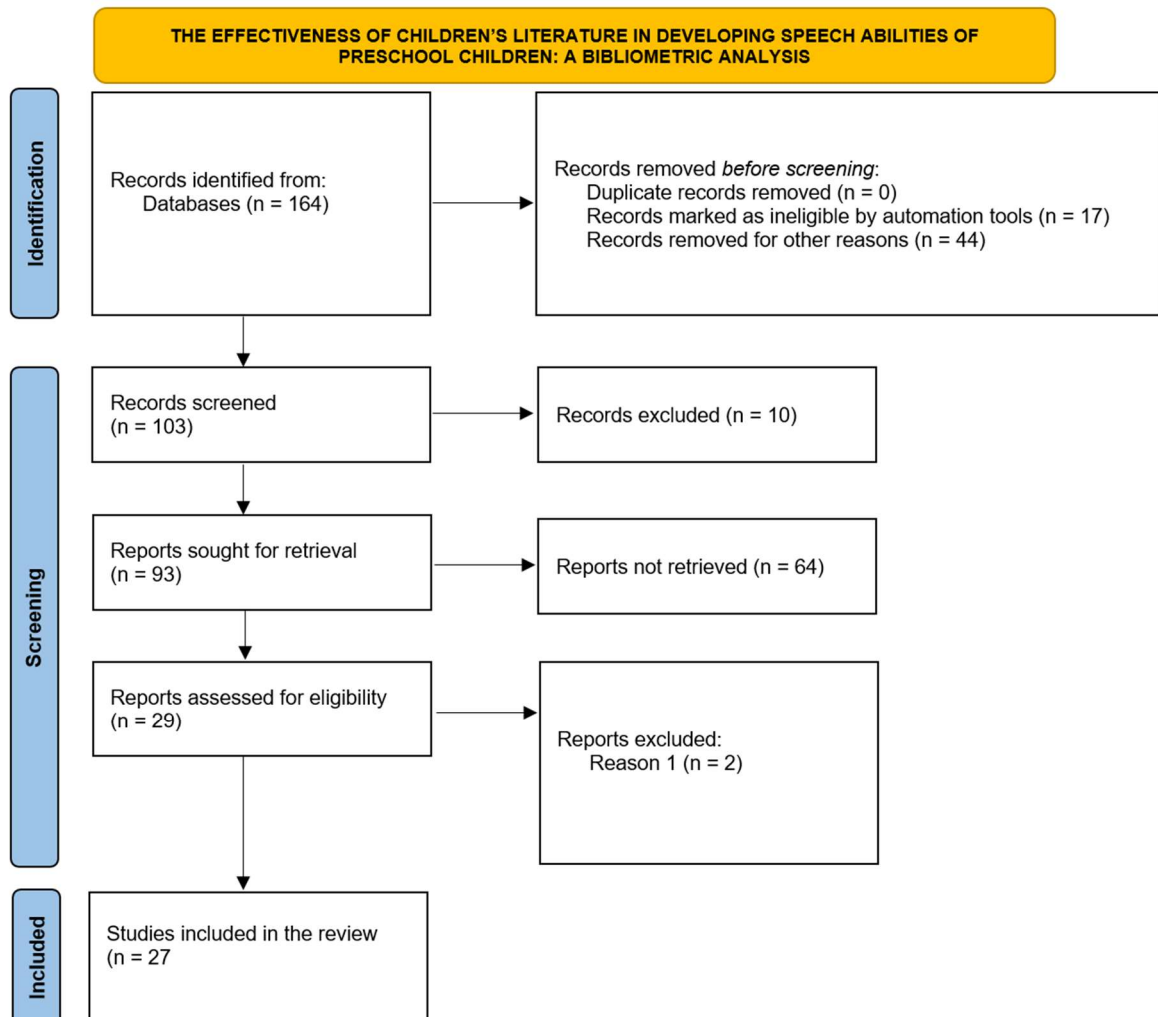


Figure 1. PRISMA flow diagram of the study selection process

incomplete records, and irrelevant documents. A PRISMA-based approach was applied to ensure transparency in the selection process, including identification, screening, eligibility, and inclusion stages (see Figure 1).

To ensure the robustness and reproducibility of the study, explicit inclusion and exclusion criteria were applied. Only peer-reviewed journal articles published in English and indexed in the social sciences category were considered, with a specific focus on studies addressing children's literature, storytelling, and speech or language development in preschool children. Publications such as conference proceedings, book chapters, and documents lacking essential bibliographic information were excluded, as well as studies not directly related to early childhood education. Following the screening and eligibility procedures, the final dataset consisted of $N = 27$ publications. The analytical phase was carried out in RStudio using the Bibliometrix package, which enables comprehensive bibliometric and scientometric analysis. The study examined key indicators, including annual publication trends, citation patterns, the most productive authors and journals, keyword co-occurrence, and thematic clusters. In addition, network analysis techniques were employed to explore collaboration patterns among countries and authors, thereby revealing the intellectual and social structure of the research field. This approach allows for a systematic mapping of the domain and the identification of both established research directions and emerging trends.

Results and discussion

The bibliometric analysis of the selected dataset ($N = 27$) reveals the intellectual structure of the research field by identifying the most influential and highly cited publications. Citation analysis serves as a key indicator of scientific impact, allowing the determination of foundational studies that have significantly shaped the discourse on the role of children's literature in the development of speech abilities in preschool children. The distribution of citations within the dataset demonstrates that the field is characterized by a limited number of highly influential works alongside a broader range of moderately cited studies, reflecting its relatively specialized and emerging nature. In particular, highly cited publications tend to focus on the broader developmental potential of children's literature, including its cognitive, social, and emotional dimensions, rather than exclusively on speech development outcomes. This suggests an interdisciplinary orientation in the field, in which language development is embedded within a holistic framework of early childhood education. To provide a clearer understanding of the most impactful contributions, the top 10 most cited studies identified in the dataset are presented in Table 1. These publications represent the core knowledge base of the field and highlight key thematic directions, including storytelling practices, narrative interaction, and the integration of children's literature into educational and socio-cultural contexts (see Table 1).

Table 1. Top 10 studies on the effectiveness of children's literature in speech development of preschool children

No	Document Title	Authors	Source	Year	Citations
1	Children's literature to promote students' global development and wellbeing	Pulimeno, M.; Piscitelli, P.; Colazzo, S.	<i>Health Promotion Perspectives</i>	2020	80
2	Narratives of change: the role of storytelling, artefacts and children's literature in building communities of inquiry that care	McAdam, J.E.	<i>Cambridge Journal of Education</i>	2019	12
3	The hybrid exhibits of the story museum: The child as creative artist and the limits to hands-on participation	Hamer, N.	<i>Museum and Society</i>	2019	11
4	Anything new here in story apps? A reflection on the storytelling mechanism across media	Zheng, Y.	<i>Libri et Liberi</i>	2016	6
5	Storytelling for a republic of childhood: rebranding China's national images in children's literature	You, C.	<i>Neohelicon</i>	2023	5
6	A critical analysis of ecological sustainability ideology in award-winning early children's literature	White, P.J.; Auld, G.; Wells, M.	<i>Australian Journal of Environmental Education</i>	2023	24
7	Harry Potter and the battle of adaptation	Goldie, D.	<i>Ekphrasis</i>	2019	4
8	Read-alouds in kindergarten classrooms and the nature of literary understanding	Terwagne, S.	<i>L1 Educational Studies in Language and Literature</i>	2006	4
9	Attention to gender diversity and inclusive education: moving towards a rainbow school	Sánchez Torrejón, B.	<i>European Public and Social Innovation Review</i>	2024	2
10	The Instantiation of Narrative in Picturebook Forms: Semiotic, Material, and Ideological Dimensions	Frank Serafini	<i>Semiotics / Semiology, Theory of Literature</i>	2024	5

Table 1 demonstrates that the most highly cited studies in the field are predominantly oriented toward the broader developmental and interdisciplinary functions of children's literature rather than narrowly focusing on speech outcomes alone. The leading publication by Pulimeno et

al. (2020), with the highest citation count, emphasizes the role of children’s literature in promoting global development and well-being, indicating that research impact is strongly associated with holistic educational perspectives. Similarly, works by McAdam (2019) and Hamer (2019) highlight storytelling and participatory cultural practices, reflecting a shift toward narrative-based and socially embedded learning approaches. At the same time, the presence of studies on digital storytelling and media environments, such as Zheng (2016), suggests an emerging interest in technological transformations within the field. Notably, the relatively moderate citation counts across most publications indicate that the research area remains in development, with a dispersed citation structure and no large, consolidated core of highly cited works. The citation patterns reveal that influential research in this domain is characterized by thematic diversity, interdisciplinary integration, and a growing emphasis on the connection between children’s literature, narrative practices, and comprehensive child development.

The temporal dynamics of publications presented in Figure 2 indicate a clear evolution of the research field from a sporadic and low-intensity stage to a phase of rapid growth and consolidation. In the early period (2005–2012), the number of publications remained minimal and irregular, reflecting limited scholarly attention and the emerging nature of the topic. A gradual increase can be observed between 2013 and 2018, where both the number of documents and citation counts begin to stabilize, suggesting the formation of a more consistent research agenda. However, the most significant shift occurs after 2020, where the field demonstrates exponential growth in publication output, reaching its peak in 2024–2025.

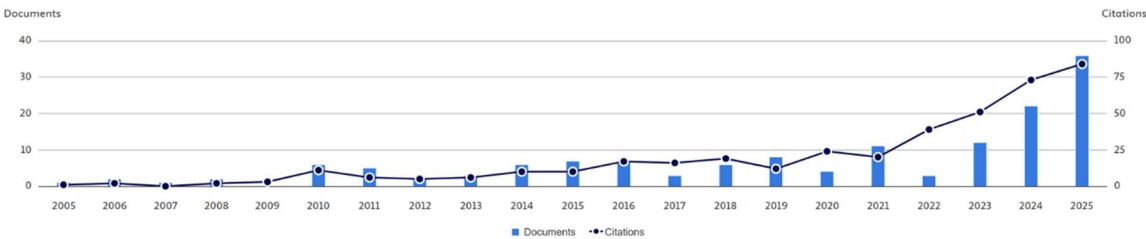


Figure 2. Annual publication and citation trends in research on children’s literature and speech development (2005–2025)

This sharp rise is accompanied by a substantial increase in citations, indicating not only a quantitative expansion but also a growing scientific impact and visibility of the research area. The post-2020 acceleration can be associated with the increasing integration of digital storytelling, technological tools, and interdisciplinary approaches in early childhood education. The trend confirms that the study of children’s literature in the context of speech development has transitioned into an actively developing and highly relevant research domain.

The country-level distribution of publications presented in Figure 3 reveals a highly uneven geographical structure of research productivity. The United States clearly dominates the field with a substantial margin, indicating its leading role in shaping the scientific agenda and contributing the largest volume of research outputs. This leadership can be explained by the strong integration of early childhood education research, advanced academic infrastructure, and sustained funding for interdisciplinary studies. The United Kingdom and Spain follow as secondary contributors, reflecting the active development of research traditions in literacy, pedagogy, and narrative studies within European contexts. A moderate level of contribution is observed in countries such as Italy, Australia, and France, suggesting a stable but less intensive engagement in this research

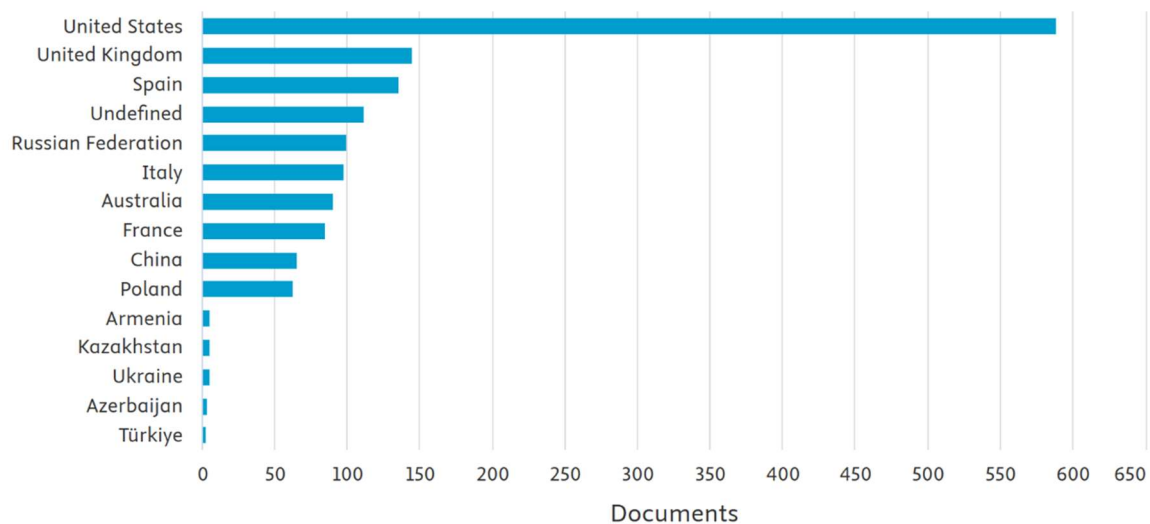


Figure 3. Country-wise distribution of publications in research on children's literature and speech development

domain.

At the same time, the presence of countries such as China and Poland indicates the gradual expansion of the field beyond traditionally dominant Western academic centers. In contrast, the relatively low publication output from Kazakhstan, Armenia, Ukraine, Azerbaijan, and Türkiye highlights an underrepresentation of research from emerging and post-Soviet contexts. This imbalance points to potential gaps in regional research development and suggests the need for greater international collaboration and inclusion. Overall, the geographical distribution underscores the concentration of scientific production in a limited number of countries, while also indicating a gradual diversification of the research landscape.

The analysis of journal-level publication dynamics presented in Figure 4 highlights the differentiated contribution of leading sources and reveals the evolution of thematic leadership within the field. The journal *Reading Teacher* demonstrates the most consistent and dominant trajectory, particularly after 2014, reaching peak publication levels around 2018–2020, which indicates its central role in disseminating research on literacy and language development. A similar upward trend, though less stable, is observed for *History of Education and Children's Literature*, which shows notable growth in the mid-to-late 2010s, reflecting increased scholarly attention to historical and theoretical perspectives. In contrast, journals such as *Children's Literature in Education* and *International Research in Children's Literature* exhibit moderate but steady

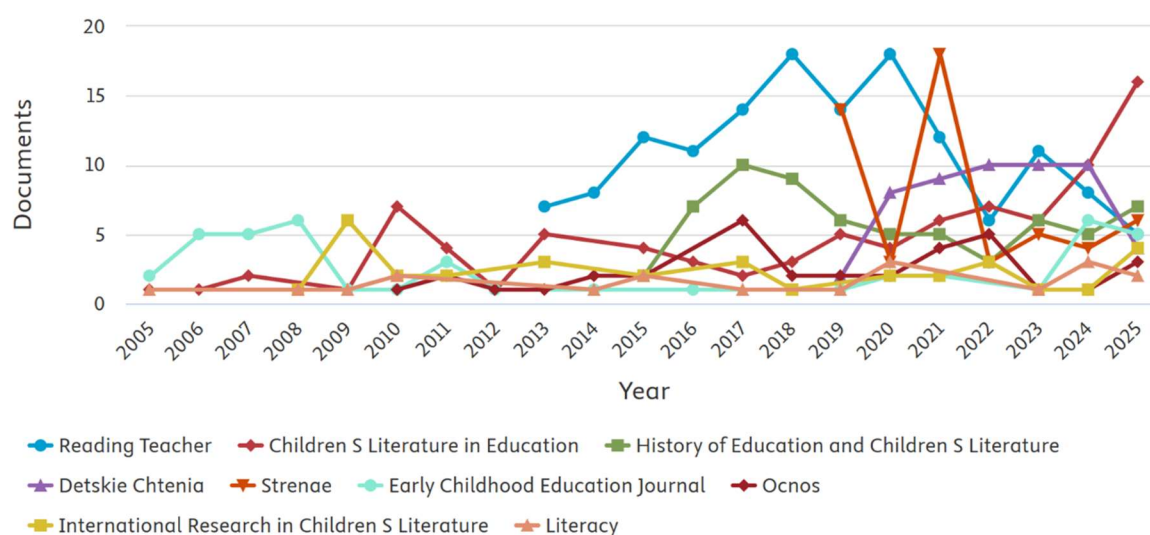


Figure 4. Temporal dynamics of leading journals publishing on children's literature and speech development (2005–2025)

contributions, suggesting their role as specialized platforms within the domain.

A distinct pattern emerges for *Strenae*, which shows sharp fluctuations with pronounced peaks around 2019 and 2021, indicating episodic but intensive publication activity, possibly linked to thematic issues or special editions. Meanwhile, *Detskie Chtenia* demonstrates a clear growth trend after 2020, highlighting the increasing participation of regional and non-English-language journals in the global research landscape. Other sources, including *Early Childhood Education Journal*, *Ocnos*, and *Literacy*, display relatively low but stable publication outputs, contributing to the diversification of the field. Overall, the figure suggests that the research domain is supported by a combination of high-impact core journals and a wider network of specialized and emerging sources, reflecting both consolidation and expansion processes in the scholarly communication structure.

The keyword co-occurrence network presented in Figure 5 reveals the conceptual structure of the research field and highlights the main thematic clusters shaping scholarly discourse. The central position of “storytelling” indicates its role as the core integrative concept, connecting multiple research directions, including education, literacy, and narrative practices. Closely linked to this core, the cluster around “children's literature” reflects the foundational focus of the field, encompassing topics such as picture books, visual storytelling, and multimodality. Another prominent cluster, centered on terms such as “child,” “children,” “literature,” and

“teaching,” emphasizes the pedagogical and developmental dimensions, particularly the application of literary practices in educational contexts.

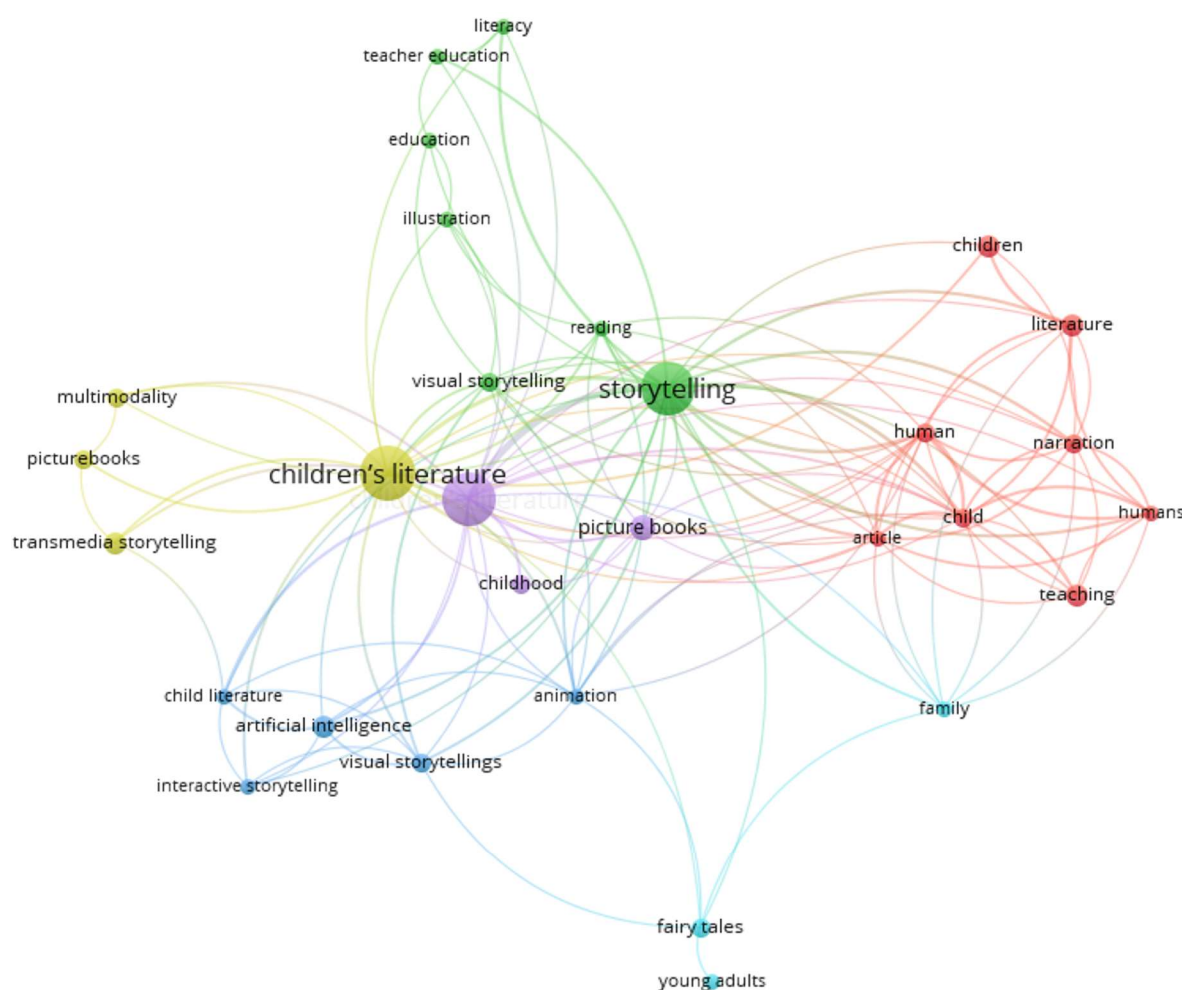


Figure 5. Keyword co-occurrence network in research on children's literature and speech development

In addition, the network demonstrates the emergence of technologically oriented themes, including “digital storytelling,” “animation,” “interactive storytelling,” and “artificial intelligence,” which form a distinct but interconnected cluster. This indicates a growing shift toward the integration of digital tools in early childhood education. The presence of terms such as “family,” “fairy tales,” and “young adults” further suggests the expansion of the research scope beyond formal education into socio-cultural and developmental contexts. Overall, the structure of the network illustrates a multidisciplinary field characterized by strong interconnections between traditional literary approaches and innovative digital practices, confirming the dynamic and evolving nature of research on children's literature and speech development.

Discussion

The findings of this bibliometric analysis show that research on children's literature and speech development has developed as an interdisciplinary field that combines early literacy, storytelling, pedagogy, and digital narrative practices. The dominance of “storytelling” in the keyword network confirms that narrative-based interaction is the central conceptual foundation of the field. This result is consistent with earlier studies showing that storytelling, shared reading, and dialogic book interaction create a rich linguistic environment in which preschool children develop vocabulary, narrative competence, listening comprehension, and expressive speech (Bus

et al., 1995; Whitehurst & Lonigan, 1998; Mol et al., 2008). Therefore, the bibliometric results support the view that children's literature should not be considered only as a supplementary educational resource, but as an active pedagogical tool for speech and language development. The citation analysis also demonstrates that the most influential studies are not limited to narrow linguistic outcomes, but emphasize the broader developmental potential of children's literature. In particular, the leading position of Pulimeno et al. (2020) indicates that contemporary research increasingly understands children's literature as a means of supporting children's cognitive, emotional, social, and communicative development. This corresponds with Nicolopoulou et al. (2015), who showed that narrative- and play-based activities contribute not only to oral language and emergent literacy, but also to social competence. Thus, the results suggest that speech development through children's literature is closely connected with imagination, emotional engagement, symbolic play, and interaction with adults and peers. Another important finding is the rapid growth of publications after 2020, which reflects the increasing relevance of this topic in the context of educational digitalization. The emergence of keywords such as "digital storytelling," "interactive storytelling," "animation," and "artificial intelligence" shows that the field is moving beyond traditional printed texts toward multimodal and technology-enhanced narrative formats. This trend is consistent with Takacs et al. (2015), who found that technology-enhanced storybooks may support story comprehension and expressive vocabulary when multimedia elements are pedagogically meaningful. However, the same authors also warned that excessive interactivity may distract children from narrative understanding. Therefore, digital storytelling should not replace adult-child communication, but should be integrated as a supportive tool within guided pedagogical practice. The geographical distribution of publications reveals a strong dominance of the United States, followed by the United Kingdom, Spain, and several European countries. This indicates that the intellectual development of the field is mainly shaped by Western research traditions in literacy, early childhood education, and children's literature. At the same time, the limited representation of Kazakhstan and other post-Soviet or emerging research contexts points to an important gap. This finding is significant because speech development, storytelling traditions, and children's literature are culturally specific. Therefore, future studies should expand the geographical scope of research and include more local, multilingual, and culturally diverse educational contexts.

Conclusion

The aim of this study, to systematically analyze the scientific literature on the effectiveness of children's literature in developing speech abilities of preschool children through a bibliometric approach, has been successfully achieved. By applying bibliometric methods to a dataset of Scopus-indexed publications, the study identified key research trends, influential studies, leading journals, dominant countries, and the field's conceptual structure. The results provide a comprehensive, structured overview of how children's literature contributes to early language development in contemporary educational research. In response to the research question, the findings demonstrate that the field is primarily organized around several core thematic areas, including storytelling and narrative practices, emergent literacy, and the integration of children's literature into pedagogical contexts. Among these, storytelling emerges as the central and unifying concept, linking various strands of research related to speech development. In addition, the study identified a growing cluster of research focused on digital storytelling, multimedia narratives, and interactive technologies, indicating a shift toward technologically enhanced learning environments. The most influential studies tend to adopt a holistic perspective, emphasizing the role of children's literature not only in linguistic development but also in cognitive, social, and emotional domains. The results also reveal that the field is in a phase of active growth and transformation. The increasing number of publications and citations, particularly after 2020, reflects the rising relevance of this topic in the context of educational innovation and digitalization.

However, the analysis highlights an uneven geographical distribution of research output, with a concentration in a limited number of countries and an underrepresentation of emerging research contexts. This suggests the need for broader international collaboration and diversification of research perspectives. The study confirms that children's literature is an effective and multifaceted educational tool for supporting speech development in preschool children. At the same time, the findings underscore the importance of integrating traditional narrative approaches with modern digital formats in a pedagogically meaningful way. Future research should focus on empirically validating different narrative strategies, conducting comparative analyses of traditional and digital storytelling, and incorporating culturally diverse contexts to enhance the applicability and impact of research in this field.

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DEVELOPMENT OF CREATIVITY OF FUTURE PRESCHOOL TEACHERS THROUGH THE USE OF ARTIFICIAL INTELLIGENCE ELEMENTS: A BIBLIOMETRIC ANALYSIS

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Abstract

The rapid development of artificial intelligence technologies has significantly transformed educational practices, creating new opportunities for enhancing creativity as a key 21st-century competence. This study aims to conduct a bibliometric analysis of global scientific publications on the development of creativity through the use of AI elements, with particular attention to implications for future preschool teacher education. The data were retrieved from the Scopus database for the period 2015 to 2025 and analyzed using bibliometric tools such as VOSviewer and the Bibliometrix package in R. The results indicate a substantial increase in research output in recent years, with a strong emphasis on generative AI, creative learning environments, and teacher competencies. Citation analysis reveals the dominance of recent high-impact publications, while source and authorship analyses highlight the concentration of contributions within a limited number of journals and leading scholars. Thematic mapping demonstrates that artificial intelligence, education, and creativity are central yet still evolving themes, whereas human-centered approaches remain well established. Despite growing interest in the field, the findings reveal a significant gap in research on early childhood education and the preparation of future preschool teachers. The study concludes that there is a need for more integrative, interdisciplinary approaches that combine technological innovation with pedagogical strategies to foster creativity. The results contribute to the theoretical development of teacher education and have practical implications for integrating AI tools into educational practice.

Keywords: artificial intelligence; creativity; teacher education; preschool teachers; bibliometric analysis; educational technology.

Introduction

The relevance of this study is обусловлена несколькими взаимосвязанными глобальными и научно-педагогическими тенденциями. In the context of rapid digital transformation and the expansion of artificial intelligence (AI) technologies across all spheres of society, education systems are increasingly required to prepare professionals capable of creative thinking, adaptability, and innovation. Creativity is recognized as a key 21st-century competence, particularly in early childhood education, where teachers play a crucial role in shaping children's cognitive flexibility, imagination, and problem-solving abilities (Beghetto & Kaufman, 2014; Henriksen et al., 2021). At the same time, the integration of AI into education is transforming traditional pedagogical approaches, offering new tools for personalized learning, content generation, and creative engagement. Recent studies highlight that AI technologies can enhance

creative processes by supporting idea generation, visualization, and interactive learning environments (Luckin et al., 2016; Holmes et al., 2022). For future preschool teachers, the ability to effectively use AI tools is becoming not only a technical skill but also a pedagogical necessity that directly influences the quality of early childhood education. Despite the growing body of research on AI in education, there remains a significant gap in understanding how AI elements specifically contribute to the development of creativity among future preschool teachers. Existing studies tend to focus either on technological aspects of AI implementation or on general teacher competencies, without providing a systematic overview of the intersection between AI and creativity in early childhood teacher education (Zawacki-Richter et al., 2019). In this regard, a bibliometric analysis is particularly relevant, as it enables the identification of key research trends, influential authors, leading journals, and thematic clusters within the scientific field. Such an approach provides a comprehensive and objective mapping of the existing knowledge base and reveals underexplored areas that require further investigation (Donthu et al., 2021). Therefore, the present study addresses an актуальную научную и практическую проблему by systematically analyzing global research on the development of creativity in future preschool teachers using AI elements. The findings are expected to contribute to the theoretical advancement of teacher education and support the integration of innovative technologies into pedagogical practice.

Research problem. Despite the increasing recognition of creativity as a core professional competency for future preschool teachers and the rapid integration of artificial intelligence into educational contexts, a critical gap persists at the intersection of these domains. While contemporary educational paradigms emphasize the importance of fostering creative thinking in early childhood education, teacher preparation programs often lack systematically structured approaches for integrating AI tools in ways that meaningfully support the development of pedagogical creativity (Henriksen et al., 2021; Holmes et al., 2022). A key problem lies in the fragmentation of existing research. On the one hand, studies on creativity in teacher education tend to focus on psychological, pedagogical, or methodological aspects without considering the transformative potential of AI technologies. On the other hand, research on AI in education predominantly addresses issues such as automation, adaptive learning, and data-driven instruction, often overlooking its role as a catalyst for creative processes and innovative teaching practices (Zawacki-Richter et al., 2019; Luckin et al., 2016). This disciplinary disconnection results in a lack of integrative theoretical frameworks that explain how AI elements can be purposefully used to enhance the creative capacities of future preschool teachers. Furthermore, there is insufficient empirical and analytical evidence regarding global research trends, dominant themes, and emerging directions in this field. The absence of comprehensive bibliometric studies limits the ability of researchers and educators to identify influential works, research gaps, and potential areas for interdisciplinary development (Donthu et al., 2021). As a consequence, educational policy and curriculum design related to AI integration in early childhood teacher education remain under-informed and inconsistent.

Research gap. Despite the growing scholarly interest in both creativity development in teacher education and the application of artificial intelligence in educational settings, a number of significant research gaps remain at their intersection, particularly in the context of preparing future preschool teachers. The existing body of literature demonstrates a clear imbalance between technological and pedagogical perspectives. While numerous studies explore AI applications in education, they primarily focus on higher education contexts, learning analytics, or automated systems, with limited attention to early childhood education and even less to teacher preparation for this level (Zawacki-Richter et al., 2019; Holmes et al., 2022). Consequently, the specific role of AI as a tool for fostering creativity in future preschool educators remains underexplored. There is a lack of conceptual integration between creativity research and AI-based

pedagogical innovation. Creativity is often studied as an independent construct within educational psychology, whereas AI is examined from a technological or instructional design perspective. This separation results in insufficient theoretical frameworks that explain how AI elements can systematically support creative teaching competencies, such as imaginative lesson design, flexible thinking, and innovative problem-solving in early childhood contexts (Beghetto & Kaufman, 2014; Henriksen et al., 2021). Current research is geographically and methodologically fragmented. Many studies are concentrated in specific regions and do not reflect a global perspective on the development of creativity through AI in teacher education.

The aim of this study is to conduct a comprehensive bibliometric analysis of global scientific publications on the development of creativity among future preschool teachers through the use of artificial intelligence elements, in order to identify key research trends, thematic structures, influential contributors, and emerging directions in this interdisciplinary field.

The object of the study is the body of scientific literature indexed in international databases Scopus that addresses issues related to creativity development in teacher education and the integration of AI technologies in educational contexts.

The subject of the study is the structural, thematic, and temporal characteristics of research focused on the development of creativity in future preschool teachers through AI elements, including publication dynamics, co-authorship networks, keyword co-occurrence, and citation patterns.

The central research question guiding this study is: *What are the main trends, thematic clusters, and research gaps in the scientific literature on the development of creativity of future preschool teachers through the use of artificial intelligence elements?*

Significance of the study. This study holds both theoretical and practical significance. From a theoretical perspective, it contributes to the systematization of fragmented knowledge at the intersection of creativity research and AI in teacher education by providing a comprehensive mapping of the scientific landscape (Donthu et al., 2021; Zawacki-Richter et al., 2019). It advances understanding of how these two domains converge, thereby supporting the development of integrated conceptual frameworks. From a practical perspective, the findings of this study can inform the design and modernization of teacher education programs by highlighting effective directions for integrating AI tools aimed at fostering creativity in future preschool educators. Additionally, the results may support policymakers, curriculum developers, and educational institutions in making evidence-based decisions about implementing innovative technologies in early childhood education (Holmes et al., 2022; Henriksen et al., 2021). Furthermore, by identifying research gaps and emerging trends, this study provides a foundation for future empirical investigations and interdisciplinary collaboration, thereby contributing to the sustainable development of education in the digital age.

Literature Review

The integration of artificial intelligence into education has become one of the most dynamically developing research areas since 2015, with particular attention to its pedagogical potential and its impact on higher-order cognitive skills, including creativity. A growing body of Scopus-indexed studies demonstrates that AI technologies are increasingly used to personalize learning, automate assessment, and support adaptive instructional strategies, thereby transforming traditional teaching and learning processes (Wang et al., 2024). These transformations create new opportunities for enhancing creative thinking by enabling interactive, flexible, and student-centered learning environments. A significant stream of research focuses on the role of AI in supporting creativity. Empirical studies indicate that AI-assisted teaching can positively influence learners' creative abilities by increasing engagement, providing personalized feedback, and facilitating idea generation processes (Zhou & Peng, 2025). In this context, AI is not merely a technological tool but also a cognitive partner that supports exploratory learning and

creative problem-solving. However, scholars note that research on creativity as an outcome of AI integration remains relatively limited compared to studies focusing on academic performance and efficiency. Another important direction in the literature concerns teacher education and professional development. Systematic reviews reveal that while AI is widely studied in terms of its application in teaching practices, significantly less attention is given to how it contributes to the professional growth of teachers, including the development of creative competencies (Tan, 2025). This imbalance highlights the need for more research focusing specifically on pre-service teacher training and the integration of AI into pedagogical skill development. Recent studies also emphasize the emergence of generative AI as a transformative force in education. These technologies enable new forms of content creation, interactive learning, and innovative teaching strategies, which are directly linked to the enhancement of creativity (Chiu, 2024; Marzano et al., 2025). At the same time, researchers point to challenges such as ethical concerns, the need for AI literacy, and the risk of over-reliance on automated systems, which may negatively affect independent creative thinking if not properly managed.

From a bibliometric perspective, recent analyses demonstrate a rapid increase in publications on AI in education, especially after 2018, with dominant contributions from technologically advanced countries and a concentration of research in higher education contexts (Durak et al., 2024). However, early childhood education and preschool teacher training remain underrepresented in these studies, indicating a clear research gap. Furthermore, contemporary research highlights the necessity of integrating creativity and AI within unified pedagogical frameworks. Some scholars propose structured models that combine creativity development with AI competencies, emphasizing the importance of aligning technological tools with educational goals and teacher training standards (Alasgarova & Rzayev, 2024). These approaches underline the importance of developing both AI literacy and creative pedagogical skills among future teachers. The literature demonstrates that while AI has significant potential to enhance creativity in education, there is still a lack of systematic research focusing on future preschool teachers as a specific professional group. Moreover, the field is characterized by fragmentation, with limited integration between technological and pedagogical perspectives. This justifies the need for a comprehensive bibliometric analysis to synthesize existing knowledge and identify future research directions.

Methods

This study employs a bibliometric analysis, combined with elements of a systematic literature review, to examine the development of creativity among future preschool teachers through the use of artificial intelligence. The methodological framework is based on the PRISMA (Figure 1) approach, which ensures transparency, reproducibility, and rigor throughout data collection, screening, and selection (Page et al., 2021).

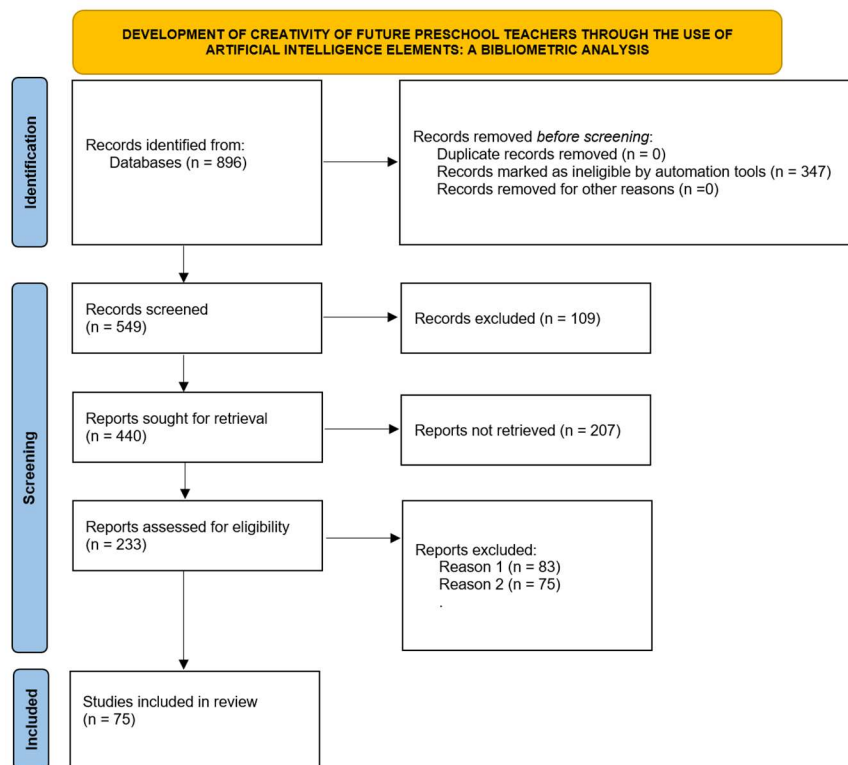


Figure 1. PRISMA flow diagram of the study selection process for bibliometric analysis

The data for the analysis were retrieved from the Scopus database, selected for its extensive coverage of high-quality peer-reviewed publications. A structured search strategy was applied using the following key terms:

TITLE-ABS-KEY ("AI " AND "creativity") AND PUBYEAR > 2015 AND PUBYEAR < 2026 AND (LIMIT-TO (EXACTKEYWORD , "Education")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))

The search was limited to publications from 2015 to 2025, ensuring the relevance of findings to contemporary developments in AI and education. The study followed a structured multi-stage procedure in accordance with the PRISMA framework. At the identification stage, 896 records were retrieved from the Scopus database. During the screening stage, records marked as ineligible by automation tools ($n = 347$) were removed, leaving 549 records for further analysis. These records were screened based on titles and abstracts, resulting in the exclusion of 109 studies deemed irrelevant to the research topic. At the eligibility stage, 440 reports were sought for retrieval; however, 207 reports were not accessible. The remaining 233 full-text articles were assessed against predefined inclusion criteria, namely relevance to artificial intelligence in education, a focus on creativity, and applicability to teacher education. Studies that did not meet these criteria were excluded. As a result, 75 studies were ultimately included in the final bibliometric analysis. The bibliometric analysis was conducted using specialized tools, including VOSviewer and the Bibliometrix package in R, which enabled the visualization and examination of co-authorship networks, keyword co-occurrence, citation relationships, and thematic clusters. These methods allowed for the identification of dominant research trends, influential publications, and emerging directions within the field (Donthu et al., 2021). The combination of systematic

review procedures and bibliometric techniques ensures a comprehensive, transparent, and objective analysis of the scientific landscape, providing both quantitative and qualitative insights into the development of this interdisciplinary research area.

Results

To identify the most influential contributions in the field, a citation analysis was conducted on the selected publications. The results are presented in Table 1, which lists the top 10 most cited studies related to artificial intelligence and creativity in education.

Table 1. Top 10 Most Cited Publications on AI and Creativity in Education

No.	Document Title	Authors	Source	Year	Citations
1	Holy or Unholy? Interview with OpenAI’s ChatGPT	Iskender, A.	European Journal of Tourism Research	2023	226
2	RoboCupJunior for promoting STEM education, 21st century skills, and technological advancement through robotics competition	Eguchi, A.	Robotics and Autonomous Systems	2016	194
3	Artificial intelligence and human behavioral development: A perspective on new skills and competences acquisition for the educational context	Benvenuti, M., Cangelosi, A., Weinberger, A., et al.	Computers in Human Behavior	2023	151
4	What’s in a text-to-image prompt? The potential of stable diffusion in visual arts education	Dehouche, N., Dehouche, K.	Heliyon	2023	112
5	Generative AI, Teacher Knowledge and Educational Research: Bridging Short- and Long-Term Perspectives	Mishra, P., Oster, N., Henriksen, D.	TechTrends	2024	63
6	Creative partnerships with generative AI: Possibilities for education and beyond	Creely, E., Blannin, J.	Thinking Skills and Creativity	2025	49
7	Educators’ Academic Insights on Artificial Intelligence: Challenges and Opportunities	Jose, J., Jose, B.J.	Electronic Journal of e-Learning	2024	47
8	Creative Learning for Sustainability in a World of AI: Action, Mindset, Values	Henriksen, D., Mishra, P., Stern, R.	Sustainability	2024	43
9	Exploring the Influence of Student Interaction with ChatGPT on Critical Thinking, Problem Solving, and Creativity	Qawqzeh, Y.	International Journal of Information and Education Technology	2024	42
10	ChatGPT in Ukrainian Education: Problems and Prospects	Fiialka, S., Kornieva, Z., Honcharuk, T.	International Journal of Emerging Technologies in Learning	2023	39

The analysis of the most cited publications reveals several important trends in the field of artificial intelligence and creativity in education. First, a significant proportion of highly cited studies were published between 2023 and 2024, indicating a rapid growth of scholarly interest driven by the emergence of generative AI technologies such as ChatGPT and text-to-image models.

The most cited article by Iskender (2023), with 226 citations, reflects the intense academic and public discourse surrounding the ethical, pedagogical, and societal implications of generative AI. Second, the presence of earlier influential work, such as Eguchi (2016), demonstrates that the foundations of this research area were initially linked to STEM education and robotics, emphasizing the development of 21st-century skills. This suggests a transition from traditional forms of educational technology toward more advanced AI-driven systems that support creativity and higher-order thinking. Third, a thematic shift is evident in recent publications, where the focus has moved toward generative AI and its role in creative processes. Studies by Dehouche (2023) and Creely and Blannin (2025) highlight the application of AI in creative domains such as visual arts and collaborative knowledge production. Similarly, research by Qawqzeh (2024) empirically demonstrates the impact of AI tools on critical thinking, problem-solving, and creativity, reinforcing the idea that AI can act as a cognitive partner in learning. Furthermore, the analysis shows that teacher-related research is gaining increasing attention, particularly in the context of AI integration. Articles by Mishra et al. (2024) and Jose and Jose (2024) emphasize the importance of teacher knowledge, competencies, and perceptions in effectively implementing AI technologies in education. This is particularly relevant for the preparation of future preschool teachers, as it underscores the need for pedagogical adaptation alongside technological innovation. Another notable trend is the growing emphasis on sustainability, ethics, and values in AI-enhanced education, as reflected in the work of Henriksen et al. (2024). This indicates a broader shift from purely technological considerations to more holistic educational paradigms that integrate creativity, ethical awareness, and responsible AI use.

Overall, the citation analysis demonstrates that the field is evolving rapidly, with a strong orientation toward generative AI, creative applications, and teacher competencies. However, despite the increasing number of high-impact studies, there remains a relative lack of research specifically focused on early childhood education and preschool teacher training, confirming the relevance and necessity of the present study. Figure 2 presents the distribution of the most relevant academic sources contributing to the research field of artificial intelligence and creativity in education. The results indicate a clear concentration of publications within a limited number of high-impact journals, reflecting the emerging yet specialized nature of this interdisciplinary domain.

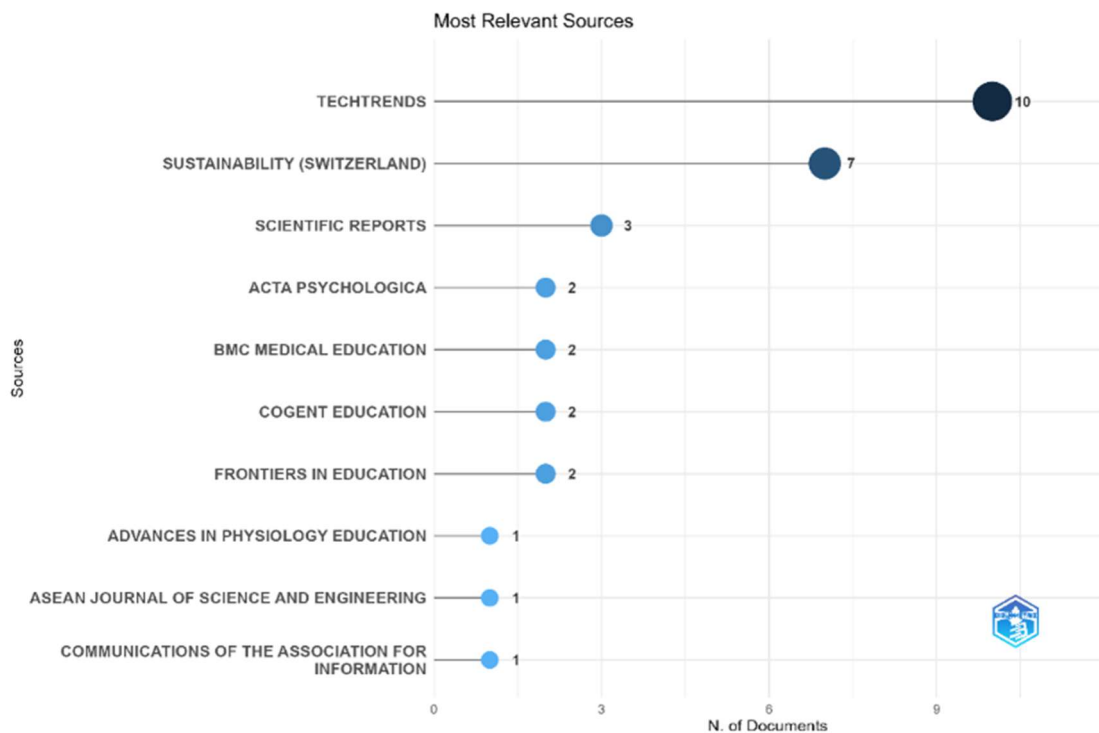


Figure 2. Most relevant sources by number of publications in the field of AI and creativity in education

The journal *TechTrends* ranks first with the highest number of publications ($n = 10$), highlighting its significant role as a leading platform for research at the intersection of educational technology, innovation, and pedagogical transformation. This dominance suggests that the discourse on AI and creativity is strongly aligned with applied educational technology and instructional design perspectives.

The second most productive source is *Sustainability (Switzerland)* ($n = 7$), which reflects a growing trend of integrating AI and creativity research within broader discussions of sustainable development, future skills, and educational transformation. This indicates that creativity supported by AI is increasingly viewed not only as a pedagogical issue but also as a component of sustainable and future-oriented education systems. Other journals, such as *Scientific Reports* ($n = 3$), *Acta Psychologica* ($n = 2$), and *BMC Medical Education* ($n = 2$), demonstrate the interdisciplinary nature of the field, spanning psychology, cognitive science, and medical education. This diversity suggests that the development of creativity through AI is being explored across multiple disciplinary contexts, extending beyond traditional teacher education research. Additionally, sources like *Cogent Education* and *Frontiers in Education* (each with $n = 2$) indicate a continued interest in pedagogical innovation and open-access dissemination, which facilitates wider academic engagement. Journals with a smaller number of publications ($n = 1$), such as *Advances in Physiology Education* and *ASEAN Journal of Science and Engineering*, further highlight the global and cross-sectoral expansion of this research area.

Figure 3 illustrates the distribution of the most productive authors contributing to the research field of artificial intelligence and creativity in education. The results reveal a clear concentration of scholarly output among a small group of leading researchers, indicating the presence of key opinion leaders shaping the development of this interdisciplinary domain. Henriksen, D. and Mishra, P. emerge as the most influential authors, each contributing the highest share of publications (16%). Their dominant position reflects their long-standing involvement in research on creativity, educational technology, and the integration of innovative pedagogical

approaches. Their work often focuses on the conceptual and practical connections among creativity, digital tools, and teacher education, which helps explain their central role in this field.

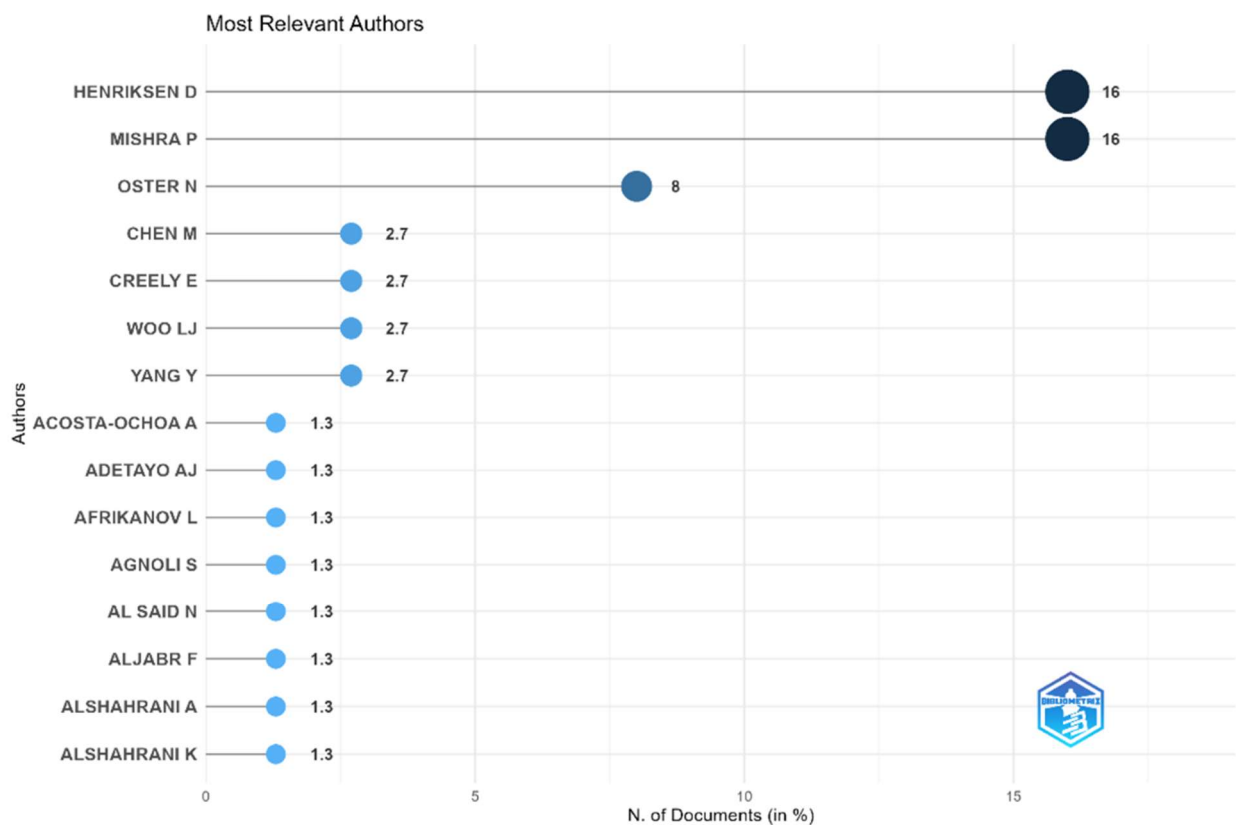


Figure 3. Most relevant authors by number of publications in the field of AI and creativity in education

Oster, N. ranks third (8%), further reinforcing the prominence of a closely connected group of scholars working collaboratively on topics related to generative AI, teacher knowledge, and creative learning environments. This pattern suggests the existence of a core research cluster that significantly influences the field's direction and theoretical development. A second tier of authors, including Chen, M., Creely, E., Woo, L. J., and Yang, Y. (each approximately 2.7%), demonstrates moderate but consistent contributions. These researchers represent a broader international engagement and reflect the diversification of research perspectives, particularly in areas such as AI applications in learning environments, creativity enhancement, and educational innovation. The remaining authors, each contributing around 1.3%, indicate a long tail distribution typical of emerging research fields, where many scholars contribute sporadically or focus on niche aspects of the topic. This pattern highlights the expanding interest in AI and creativity across different regions and disciplines, while also suggesting that the field has not yet reached full maturity in terms of author concentration.

Figure 4 presents the distribution of countries based on the average number of citations per article, highlighting the geographical impact and visibility of research in the field of artificial intelligence and creativity in education. The results reveal notable disparities in citation influence across countries, indicating differences in research quality, international collaboration, and thematic relevance. Thailand ranks first with a significantly higher average citation rate (112), demonstrating an exceptional impact relative to other countries. This result may be attributed to a smaller number of highly influential publications that have gained substantial recognition within the academic community. Italy (55) and the United States (41.2) follow as leading contributors,

reflecting their strong research infrastructure and active involvement in AI and educational innovation.

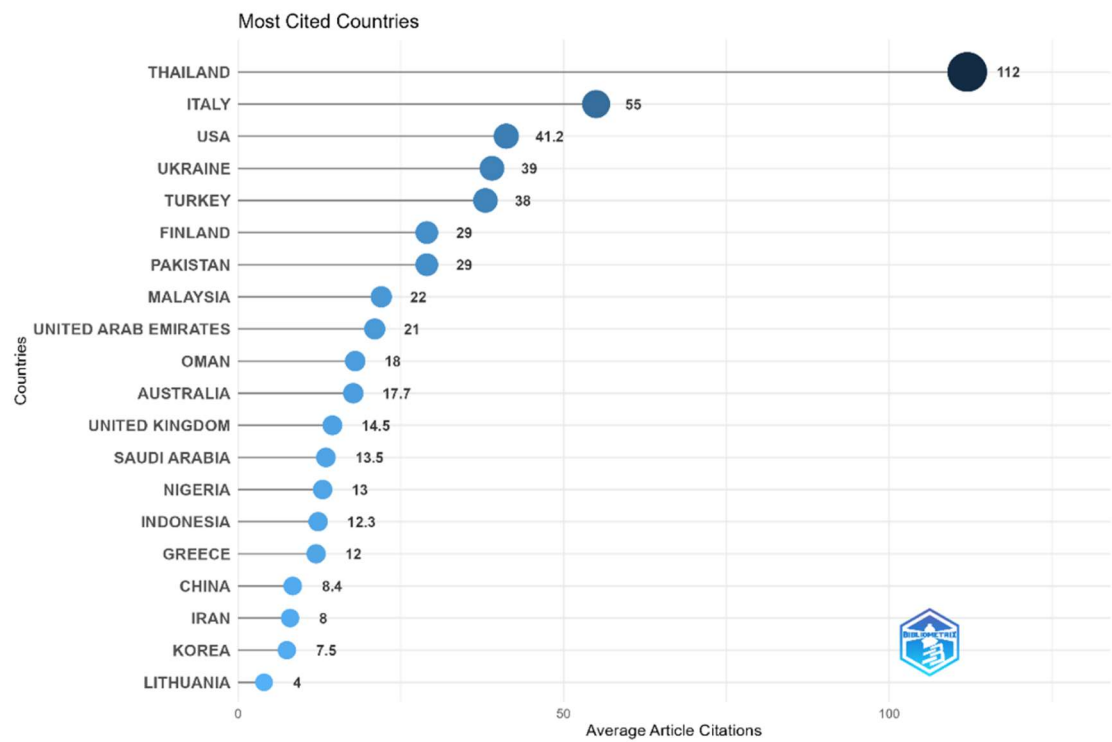


Figure 4. Most cited countries by average article citations in the field of AI and creativity in education

European countries such as Ukraine (39), Turkey (38), and Finland (29) also show relatively high citation impact, indicating the growing importance of this research area across diverse regional contexts. These findings suggest that impactful research is not limited to traditionally dominant academic systems but is increasingly distributed across a wider range of countries. Countries such as Pakistan (29), Malaysia (22), and the United Arab Emirates (21) represent emerging contributors, highlighting the global expansion of research on AI and creativity in education. Their presence in the ranking reflects increasing investment in educational technologies and innovation-driven research agendas. Lower average citation rates observed in countries such as China (8.4), Iran (8), and Korea (7.5) may indicate either a larger volume of publications with varying impact or a relatively recent engagement with the topic. Similarly, Lithuania (4) represents the lower end of the citation spectrum, suggesting limited visibility or smaller research output in this specific domain.

Figure 5 presents a thematic map based on keyword co-occurrence, illustrating the conceptual structure of the research field according to two dimensions: centrality (relevance degree) and density (development degree). The map is divided into four quadrants: motor themes, niche themes, emerging or declining themes, and basic themes, each reflecting different levels of importance and maturity within the field. The motor themes quadrant (upper-right) includes highly developed and central topics such as *humans*, *students*, and *human-related studies*. These themes are well-established and play a critical role in shaping the research field. Their strong centrality indicates that they are widely connected to other topics, while their high density reflects a well-developed internal structure. This suggests that human-centered approaches remain at the core of research on AI in education.

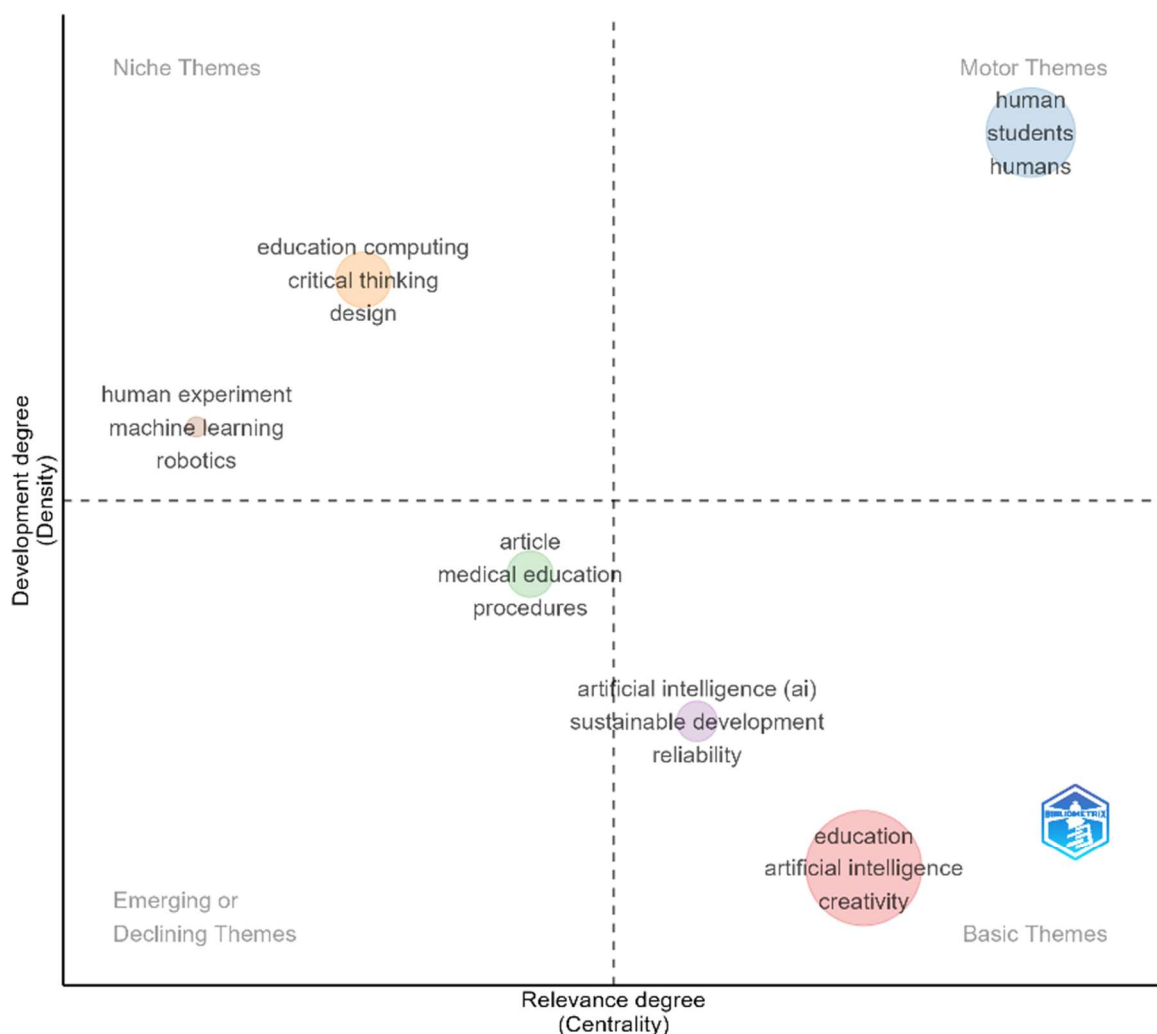


Figure 5. Thematic map of research on artificial intelligence and creativity in education

The basic themes quadrant (lower-right) contains fundamental but less developed topics, including *artificial intelligence*, *education*, and *creativity*. Despite their lower density, these themes exhibit high centrality, meaning they are essential to the field but still evolving in terms of theoretical and methodological sophistication. The positioning of *creativity* in this quadrant confirms that, although it is a key concept, it has not yet reached full maturity as a research domain within AI in education.

In the niche themes quadrant (upper-left), topics such as *education computing*, *critical thinking*, and *design* are identified. These themes are well-developed internally but have limited connections to the broader field. This suggests that they represent specialized research areas that may not yet be fully integrated into the mainstream discourse on AI and creativity.

The emerging or declining themes quadrant (lower-left) includes topics such as *machine learning*, *robotics*, and *human experiments*. These themes show low centrality and low density, indicating that they are either in the early stages of development or gradually losing relevance within this specific research context. Their position suggests potential opportunities for future research, particularly if these areas are reconnected to creativity and pedagogical innovation.

Additionally, intermediary clusters such as *artificial intelligence*, *sustainable development*, and *reliability* indicate the growing diversification of the field, linking technological advancements with broader societal and educational challenges.

Discussion

The findings of this bibliometric analysis provide important insights into the evolving landscape of research on artificial intelligence and creativity in education, while also confirming and extending existing literature. As demonstrated in the results, the field is characterized by rapid growth, thematic diversification, and increasing scholarly attention, particularly after 2020. This trend is consistent with previous studies highlighting the acceleration of AI-related educational research in recent years (Zawacki-Richter et al., 2019; Holmes et al., 2022). One of the key findings of this study is the dominance of generative AI-related topics in highly cited publications. This aligns with recent research emphasizing the transformative potential of generative technologies, such as ChatGPT and text-to-image systems, in supporting creative processes and redefining educational practices (Chiu, 2024; Creely & Blannin, 2025). The prominence of such studies suggests a paradigm shift from traditional instructional technologies toward AI systems that actively participate in knowledge construction and creative thinking. This supports the argument by Luckin et al. (2016) that AI can function not only as a tool but also as a partner in learning. At the same time, the results highlight the continued importance of foundational concepts such as creativity, human-centered learning, and teacher competencies. The thematic map indicates that while *creativity* is a central concept, it remains underdeveloped compared to other themes. This finding is consistent with earlier research suggesting that creativity is often treated as a secondary outcome rather than a primary focus in AI-related educational studies (Henriksen et al., 2021). Moreover, the strong presence of human-centered themes reinforces the idea that technological innovation in education must be aligned with pedagogical and psychological principles (Beghetto & Kaufman, 2014). Another significant contribution of this study is the identification of leading authors and journals shaping the field. The dominance of scholars such as Henriksen and Mishra reflects their influential role in integrating creativity, technology, and teacher education. Their work emphasizes the need for developing creative pedagogical thinking alongside digital competencies, which is particularly relevant for preparing future preschool teachers (Henriksen et al., 2021; Mishra et al., 2024). This finding supports the broader literature, which highlights the importance of teacher readiness and professional development in the successful implementation of AI in education (Jose & Jose, 2024).

The geographical distribution of citations further reveals the global nature of this research field, with contributions from both developed and emerging countries. However, the uneven citation impact suggests disparities in research visibility and influence, which may be linked to differences in research infrastructure and international collaboration. Similar patterns have been reported in previous bibliometric studies, which note the concentration of high-impact research in specific regions (Donthu et al., 2021). Importantly, the findings confirm a critical gap identified in the literature: the limited focus on early childhood education and the preparation of future preschool teachers. While AI and creativity are widely studied in higher education and general pedagogical contexts, their intersection within preschool teacher education remains insufficiently explored. This supports the conclusions of prior studies, which emphasize the need for more targeted research in this area (Zawacki-Richter et al., 2019; Holmes et al., 2022). Furthermore, the thematic analysis reveals that emerging topics such as machine learning and robotics are not yet fully integrated into the discourse on creativity. This indicates potential directions for future research, particularly in exploring how these technologies can be applied to support creative pedagogical practices in early childhood education.

Conclusion

This study provides a comprehensive bibliometric analysis of research on the development of creativity through artificial intelligence in education, with a particular focus on implications for future preschool teacher training. The findings demonstrate that the field has experienced rapid growth in recent years, especially with the emergence of generative AI technologies, which have

significantly influenced research directions and educational practices. The results reveal that the research landscape is characterized by strong interdisciplinarity, integrating perspectives from educational technology, psychology, and sustainability studies. At the same time, the analysis highlights a concentration of influential publications, authors, and journals that shape the development of this domain. Thematic mapping indicates that while artificial intelligence and creativity are central concepts, they remain insufficiently developed in terms of theoretical integration, particularly within the context of teacher education. Importantly, the study identifies a critical research gap related to the limited attention given to early childhood education and the preparation of future preschool teachers. Despite the recognized importance of creativity as a core professional competence, the role of AI in fostering creative pedagogical skills at this level remains underexplored. This finding underscores the need for more targeted and practice-oriented research that bridges technological innovation with pedagogical theory. The study contributes to the systematization of existing knowledge and provides a foundation for future research by identifying key trends, influential contributors, and emerging themes. The results emphasize the importance of developing integrated frameworks that combine AI literacy with creative teaching competencies, thereby supporting the modernization of teacher education in the digital age.

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The Use of Game-Based Learning to Enhance Vocabulary Acquisition in High School Students

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ABSTRACT

This study investigates the usage of Game-Based Learning (GBL) to develop vocabulary acquisition among junior high secondary school students. The purpose of the study is to determine whether activities based on GBL can help to facilitate learners' confident vocabulary acquisition and ability to apply gained knowledge in appropriate contexts. The study employed a survey method to collect data from teachers of English, sharing their thoughts and classroom observations on the approach being discussed. Results indicate that FL teachers find GBL effective and implement into their lessons. The study concludes that GBL is a productive pedagogical tool for enhancing lexical competence and recommends its integration into language teaching process.

Key words: Game-Based Learning (GBL), vocabulary acquisition, foreign language education, lexical competence, Non-Digital Games, Digital games.

INTRODUCTION

Learning vocabulary is one of the most laborious and at the same time fundamental components of learning any foreign language. Without a sufficient vocabulary, the learner will not be able to fully understand the interlocutor's speech or clearly express his/her thoughts. It is no coincidence that Nation (2001) noted that lexical competence underlies four types of speech acts. Moreover, traditional approaches – memorizing lists of words, translating them and repeating them repeatedly – do not always give the desired results. High school students learning English as a foreign language lose interest in vocabulary exercises, considering them boring and far from real communication. A natural question arises: how can the process of learning words can be made lively and stimulating?

Game-based learning (GBL) is considered one reliable answer. The idea of using games as a pedagogical tool is not new: L.S. Vygotsky (1993) considered the game as a fundamental activity in which children master social roles, develop imagination and develop higher mental functions. Today, with the advent of digital technologies, the idea of "learning through play" has taken on new forms – from card games to full-fledged mobile applications.

The purpose of this study is to investigate how secondary school teachers perceive and implement game-based learning for vocabulary development of secondary school students and to assess the extent to which this approach contributes to the confident acquisition and active use of new vocabulary.

Speaking of the **theoretical foundations** of game-based learning it is wise to rely on the work of L.S. Vygotsky (1993), who considered play as a space in which children "go beyond" their

actual level of development. From the point of view of foreign language acquisition, play is especially important because it alleviates the fear of making mistakes – this fear often inhibits students' verbal activity. From a practical point of view, Nation (2001) proposed the most systematic method for vocabulary development. He identified three main aspects of word knowledge – form, meaning, and use – and noted that repeated exposure to words in different contexts is important for long-term memory. Game-based activities provide such repeated encounters emotionally, increasing the possibility of long-term memory. In Kazakhstani methodology, S.S. Kunanbayeva (2015) made a significant contribution to the understanding of foreign language learning: her works emphasize that modern language teaching should be based on the principles of communication, cultural sensitivity, and personal involvement.

In recent years, a large body of empirical research on gamification in English language teaching has emerged. A systematic review by Zhang and Hasim (2023) found that gamified activities have positive effects on motivation and engagement, although their impact on learning outcomes varies depending on the design of the task. Yu (2023) found, based on quantitative research, that gamified vocabulary learning increased student satisfaction and improved learning outcomes compared to traditional methods.

Research focusing on lexical competence is particularly clear. Kulkova and Nuriyeva (2024) concluded that gamification promotes the development of active rather than passive vocabulary in schoolchildren. Hwang, Wang, and Lai (2021) showed that mobile game applications based on the ubiquitous learning principle improve both learning outcomes and engagement. A systematic review by Vnuchko and Klimova (2023) confirms that digital games can promote vocabulary acquisition, but only when integrated into the learning process. More “low-tech” solutions are equally valuable: Hassan et al. (2024) studied the Baamboozle platform and found that simple interactive quizzes significantly contributed to the memorization of new words, while Gunavan (2025) showed that game-based learning has a beneficial effect not only on vocabulary, but also on general oral language. Thus, the collected data allow us to consider game-based learning as a pedagogically sound approach. However, how the approach is perceived by teachers themselves – those who directly use it in the classroom – is relatively poorly studied, especially in the context of Kazakhstani education.

The effectiveness of game-based learning in vocabulary development is explained by a combination of cognitive, motivational and social factors. From a cognitive perspective, games create conditions for “deep” learning: students do not just memorize words mechanically, but encounter them in meaningful contexts, repeatedly use them to solve game-based problems, and thus engage in active memorization processes. According to Nation (2001), such repeated exposure to words in different contexts is one of the main conditions for the transition of vocabulary from passive to active.

The emotional and motivational component is also important. Games alleviate the fear of making mistakes – a psychological barrier that often prevents students from trying new words. In a game-based situation, mistakes are perceived as part of the process, not as failures; students are willing to take risks and, as a result, gain more experience. Yu (2023) experimentally showed that gamified vocabulary learning leads not only to higher levels of mastery, but also to a significant increase in motivation and satisfaction with the lesson. Zhang and Hasim (2023) come to similar conclusions: according to their data, game elements consistently increase students' engagement in the EFL classroom.

Regarding vocabulary competence, the effectiveness of game-based learning has been confirmed by a number of empirical studies. Hwang et al. (2021) recorded a significant increase in the vocabulary of schoolchildren who studied using mobile game applications compared to a control group. Hasana et al. (2024) noted that, studying the Baamboozle platform, students memorized new vocabulary items faster and repeated them more accurately after several game

sessions. Kulkova and Nuriyeva (2024) complement this view, noting that the main result of the game is the transfer of words from passive to active vocabulary, which is the ultimate goal of vocabulary training.

At the same time, a number of authors warn against unrealistic expectations. A systematic review by Vnuchko and Klimova (2023) shows that the effectiveness of digital games depends significantly on how well they are integrated into the overall learning process: entertainment elements alone, not supported by methodologically designed vocabulary training, do not produce significant results. In other words, a game is a tool, and its effectiveness depends on how the teacher uses it.

Talking about the **methodology** the study was based on a survey design, which allows for the collection of standardized data from a group of participants and the identification of general trends in the use of game-based learning. This approach was chosen due to its effectiveness in identifying teachers' attitudes, opinions and specific experiences. The survey was conducted among secondary school English teachers. The sample was created through voluntary participation (non-random sampling). The teaching experience of the respondents was diverse, which provided a broader perspective on the use of GBL in real-world classroom practice.

A structured questionnaire was developed, which included closed and open-ended questions. The closed questions were designed to obtain quantitative data on the frequency of use of game-based learning, the types of games used, and their effectiveness in vocabulary development. The open-ended questions allowed teachers to share their observations, experiences, and opinions. The survey was conducted online and anonymously, which ensured accessibility and convenience for the participants. Respondents were informed in advance about the purpose of the study; participation was completely voluntary. The data obtained were processed using basic quantitative methods – descriptive statistics, frequencies, and percentages. This allowed us to identify general trends in the responses and assess the impact of game-based learning on vocabulary development. Qualitative comments were analyzed using thematic clustering and used to complement the quantitative results.

The survey **results** showed a clear positive attitude of teachers towards game-based learning. The vast majority of respondents (92%) considered this approach to be a very effective tool for developing students' language skills. In addition, 63% of teachers reported using GBL regularly, which indicates a high level of practical integration of the method into the real-world learning process. Regarding the format, only 36% of respondents preferred exclusively digital games. A much larger proportion (78%) supported a mixed format that combines digital and non-digital game-based activities. This result is consistent with the findings of Vnuchko and Klimova (2023) that the greatest impact is achieved through a reasonable balance between technological and paper-based resources.

Despite the generally positive opinion, 70% of teachers noted a significant difficulty: game-based activities require significant preparation. Apparently, this factor prevents the method from being used more often. Another important finding is that 82% of respondents indicated that they would be willing to use ready-made materials available on online platforms or in printable PDF format. In other words, the demand for accessible and quickly usable game-based resources among teachers is indeed high.

These data allow us to make several important observations. First, teachers generally agree with what has long been proven in international research: game-based learning is not just a fun addition to the lesson, but a full-fledged methodological tool. The high percentage of those who consider GBL effective (92%) is consistent with the findings of Zhang and Hasim (2023), Yu (2023), and Kulkova and Nuriev (2024).

Second, the clear preference for a mixed format (78%) indicates that teachers take a pragmatic approach to the choice of games. Digital resources are good for individual work and

automatic feedback, while non-digital formats – flashcards, board games and role-playing games – are better for communicative interaction and breaking the psychological barrier described by Vygotsky (1993). As stated by 70% of teachers, preparation time remains a significant obstacle. The willingness of 82% of respondents to use ready-made materials indicates that the development of high-quality banks of game-based tasks can significantly improve the implementation of GBL in school practice.

In Kazakhstan, where much attention is paid to multilingualism and the development of a “linguistic personality” (Kunanbayeva, 2015), game-based learning can play a special role: it allows you to integrate language, culture and personal experience into a single, emotionally rich process.

CONCLUSION

Overall, the study results confirm that teachers consider game-based learning a highly effective approach. Digital games, used across various platforms, provide more opportunities for active student engagement in the lesson. Non-digital formats are equally valuable – their flexibility allows for easy integration into lessons without the need for internet access or specialized devices. A clear theme emerged from the teachers' responses: the need for accessible, ready-to-use resources that would make this method more realistic. This is the gap our doctoral research aims to fill. The goal is to develop and systematize digital and non-digital practical materials that teachers can directly use in their classrooms.

There remain several avenues for further research. Future studies will examine how different types of games impact specific components of vocabulary competence and which strategies are best for integrating them into various educational contexts. Particular attention will be paid to the balance between pedagogical effectiveness and time optimization – one of the main concerns raised by teachers. Ultimately, further work in this area should contribute not only to our theoretical understanding, but also to the practical improvement of teaching methods in foreign language didactics in Kazakhstan.

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Модель профессионального роста педагогов ДЛЯ РАБОТЫ в инклюзивном образовании: ОПЫТ И ПОДХОДЫ

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В статье представлен концептуальный анализ моделей профессионального развития педагогов в системе инклюзивного образования одаренных детей. Автор рассматривает международный опыт, включая рамки European Agency и принципы WCGTC, а также специфические модели (4-P, PASCAGE, Lifelong Learning), выявляя их преимущества и системные дефициты. Особое внимание уделено обоснованию и описанию авторской модели профессионального роста, адаптированной к образовательному контексту Республики Казахстан. Новизна подхода заключается в интеграции компетентностного, личностно-ориентированного и социально-средового подходов, применении пятифакторной модели личности (Big Five) и методов Action Research и Lesson Study. Модель представлена как совокупность целевого, методологического, содержательного, оценочного и результативного компонентов. Внедрение данной системы направлено на трансформацию роли учителя в позицию «рефлексивного практика», владеющего принципами Evidence-Based Practice и способного проектировать индивидуальные траектории развития талантов (ускорение и обогащение). Реализация модели призвана сформировать интегративную профессиональную компетенцию педагога-исследователя и наставника, обеспечивающего качественное сопровождение одаренных обучающихся в гетерогенной среде.

Ключевые слова: инклюзивное образование одаренных детей, модель профессионального роста педагогов, рефлексивный практик, Action Research и Lesson Study, компетентностный подход, образовательная среда Казахстана, Evidence-Based Practice.

Современное инклюзивное образование предполагает не только работу с детьми с особыми образовательными потребностями, но и с одаренными обучающимися, которые

зачастую остаются вне фокуса систем подготовки педагогов. Международное исследование показывают, что большинство учителей не получают достаточной профессиональной подготовки по работе с одаренными детьми [1].

В данной статье представлен анализ существующих моделей профессионального развития педагогов, ориентированных на работу в инклюзивных образовательных средах с одаренными детьми, а также дается оценка их эффективности и возможностей для адаптации в национальные контексты.

Международные компетентностные рамки для инклюзивного образования. Европейское агентство по специальному образованию и инклюзивному обучению (European Agency for Special Needs and Inclusive Education) разработало «Profile for Inclusive Teacher Professional Learning: Including all education professionals in teacher professional learning for inclusion» (2022), которое представляет собой расширенную компетентностную рамку для подготовки педагогов к работе в инклюзивных условиях [2]. В документе выделяются пять ключевых измерений профессионального роста учителя:

- раннее выявление разнообразных потребностей;
- дифференцированное обучение;
- индивидуализированное и междисциплинарное планирование;
- оценка и рефлексия;
- сотрудничество с семьями и участниками системы.

Данная рамка, не ограничиваясь лишь сферой работы с одаренными детьми, предлагает системный инструментарий для подготовки педагогов к взаимодействию с самыми разными категориями учащихся, в том числе и в условиях инклюзии. Следует подчеркнуть: в рамках компетентностного подхода акцент делается на формировании профессиональной идентичности учителя как специалиста «всестороннего» профиля. Именно такой педагог берет на себя ответственность за достижения каждого воспитанника, вне зависимости от специфики его индивидуальных образовательных потребностей.

Глобальные принципы профессионального обучения в образовании одаренных детей. Мировым советом по одаренным и талантливым детям (World Council for Gifted and Talented Children, WCGTC) был разработан документ «Global Principles for Professional Learning in Gifted Education» (2021), который содержит десять ключевых принципов профессионального обучения для педагогов, работающих с одаренными детьми [3]. Эти принципы включают:

- ориентация на практику;
- контекстуальная зависимость;
- инклюзивность и диверсификация;
- междисциплинарность;
- когнитивная и эмоциональная поддержка;
- само- и взаимооценка;
- коучинг и менторство;
- профессиональное сотрудничество;
- непрерывность обучения;
- системная поддержка.

Данные принципы нашли успешное применение в практике начальных школ Италии, где учителя взаимодействовали с одаренными учащимися в условиях общеобразовательных классов. Результаты исследования подтверждают, что такая модель профессионального обучения содействует совершенствованию педагогических компетенций, необходимых для реализации дифференцированного подхода и индивидуальной поддержки талантливых детей.

*Модели профессионального развития педагогов в работе с одаренными детьми.
Гонконгская модель (4-P Model)*

Исследование в Гонконге представило PD-программу по одаренному образованию, основанную на 4-P модели: Personal knowledge – личностно-профессиональное знание; Practice – педагогическая практика; Philosophy – образовательная философия; Partnership – профессиональное партнерство[4].

В рамках данной модели оценка динамики знаний, установок и поведения педагогов осуществлялась на основе фреймворка КАВ (Knowledge-Attitudes-Behaviors). В течение шестимесячного курса подготовки учителя участвовали в семинарах, выполняли практические кейсы и занимались рефлексивным анализом. Итоговые данные подтвердили существенный рост профессиональных компетенций участников в сфере обучения и сопровождения одаренных детей.

Модель PAcKaGE (система непрерывного профессионального развития педагогов в цифровой среде)

Исследование 2017 года «Online Teacher Professional Development for Gifted Education» (Дистанционное профессиональное развитие педагогов в области педагогики одаренности) представило PAcKaGE Model oTPD (online Teacher Professional Development), включающую пять компонентов: контент-поддержку, когнитивную поддержку, техническую поддержку, социальную поддержку и поддержку мотивации [5]. Результаты исследования подтвердили, что разработанная в США модель обеспечивает позитивную динамику в пяти ключевых аспектах педагогической деятельности: практической работе, профессиональных установках, уровне сотрудничества, содержательной базе знаний и эффективности процессов целеполагания.

Модель непрерывного обучения (Lifelong Learning Model (автономная образовательная система)

В Австрии и ряде других стран Европы реализуется концепция Lifelong Learning, в рамках которой высшие учебные заведения и педагогические институты организуют краткосрочные программы, модули и семинары, посвященные обучению одаренных детей в условиях инклюзии. При этом Австрийский центр по вопросам одаренности принимает непосредственное участие в формировании учебных планов для педагогических факультетов [6]. Эта модель демонстрирует высокую гибкость и возможность адаптации к национальным контекстам.

Согласно обзору исследователя Г. Тауненда, результативность программ подготовки обеспечивается их долгосрочным характером, использованием инструментов коучинга и менторства, а также учетом специфики школьного контекста [7]. Автор особо отметил, что в большинстве современных программ обучения работе с одаренными детьми отсутствует этап предварительной подготовки будущих педагогов.

В таблице 1 указаны преимущества и недостатки моделей профессионального развития педагогов в работе с одаренными детьми.

Таблица 1 – Сравнительная таблица моделей профессионального развития педагогов в работе с одаренными детьми

№	Модель	Страна/Регион	Преимущества	Недостатки
1	Гонконгская модель (4-P Model)	Гонконг	Сильная диагностика через КАВ-фреймворк; эффективное развитие педагогических компетенций	Требует высокой поддержки администрации; сложно масштабировать
2	Модель PASCAGE	США	Четкая онлайн-структура; пять компонентов поддержки	Слабо связана с институциональной карьерой педагога
3	Модель непрерывного обучения	Австрия/Европа	Гибкие курсы, встроены в систему НПО	Нет единой карьерной лестницы

Оценка и рекомендации. Изучение актуальных моделей подготовки педагогов к работе с одаренными обучающимися в инклюзивной среде свидетельствует о том, что наиболее результативные стратегии профессионального роста базируются на: обеспечении пролонгированного сопровождения, внедрении практик коучинга и менторства, регулярном мониторинге и диагностике происходящих изменений, интеграции данных подходов в национальные системы образования. Преимуществами моделей являются:

- ориентация на практическую деятельность, дифференциацию, инклюзию обучающихся и сотрудничество;
- развитые диагностирующие инструменты (КАВ, 4-P, уровни компетенций);
- частое использование онлайн-форматов и игровых технологий.

В то же время представленные модели характеризуются типичными недостатками. К ним относятся отсутствие унифицированной траектории профессионально-карьерного продвижения педагога в сфере инклюзивного обучения одаренных детей (от начального до высшего уровня), а также недостаточная корреляция этих моделей с процедурами аттестации и должностными регламентами. В этой связи, для проектирования результативной системы профессионального развития учителей в инклюзивной среде, рекомендуется:

- синхронизировать существующие компетентностные рамки с основополагающими принципами профессионального обучения, предложенными WCGTC;
- сформировать многоуровневую структуру профессионального роста, объединяющую этапы вузовской подготовки (*pre-service*), повышения квалификации без отрыва от производства (*in-service*) и непрерывного образования (*lifelong learning*);
- внедрять цифровые платформы и геймифицированные форматы обучения для стимулирования мотивации и вовлеченности педагогических кадров.

Результаты изучения мировых практик и отсутствие унифицированных траекторий развития обуславливают потребность в создании адаптивной системы подготовки педагогов, призванной учитывать специфику национальных образовательных реформ и актуальных запросов современного Казахстана.

Сегодня в нашей стране вопросам образования одаренных детей уделяется приоритетное внимание, что обусловлено глубокими социально-экономическими трансформациями и глобальным трендом на интеллектуализацию труда. Согласно

государственным документам развития образования, поддержка одаренности рассматривается как ключевой вклад в научно-технологический суверенитет страны [8-14]. Однако реализация этого потенциала невозможна без педагога нового типа. Темы работы с одаренными учащимися в инклюзивной среде становятся все более актуальными, так как именно эти они формируют будущую инновационную элиту, определяющую вектор развития науки и культуры. В связи с этим, одной из важнейших задач отечественной системы образования является создание условий не только для выявления одаренности, но и для профессионального становления и развития педагогов, способных обеспечить их гармоничное развитие.

В Казахстанской системе образования, в последние годы, была реализована концепция, направленная на поддержку и развитие талантливых учащихся. Важным элементом этой концепции стало признание особой роли педагогов, работающих с одаренными детьми, и необходимость их профессиональной подготовки.

На основе анализа международного опыта и систематизации практических рекомендаций была разработана собственная модель профессионального роста педагогов для работы в инклюзивном образовании (см. таблица 2), включающая основные этапы подготовки и переподготовки в соответствии с векторами развития образовательной политики Республики Казахстан.

Востребованность данной модели продиктована необходимостью восполнения профессионального дефицита педагогов в области раннего выявления и системной поддержки одаренных детей в условиях инклюзивного класса. Новизна подхода заключается в интеграции нескольких ключевых подходов:

- методологический подход: гармоничное сочетание компетентностного, личностно-ориентированного и социально-средового подходов;
- психометрические показатели: применение пятифакторной модели личности (Big Five) для глубокой диагностики психологического профиля и индивидуальных черт педагога;
- практико-ориентированный этап: приоритетное использование современных методов исследования образовательной среды, таких как Action Research и Lesson Study.

Разработанная модель выступает системным ответом на актуальные запросы казахстанской школы. В ее центре находится концепция развития «рефлексивного практика» профессионала, владеющего инструментами дифференциации, опирающегося на принципы гуманизма и научно-доказательные подходы (Evidence-Based Practice).

Структурно модель представляет собой завершенную систему, объединяющую функционально связанные блоки: целевой, методологический, содержательный, оценочный и результативный.

Целевой компонент задает вектор всей системе и фокусируется на формировании готовности педагога к высокопродуктивной деятельности в инклюзивном пространстве, включая специфику психолого-педагогического сопровождения одаренных и талантливых обучающихся.

Методологический компонент базируется на совокупности взаимодополняющих подходов. Компетентностный подход смещает акцент образовательного процесса на овладение прикладными профессиональными компетенциями. Личностно-ориентированный подход позволяет кастомизировать обучение, опираясь на уникальные запросы педагога и проектирование его индивидуальной образовательной траектории. Социально-средовой подход фокусируется на интеграции ресурсов экспертных сообществ, развитии сетевого сотрудничества и активном обмене профессиональным опытом.

Содержательный компонент детализирует внутреннюю архитектуру процесса подготовки и объединяет ряд взаимозависимых векторов. Мотивационно-когнитивный блок сфокусирован на стимулировании внутренней профессиональной мотивации и

качественном расширении познавательного потенциала учителя. Диагностический блок служит инструментом для прецизионного выявления и систематизации имеющихся профессиональных дефицитов. Практический блок находит свое воплощение в активном освоении прикладных методов работы, проведении профессиональных исследований и глубоком анализе педагогических кейсов.

Оценочный компонент базируется на градации уровней профессионального роста педагогов, для каждого из которых установлены конкретные критерии и диагностический инструментарий. Например, квалификационный уровень «педагог-модератор» предусматривает использование таких оценочных методов, как тестирование и разбор базовых педагогических кейсов, что обеспечивает объективность проверки степени сформированности фундаментальных компетенций.

Результативный компонент формулирует прогнозируемый эффект от внедрения модели, центральным звеном которого является становление педагога как «рефлексивного практика». Итогом обучения становится специалист, профессионально готовый к сопровождению одаренных и талантливых детей в рамках инклюзивной парадигмы. Данный педагог свободно оперирует инструментарием Action research и опирается на принципы Evidence-Based Practice, что позволяет ему эффективно диагностировать одаренность в гетерогенной образовательной среде. Кроме того, он способен выстраивать индивидуальные образовательные траектории (используя стратегии ускорения и обогащения), а также активно масштабировать собственный опыт через научные публикации, публичные выступления и наставническую деятельность.

Стратегическая задача данной модели заключается в формировании и совершенствовании интегративной профессиональной компетенции педагога, которая служит фундаментом для продуктивной идентификации, сопровождения и развития потенциала талантливых и одаренных детей в рамках инклюзивной образовательной среды.

Таблица 2 – Модель профессионального роста педагогов для работы в инклюзивном образовании

Целевой компонент:	Методологический компонент						Содержательный компонент												
	Подходы						Этапы												
Подготовка педагогов для работы в инклюзивном образовании Стратегическая задача: формирование и развитие интегративной профессиональной компетенции педагога, обеспечивающих эффективное выявление, сопровождение и развитие талантливых и одаренных обучающихся в инклюзивной образовательной среде. Целевая аудитория: учителя-предметники, педагоги-психологи, методисты, тьюторы, педагоги дополнительного образования, руководители методических объединений школ, методисты	Компетентностный подход (Ориентация на формирование практических компетенций)		Личностно-ориентированный подход (Учет индивидуальных особенностей и траекторий развития педагога)		Социально-средовой (Использование ресурсов профессиональных сообществ)		Мотивационно-когнитивный (Развитие мотивации и когнитивных способностей педагога)	Диагностический (Системное выявление профессиональных дефицитов)	Практический (Обучение через решение педагогических кейсов и исследований)										
	Критерии						Критерии												
	Сотрудничества (Умение работать в команде, выстраивать партнерские отношения с коллегами, родителями, специалистами)	Дифференциации (Способность адаптировать содержание, методы и формы обучения под индивидуальные особенности одаренных учащихся)	Гуманизма (Признание ценности каждого ребенка, создание безопасной и поддерживающей образовательной среды)	Рефлексивности (Анализ практики, самокоррекция)	Исследовательской активности (Проверка гипотез, использование данных)	Инклюзивности (Развитие без изоляции, ресурс для класса)	Открытости к инновациям (Освоение нового, отказ от шаблонов)	- эмоциональная устойчивость; - саморазвитие; - гибкость и креативность - эмпатия - рефлексивность	- знание норм и прав; - умение идентифицировать одаренность и знание ее видов; - знание психолого-педагогических особенностей ОД; - умение проектировать и организовать образовательный процесс и управление его качеством; - знание особенностей развития личности ОД; - навыки исследовательской деятельности для улучшения практики развития одаренности; - навыки сетевого взаимодействия	- решение педагогических кейсов.									
							Уровни готовности												
							-открытость -сознательность -экстраверсия доброжелательность -нейротизм	- «Педагог» - «Педагог-модератор» - «Педагог-эксперт» - «Педагог-исследователь» - «Педагог-мастер»	- знает основы; - применяет алгоритмы; - адаптирует методы; - исследует практику; - создает и транслирует.										
ПЕДАГОГИЧЕСКИЕ УСЛОВИЯ ПРОФЕССИОНАЛЬНОГО РОСТА ПЕДАГОГОВ ДЛЯ РАБОТЫ В ИНКЛЮЗИВНОМ ОБРАЗОВАНИИ																			
Программа спецкурса бакалавриат «Педагогические технологии развития одаренных и талантливых школьников» (4 кредита)		Курсы повышения квалификации 1 («Педагогические технологии развития одаренных и талантливых школьников» (80 ч.)		Курсы повышения квалификации 2 «Инновационные подходы в современной педагогической практике работы с одаренными и талантливыми школьниками (80 ч.)			Лаборатория педагогических инноваций, включающая научно-образовательные комплексы по направлениям	Школьное профессиональное сообщество											
КЛЮЧЕВЫЕ МЕТОДЫ ОБУЧЕНИЯ				1. Решение педагогических кейсов 2. Action Research (исследование в действии) 3. Пиринг-ревью (взаимооценивание) 4. Портфолио доказательств 5. Публичная защита проекта 6. Метод «Lesson Study» 7. Супервизия и интервизия															
ОЦЕНОЧНЫЙ КОМПОНЕНТ				<table><tr><td>Уровень</td><td>Основные методы оценки</td></tr><tr><td>Педагог, модератор</td><td>Тестирование, решение базовых кейсов</td></tr><tr><td>Эксперт</td><td>Анализ планов уроков, разработанных заданий, видеонаблюдение/ видеозабор урока</td></tr><tr><td>Исследователь</td><td>Защита проекта Action Research, анализ портфолио, описание проведенного исследования</td></tr><tr><td>Мастер</td><td>Экспертная оценка выступлений, публикаций, программ семинаров, отзывы коллег-менты, анализ руководства исследовательскими проектами других педагогов</td></tr></table>						Уровень	Основные методы оценки	Педагог, модератор	Тестирование, решение базовых кейсов	Эксперт	Анализ планов уроков, разработанных заданий, видеонаблюдение/ видеозабор урока	Исследователь	Защита проекта Action Research, анализ портфолио, описание проведенного исследования	Мастер	Экспертная оценка выступлений, публикаций, программ семинаров, отзывы коллег-менты, анализ руководства исследовательскими проектами других педагогов
Уровень	Основные методы оценки																		
Педагог, модератор	Тестирование, решение базовых кейсов																		
Эксперт	Анализ планов уроков, разработанных заданий, видеонаблюдение/ видеозабор урока																		
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РЕЗУЛЬТАТИВНЫЙ КОМПОНЕНТ				ПЕДАГОГ, ГОТОВЫЙ РАБОТАТЬ С ОДАРЕННЫМИ И ТАЛАНТЛИВЫМИ ОБУЧАЮЩИМИСЯ В ИНКЛЮЗИВНОМ ОБРАЗОВАНИИ Рефлексивный практик, владеющий Action research и Evidence-Based Practice, способный выявлять одаренность в гетерогенной среде, проектировать индивидуальные траектории (ускорение, обогащение), транслировать опыт через публикации и выступления, осуществлять наставничество															
ПОСМКУРСОВОЕ СОПРОВОЖДЕНИЕ				1. Включение в профессиональное сообщество выпускников на онлайн-платформе для продолжения обмена опытом и взаимопомощи. 2. Консультационная поддержка тьюторов при доработке исследовательских проектов для участия в конкурсах педагогического мастерства, научно-практических конференциях, подаче заявок на гранты. 3. Информационная рассылка об актуальных конкурсах, грантах, конференциях, вебинарах и новых публикациях в сфере педагогики одаренности. 4. Возможность прохождения повторной диагностики через 6-12 месяцев для отслеживания профессионального роста и корректировки индивидуального плана развития.															

Целевая аудитория охватывает широкий спектр специалистов системы образования: учителей-предметников, педагогов-психологов, методистов, тьюторов, специалистов дополнительного образования, а также руководителей школьных методических объединений.

Реализация предложенной модели призвана качественно повысить уровень образовательного процесса и обеспечить динамичный профессиональный рост педагога. Это достигается за счет фундаментальной трансформации его профессиональной роли: перехода от позиции транслятора контента к статусу исследователя и наставника, способного эффективно функционировать в условиях инклюзивной образовательной среды.

Примечание. Исследование проведено в рамках финансирования Комитета науки Министерства науки и высшего образования Республики Казахстан (ИРН BR28712263 «Создание комплексной научно-инновационной системы подготовки педагогических кадров по развитию одаренных детей Казахстана»).

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The Use of Authentic Video Materials to Teach Foreign Languages to Primary School Students

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Abstract.

Integrating authentic video content in primary foreign-language instruction is widely advocated for its motivational and real-world benefits. “Authentic” materials are defined as content created for native speakers (Morrow, 1977). Graded authenticity refers to adapting such real materials (through pre-teaching, simplified tasks, etc.) so they are comprehensible to young learners. Proponents argue authentic videos engage children and expose them to natural language and culture. Critics warn of excessive complexity, cultural references, and cognitive load. We review both perspectives and evidence. Studies indicate that, with appropriate scaffolding, authentic video can boost young learners’ listening, speaking, vocabulary and motivation. We reconcile opposing views by emphasizing graded authenticity: careful selection of age-appropriate videos (often animated) and supportive pre-/while-listening activities. Finally, we discuss practical guidelines and limitations (e.g. need for teacher preparation, potential overload) to ensure authentic videos serve as effective language input for children.

Keywords: authentic materials; graded authenticity; multilingual learners; young learners; authentic videos.

1. Introduction

Authentic materials are defined as texts or media not created for language instruction but for native audiences. In language education, using such materials (including videos) is said to immerse learners in “real” language and culture. For example, Öztürk et al. (2022) describe using a BBC children’s cartoon “Bing” with Turkish 3rd-4th graders and found significant improvements in listening and speaking after 14 weeks of authentic video exposure. However, authentic materials were originally intended for fluent speakers, so scholars debate their use with young or low-level learners. This review examines graded authenticity – the idea of adapting real videos to learner level – and surveys arguments from both proponents and opponents of authentic video in primary classrooms. We then present empirical findings and suggest ways to balance authenticity with learner needs.

2. Defining Authentic Materials and Graded Authenticity

“In authentic materials, learners encounter real language as used by native speakers” (e.g. in TV, cartoons, songs). Wilkins (1976) notes authentic texts target native audiences, not learners. Morrow (1977) similarly defined them as “real language, produced by a real speaker or writer for a real audience”. In practice for young learners, many “authentic” videos may be children’s cartoons or educational shows not made as lessons, so still genuine but often simpler than adult content.

Graded authenticity involves selecting or modifying authentic videos so learners can process them. This might mean using cartoons (with clear visuals and slower speech), adding context or subtitles, or pre-teaching key vocabulary. For example, Donley (2000) found that many authentic films and TV shows speak too fast and idiomatically for learners; thus instructors should either choose videos with simpler input or scaffold them with pre-viewing questions or quizzes. In effect, graded authenticity bridges real content and comprehensibility: one could show a familiar cartoon episode (real content) but pause to explain words or rerun scenes (scaffolding). The goal is “optimal comprehensible input” – material that is realistic and interesting yet understandable. Our review considers authentic video use under this graded framework.

Benefits of Authentic Video for Young Learners

Real-world language and culture: Authentic videos expose children to target-language culture and natural usage. They often include gestures, intonation and visual context that aid understanding. Research suggests learners build intercultural awareness and pragmatics from genuine media. For instance, recent reviews highlight that authentic materials “allow students to understand the cultural context along with usage of English in real-life conversations”. Such exposure can boost confidence: authentic stories or cartoons often align with children’s interests and can make learning enjoyable.

Motivation and engagement: Children typically find cartoons and videos engaging. Several authors note that authentic cartoons or programs capture young learners’ attention more than contrived texts. donlets (2018) emphasizes that video’s combination of audio and vivid visuals is “interesting and salient for young learners”. One study found 4th graders enjoyed repetitive viewings of cartoon episodes and benefited from visual cues. In our sources, Öztürk et al. (2022) reported that Turkish primary students reacted positively to watching Bing cartoons, and “developed the habit of using authentic videos as a language tool”.

Empirical studies show authentic videos can improve children’s language skills when well selected. Öztürk et al. (2022) found that 3rd-grade EFL students taught with the Bing cartoon outperformed controls in listening. Similarly, McCallum (2020) documented that children who regularly watched English videos (with appropriate tasks) significantly expanded their vocabulary and pragmatic knowledge. Another quasi-experiment (Polat & Erişti, 2019) with A1–B1 level learners found that authentic videos produced “highly effective results” in listening skills and even lowered listening anxiety. Though this study involved older students, it suggests even novices can gain from real input if it’s accessible.

Videos combine visual clues and sound, which help children infer meaning. Young learners rely heavily on pictures and context. Nightingale (2014) notes that even without subtitles, “colorful and attractive imagery” in cartoons aids understanding. Rodgers (2018) also highlights video’s visual support: scenes with clear images make comprehension easier for children. For example, a dubbed cartoon shows characters performing actions in sync with speech, so kids can guess new words from actions or on-screen text. These multimodal cues can compensate for some unknown vocabulary.

Critics’ Concerns and Counterarguments

Despite these benefits, several scholars caution about authentic video for young beginners. The main criticisms center on difficulty of content, cultural or inappropriate material, and cognitive overload. We outline key objections and note how graded authenticity can address them. Real speech can overwhelm new learners. Donley (2000) observes that movies and TV often use “overly fast, difficult, idiomatic” language that many students cannot follow. Similarly, Gilmore (2007) warns that the unmodified complexity of authentic input may cause cognitive overload relative to learners’ level. In effect, if children cannot decode the language, videos lose educational value (and may induce anxiety).

Authentic videos frequently contain culturally-specific content. Children unfamiliar with foreign customs or idioms may find such content confusing. Martinez (2002, cited in Radić-Bojanić 2020) pointed out disadvantages of authentic materials: they “may be overly culturally based, so that they are incomprehensible for a learner outside the language community”. For example, a UK news clip about local events or school systems may puzzle students from another country, distracting from language goals.

Some educators worry that videos can turn children passive or simply entertain without learning. As noted in British Council guidelines, children accustomed to passive TV watching may “switch off” if not engaged by activities. Critics argue that if class time is spent watching TV, parents might complain that “kids just played on a screen instead of learning.” In primary settings, maintaining interaction (e.g. prediction, discussion) is needed to avoid this pitfall.

Authentic media may include violence, adult themes or unfamiliar settings. Teachers must screen for age-appropriateness. Research on adult classrooms (Aisha A., 2017) shows instructors often avoid controversial material for fear of distracting or upsetting learners. Analogously, a primary teacher would avoid a video with inappropriate scenes or slang. Although this concern is practical rather than theoretical, it underscores the need to carefully curate authentic videos for children. Recent reviews echo the need for caution. Duncan and Paradis (2019) found that after a certain threshold (≈ 10 hours/week) of general TV viewing, children’s academic performance can decrease, depending on content. They warn against “indiscriminate” screen time. Danan (2004) similarly cautions that “massive exposure to authentic audiovisual material which has not been carefully... made accessible to non-native viewers can be a very inefficient pedagogical approach”. These findings do not reject authentic video outright but stress that how videos are used (and the quality of content) is crucial.

Another concern is the extra work required. Authentic videos often need teacher effort to prepare worksheets, subtitles, or discussion tasks. Some scholars note that adapting such material is time-consuming. In contexts with rigid curricula, teachers may fear straying from textbooks.

Most critics do not say “never use authentic videos”; rather they highlight potential pitfalls if used poorly. In fact, many accept that with support, authentic videos can benefit young learners. As Radić-Bojanić (2020) concludes, teachers often assume authentic materials “will confuse pupils”, but with creativity “it is possible and just as effective” to use them even at primary levels. The key is grading and scaffolding to meet learner needs.

3. Possibilities and Limitations

When done well, authentic video can accomplish things classroom materials cannot. It provides natural pronunciation, idioms, and nonverbal cues in context. Children learn not just words but how they are used in stories and interactions. Authentic videos can also boost confidence: as Radić-Bojanić (2020) notes, students often feel a sense of achievement working with real language content, which may improve attitude towards English. Additionally, teachers can capitalize on children’s media use: since kids already watch cartoons in English at home (YouTube, TV), classroom videos can connect with that experience in a purposeful way. Pedagogically, authentic video supports multiple skills simultaneously (listening, speaking, cultural knowledge) and can be integrated with literacy (through storybooks or comics related to the video).

Nonetheless, there are constraints. First, comprehension ceiling: even scaffolded, very young learners have limited processing capacity. If a video has too many unfamiliar words or abstract concepts, it may still lead to frustration. Some language features (fast contractions, humor, cultural jokes) may be lost on children. Susanto (2021) and Gilmore (2007) both emphasize that without careful matching of language level, students may be overwhelmed. Teachers must gauge their class’s readiness and not assume any real content is automatically “easy” simply because it’s on screen.

Second, resource intensity: Preparing lessons around authentic video takes teacher effort. Finding suitable clips, creating or editing materials (e.g. adding subtitles or dubbing), and designing scaffolding activities require time. In large classes or under-resourced schools, this may not be practical for every lesson. Some authors note that adapting authentic media can be “time consuming”, and without teacher training even well-chosen videos might not be used effectively. Third, content appropriateness: As mentioned, authentic media may contain material unsuitable for children. This not only includes violent or adult themes, but also social norms (e.g. classroom scenes that follow foreign curricula) that children won’t grasp. Any controversy (advertisements, stereotypes) must be edited out. While this is not a theoretical limit, it means teachers must pre-screen meticulously, which can be challenging.

Fourth, curricular fit: Some critics argue that if the school curriculum is rigidly grammar-focused, authentic videos may seem tangential. Language policies differ worldwide: in some primary programs, emphasis is on very basic phrases and songs, with little space for extended listening comprehension. Embedding authentic video requires curricular flexibility and teacher initiative.

Lastly, equity issues: Access to technology and the internet varies. In well-equipped classrooms or homes, teachers can easily stream or download videos. In others, lack of devices or internet could hamper using authentic video, relegating it to a “luxury” rather than core resource.

4. Conclusion

Evidence shows that authentic video materials can be a powerful tool for foreign-language instruction in primary schools – provided they are used thoughtfully. By applying the principle of graded authenticity (selecting suitable content, pre-teaching support, interactive tasks), teachers can harness the motivational and contextual benefits of real media without overwhelming young learners. Empirical studies (e.g. Öztürk et al. 2022; Polat & Erişti 2019) confirm positive effects on listening and vocabulary when conditions are right. Critics’ concerns about complexity and overload are valid but are largely addressed by scaffolding and moderation.

In practice, educators should aim for a balanced approach. Short animated clips or simple authentic songs, supplemented by pre-viewing vocabulary and follow-up activities, can enrich the classroom. Over time, this exposure builds learners’ ear for the language and global awareness. However, teachers must remain vigilant about content and keep viewing times reasonable. When integrated thoughtfully, authentic video broadens children’s understanding of the world and provides a lively complement to textbooks.

Much research on authentic video involves older learners; more studies focusing explicitly on young children are needed. Specific questions remain about the optimal degree of “grading” and how to train teachers in this practice. Future empirical work could investigate long-term outcomes (e.g. sustained motivation, cross-cultural skills) of early authentic video use. Additionally, as technology evolves (interactive videos, VR, and AI), exploring new ways to make authentic content accessible to children is an open avenue.

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THE IMPACT OF VIRTUAL REALITY ON EFL LEARNERS' SPEAKING ANXIETY AND CONFIDENCE

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Abstract. Speaking anxiety remains one of the most persistent barriers to oral proficiency development in English as a Foreign Language (EFL) contexts. Although communicative language teaching and task-based approaches have expanded opportunities for interaction, many traditional classrooms still struggle to provide the psychologically safe and low-pressure speaking environments that highly anxious learners may require. Virtual Reality (VR) technologies offer a potentially valuable response by creating immersive speaking environments in which the perceived social risks of performance may be reduced.

This article examines the potential of VR to reduce EFL speaking anxiety and strengthen learner confidence through a synthesis of three theoretical perspectives: Krashen's (1982) Affective Filter Hypothesis, Bandura's (1997) self-efficacy theory, and Csikszentmihalyi's (1990) flow theory. Drawing on recent empirical studies published between 2020 and 2025, the article argues that VR may influence anxiety indirectly through the development of communicative confidence and perceived fluency. A three-mechanism framework is proposed involving reduced evaluative pressure, self-efficacy development through repeated mastery experiences, and flow-oriented task engagement. Pedagogical implications are discussed with particular attention to communicative task design, graduated exposure, learner agency, and the principled integration of VR into EFL speaking instruction.

Keywords: *EFL speaking, foreign language anxiety, virtual reality, self-efficacy, affective filter hypothesis, confidence, immersive learning, communicative competence*

1. Introduction

Of all the affective challenges that EFL learners face, speaking anxiety is among the most significant barriers in EFL learning. Unlike reading anxiety or writing apprehension, foreign language speaking anxiety unfolds in public, in real time, and under conditions of social evaluation that render every communicative attempt a potential source of embarrassment. Since Horwitz, Horwitz, and Cope's (1986) landmark operationalization of foreign language classroom anxiety (FLCA), speaking has been consistently identified as its primary trigger and its most damaging site of expression. The three components of FLCA – communication apprehension, test anxiety, and fear of negative evaluation – converge in the speaking context with particular force, because oral performance is simultaneously public, unrepeatable, and immediately legible to others as evidence of linguistic inadequacy.

The consequences of speaking anxiety for language development are substantial and well-documented. Anxious learners avoid speaking opportunities, producing less output and engaging in fewer interactions that facilitate language acquisition. Further reduced practice leads to a decrease in fluency, which, in turn, increases anxiety, and the vicious cycle that results can persist for years of language learning, preventing learners with substantial receptive competence from being able to use it in productive oral communication. A recent systematic review of 99 empirical studies on technology and foreign language anxiety (Huang & Liu, 2025) showed that

speaking remains the most extensively studied and most anxiety-prone of the four language skills, while existing solutions show mixed and uneven effectiveness.

Speaking anxiety has a great impact on language development and the problem is well-known. Anxious learners are less likely to speak, so they produce less output and have fewer interactions that facilitate language acquisition. As practice is further reduced, fluency drops, and the anxiety that this engenders can linger for years of language learning, preventing learners with substantial receptive competence from being able to make use of it in productive oral communication. Speaking has been the most frequently studied and anxious language skill among the four language skills in the 99 empirical studies of technology and foreign language anxiety in a recent systematic review (Huang & Liu, 2025), and the effectiveness of current interventions is mixed and uneven.

Traditional EFL classrooms may face structural constraints in addressing speaking anxiety. Even with skilled teaching and communicative methodologies, many classrooms retain features such as large class sizes, peer observation, public error exposure, and time-limited performance tasks that can intensify learners' fear of negative evaluation, a central component of foreign language classroom anxiety (FLCA). These challenges do not reflect failures of pedagogy; rather, they are common institutional conditions that may limit opportunities for low-pressure speaking practice.

Virtual Reality (VR) technologies offer an alternative response. By creating fully immersive digital environments in which learners participate in simulated scenarios and interact with virtual characters, VR can structurally reduce some of the social evaluative components of speaking practice. Errors are witnessed only by virtual characters; failure carries no real-world social consequences; and the learner can repeat the same communicative scenario as many times as necessary without the memory of prior failure being accessible to real peers or teachers. Rather than replacing the conventional classroom, VR may complement it by changing some of the conditions under which speaking practice takes place.

The empirical evidence for the effectiveness of VR to reduce speaking anxiety is growing. The positive effects of VR-assisted language learning on motivation, confidence, engagement, and reductions in foreign language anxiety have been generally reported in the recent review of the literature by Hua and Wang (2023). In a controlled study, Kaplan-Rakowski and Gruber (2023) found that learners practicing speaking in high-immersion VR (HiVR) reported significantly lower FLCA than learners completing comparable speaking tasks before live audiences via Zoom. Despite the growing body of evidence, the theoretical mechanisms by which VR produces these affective benefits remain insufficiently explained. Most existing studies have explored what VR achieves; this article seeks to explain why and how.

The empirical evidence for VR's effectiveness in reducing speaking anxiety is growing. A recent review by Hua and Wang (2023) found that studies on VR-assisted language learning generally reported positive effects on motivation, confidence, engagement, and reduced foreign language anxiety. Kaplan-Rakowski and Gruber (2023) demonstrated, in a controlled study, that learners practicing speaking in high-immersion VR (HiVR) reported significantly lower FLCA than those practicing before real audiences via Zoom. Despite this empirical momentum, however, the theoretical mechanisms through which VR achieves these affective effects remain underspecified. Most existing research documents what VR achieves; this article aims to explain why and how.

Based on the Affective Filter Hypothesis (Krashen, 1982), self-efficacy theory (Bandura, 1997), and flow state psychology (Csikszentmihalyi, 1990), this article proposes a three-mechanism theoretical model to explain the effects of VR on EFL speaking anxiety and confidence. Section 2 outlines the methodology used for the conceptual review. Section 3 reviews relevant theoretical perspectives and connects them to specific affordances of VR. Section 4 analyzes the

three proposed mechanisms. Section 5 addresses pedagogical implications. Section 6 addresses limitations and future research directions. Section 7 concludes the article.

2. Methodology

This article presents a conceptual review and narrative synthesis of peer-reviewed studies on Virtual Reality (VR) in EFL speaking environments published between 2020 and 2025. The literature search was conducted through ERIC, Scopus, and Web of Science with combinations of the keywords *virtual reality*, *EFL speaking*, *foreign language anxiety*, *speaking self-efficacy*, and *immersive learning*. Sources were selected on the basis of three criteria: (1) direct relevance to foreign language speaking anxiety or communicative confidence; (2) empirical evidence or clear theoretical relevance; and (3) publication in a peer-reviewed journal or in the proceedings of an indexed conference. Studies that did not use EFL populations or only examined reading or listening were excluded.

The analysis is based on three well-established theoretical frameworks – Krashen’s (1982) affective filter hypothesis, Bandura’s (1997) self-efficacy theory and Csikszentmihalyi’s (1990) flow state psychology – to explain how VR may decrease EFL speaking anxiety and enhance learner confidence. The choice of these frameworks is based on the fact that each of them addresses a different dimension of the affective speaking process: acquisition conditions, learners’ beliefs about capability and optimal task engagement. This article does not provide original empirical data; its contribution lies in theoretical synthesis and pedagogical application.

3. Theoretical Framework and Literature Review

3.1 Speaking Anxiety and Self-Efficacy in EFL

Foreign language classroom anxiety was conceptualized by Horwitz, Horwitz, and Cope (1986) as a distinct and complex construct specific to the language learning experience, encompassing three interrelated components: communication apprehension – the fear or anxiety associated with real or anticipated communication; test anxiety – apprehension about academic evaluation of language performance; and fear of negative evaluation – concern about others’ judgments of one’s language ability. All three components are activated with particular intensity in EFL speaking contexts, where learners must produce language publicly, under time pressure, and in full awareness of the gap between their communicative intentions and their linguistic means.

The relationship between speaking anxiety and performance is often bidirectional. High FLCA suppresses speaking attempts, which limits practice and slows fluency development; lower fluency generates more failure experiences, which deepens anxiety. This cycle can be reinforced in classroom settings, where every speaking turn simultaneously functions as a language practice opportunity and a public assessment event.

Bandura’s (1997) theory of self-efficacy provides the positive counterpart to anxiety in understanding EFL speaking development. Self-efficacy – an individual’s belief in their capacity to perform a specific task – is not a generalized trait but a task and context-specific judgment. Learners with high speaking self-efficacy are more likely to attempt communicative challenges, persist through difficulty, recover from errors, and ultimately develop the fluency that sustained practice produces. Self-efficacy and anxiety are typically inversely related and causally linked: building self-efficacy reduces anxiety, and reducing anxiety may support further confidence-building experiences.

Bandura (1997) identifies four sources through which self-efficacy is built: mastery experiences (successful performance of the target task), vicarious experiences (observing comparable others succeed), social persuasion (encouragement from trusted others), and physiological states (bodily responses associated with task performance). As this article argues, VR

environments may support all four of these sources in ways less readily available in conventional classrooms. A recent validation study of an EFL Speaking Self-Efficacy Scale (Wang & Sun, 2024) showed that these sources are measurable and significantly associated with speaking self-efficacy in the EFL context.

3.2 Krashen's Affective Filter Hypothesis

According to Krashen's (1982) Affective Filter Hypothesis, affective variables such as anxiety, motivation, and self-confidence influence the amount of comprehensible input available for language acquisition. When anxiety is high, learners may be less receptive to input; when confidence is stronger, acquisition is more likely to occur. In speaking contexts, increased anxiety may also lead to reduced willingness to communicate and to limit the demonstration of existing competence in evaluative contexts.

The most theoretically significant empirical contribution to the application of Krashen's model to VR comes from Gu et al. (2025), conducted with 1,086 Chinese EFL learners. Using mediation analysis, Gu et al. found that VR exposure does not directly reduce foreign language anxiety; rather, VR first builds communicative confidence and perceived fluency, which then reduce anxiety. The direct path from VR to foreign language anxiety was not statistically significant. This article treats this finding as a crucial refinement of Krashen's framework: the Affective Filter is not lowered by removing the threat but by first building the learner's belief in their capacity to manage it. This mediation model is consistent with Bandura's (1997) self-efficacy theory and with the substantial body of research linking self-efficacy to FLCA.

3.3 Flow State Psychology

Csikszentmihalyi's (1990) concept of flow – the state of deep absorption in a challenging yet manageable task – represents the third theoretical pillar of the framework proposed in this article. Flow is characterized by reduced self-consciousness, altered time perception, intrinsic motivation, and a sense of effective engagement. For the present argument, the key relevance of flow is that intense task absorption may reduce the self-focused attention that often sustains speaking anxiety. Learners who are fully engaged in communicative tasks are less likely to monitor their performance excessively for signs of inadequacy.

The conditions for flow as specified by Csikszentmihalyi (1990) – a balance between challenge and skill – are directly relevant to VR speaking task design. Tasks that are too easy may produce boredom, while tasks that are too difficult may increase anxiety. The optimal challenge zone is where speaking development and anxiety reduction may coincide. VR environments, more readily than many conventional classrooms, allow this calibration to be individualized: task difficulty, scenario complexity, interlocutor behavior, and audience size can be adjusted to better match learners' skill levels.

4. Discussion

4.1 How VR Reduces Speaking Anxiety: Three Structural Mechanisms

The three theoretical frameworks reviewed above converge on a unified account of VR's anxiety-reducing effects. VR may reduce speaking anxiety not only because it is engaging or novel, but because it may modify three conditions that trigger and sustain foreign language classroom anxiety (FLCA) in conventional instruction.

First, VR may significantly reduce the social visibility of error. In many EFL classrooms, speaking errors occur in the presence of peers and teachers, which can activate the fear of negative evaluation at the core of FLCA. In VR, the social audience of performance is virtual, meaning that errors may be less publicly visible to real social others. For many learners, this may lower the perceived social stakes of communicative performance.

Second, VR enables lower-pressure repetition. FLCA is sustained by avoidance: learners who avoid speaking preserve their anxiety by preventing the corrective experiences that would naturally reduce it. VR substantially reduces the perceived social cost of repetition, allowing learners to practice the same scenario multiple times without the accumulating social memory of failure that often characterizes repeated public speaking in conventional settings. Park et al. (2025) found that repeated use of a customizable VR public speaking application significantly reduced foreign language anxiety, with some learners benefiting from gradually increasing audience challenge levels.

Third, VR builds confidence through mastery experience. Each successful VR communicative interaction may constitute a mastery experience in Bandura's (1997) sense: direct, personal evidence of communicative capability. These mastery experiences accumulate into self-efficacy, which reduces anxiety through the mediating pathway identified by Gu et al. (2025): VR speaking practice → communicative confidence → perceived fluency → reduced anxiety. Conventional instruction may struggle to replicate this sequence with comparable frequency because the social costs of performance failure in real classroom settings can make learners rationally reluctant to generate the repeated speaking attempts from which mastery experiences could be derived.

4.2 How VR Builds Speaking Confidence

VR may support the development of speaking confidence through several of Bandura's (1997) proposed sources of self-efficacy. In particular, VR environments may facilitate mastery experiences, vicarious experiences, and more positive interpretations of physiological states.

First, mastery experiences may occur when learners successfully complete communicative tasks in VR, such as navigating a virtual job interview or responding appropriately in a simulated conversation. Even when the interlocutor is virtual, successful task completion may still be experienced as evidence of communicative capability. Repeated success of this kind may strengthen speaking self-efficacy.

Second, vicarious experiences may be available in multi-user VR environments, where learners can observe more proficient peers completing similar tasks. Observing comparable others succeed can increase learners' beliefs that they themselves are capable of similar performance.

Third, VR may positively affect physiological states by offering lower-pressure speaking environments. Reduced concern about immediate peer judgment may help learners interpret arousal as engagement rather than anxiety, thereby supporting confidence during speaking tasks.

More broadly, the customizable and immersive nature of VR may provide learners with repeated opportunities to practice speaking in conditions that gradually build confidence over time.

4.3 The Flow Mechanism and Language Development

The flow state generated by well-designed VR speaking tasks may contribute to language development through a mechanism distinct from anxiety reduction. When a learner becomes deeply absorbed in a VR communicative task – attention fully occupied by the scenario, the interlocutor, and the communicative goal – excessive self-monitoring may temporarily decrease. As a result, learners may produce language more naturally and with less conscious interference from the evaluative processes that often disrupt anxious speakers.

This has direct implications for fluency development. Fluency is not merely a consequence of reduced anxiety; it is a skill that may be facilitated by repeated practice in lower-monitoring conditions. Speaking continuously, making real-time lexical and syntactic choices, and maintaining conversational coherence without the option of revision all require extensive practice in conditions where self-consciousness does not interrupt the flow of production. The immersive

quality of VR may help create such conditions by sustaining task engagement and directing attention toward communication rather than self-evaluation.

5. Pedagogical Implications for EFL Teachers

The three-mechanism framework proposed in this article has several implications for how EFL teachers design and facilitate VR speaking activities. First, VR speaking tasks should be designed around communicative goals, rather than exclusively linguistic performance targets. The anxiety-reducing and self-efficacy-building mechanisms identified above are more likely to emerge when learners use English to accomplish meaningful tasks rather than simply produce linguistically accurate but communicatively limited responses. Teachers should assess VR speaking tasks by the quality of communicative interaction they generate, while also attending to language accuracy where appropriate.

Second, graduated exposure should guide task sequencing. The first VR speaking session should be explicitly non-evaluative and devoted to environmental familiarization – learners exploring the virtual space, interacting with simple prompts, and building comfort with the technology – before communicative demands are introduced. Speaking demands should then be introduced progressively: single-turn responses before extended monologue; one-on-one virtual interaction before group scenarios; familiar social contexts before high-stakes professional situations.

Third, post-task debriefing can help consolidate the gains of VR speaking practice. Reflection may begin with learners' affective responses – how they felt and what they found manageable – before moving to communicative effectiveness and, finally, selected aspects of linguistic form. Such sequencing may help preserve confidence while ensuring that feedback supports continued language development.

Finally, allowing learners some degree of control over avatar appearance or scenario settings may further increase comfort, engagement, and willingness to participate.

6. Limitations and Future Research

This article's conclusions are subject to several limitations that future research should address. First, the theoretical framework proposed here is derived largely from studies conducted with East Asian EFL learners. Its applicability to other contexts, including Central Asian settings such as Kazakhstan, remains underexplored. Cultural and educational differences may influence how speaking anxiety is experienced and reduced.

Second, much of the existing VR-anxiety literature, like the broader literature on technology and foreign language anxiety, relies on self-report measures. A recent systematic review by Huang and Liu (2025) recommends combining self-report data with physiological indicators and other multimodal measures.

Third, the studies on which this article draws are predominantly short-term, with intervention periods ranging from four to twelve weeks. The longitudinal sustainability of anxiety reduction and self-efficacy gains has not been established over extended periods. More longitudinal research is needed to determine whether such benefits transfer to conventional speaking contexts and persist over time.

Fourth, VR may also generate technology-related challenges, particularly among learners with limited digital experience or low familiarity with immersive tools. Future studies should examine how orientation sessions, technical support, and gradual familiarization can reduce these barriers.

Future research should prioritize three directions: (1) longitudinal studies examining anxiety, self-efficacy, willingness to communicate, and oral proficiency over extended periods; (2)

cross-cultural studies in underrepresented EFL contexts; and (3) investigations into the integration of generative AI with VR interlocutors capable of adaptive speaking interaction.

7. Conclusion

Speaking anxiety should not be viewed merely as an individual psychological weakness of EFL learners. It can also be understood as a response to structural conditions frequently present in language classrooms, including the public visibility of performance, the memory of unsuccessful speaking experiences, and the simultaneous demands of linguistic accuracy and communicative effectiveness under real-time evaluation. Krashen's (1982) Affective Filter Hypothesis helps explain the acquisition-related consequences of anxiety; Bandura's (1997) self-efficacy theory clarifies the confidence-building processes that may reduce it; and Csikszentmihalyi's (1990) flow theory identifies an optimal affective state for speaking development. Together, these perspectives provide a theoretical basis for understanding why conventional instruction may not always fully address speaking anxiety and why VR may offer a valuable complement.

An important empirical finding in recent research is that VR may reduce anxiety indirectly through the mediating roles of communicative confidence and perceived fluency rather than through direct exposure alone (Gu et al., 2025). This suggests that VR may function less as an anxiety-removal tool than as an anxiety-transformation environment, in which speaking practice becomes more manageable, repeatable, and confidence-building. The affective filter may be lowered not because virtual scenarios are inherently easier than real ones, but because learners may enter real communicative situations having already gained practice-based confidence through repeated rehearsal.

This article has proposed a three-mechanism framework consisting of affective filter lowering through reduced evaluative pressure, self-efficacy development through mastery experience and avatar-mediated participation, and fluency support through flow-oriented task engagement. Taken together, these mechanisms synthesize relevant theoretical and empirical literature into a coherent explanation of how VR may influence EFL speaking anxiety and learner confidence. The pedagogical implications discussed in this article – graduated exposure, communicative task design, post-task reflection, and avatar agency– offer practical guidance for teachers seeking to implement VR in principled and evidence-informed ways.

VR does not make speaking effortless. However, it may make speaking practice more accessible for learners who are highly anxious, self-conscious, or reluctant to take the communicative risks required for language development. By offering a space in which mistakes carry fewer social consequences, VR may create conditions that support the gradual growth of speaking competence. Future longitudinal and cross-cultural research is needed to determine the durability of these effects and the conditions under which VR-supported confidence translates into sustained real-world communicative competence.

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ARTIFICIAL INTELLIGENCE AND STUDENTS' COGNITIVE DEVELOPMENT: A DIDACTIC ANALYSIS

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Abstract

The rapid integration of artificial intelligence into higher education is transforming learning processes and raising critical questions about its impact on students' cognitive development. This study aims to examine the relationship between AI usage and key cognitive indicators, including critical thinking, metacognitive awareness, and information literacy, from a didactic perspective. The research is based on a quantitative design with elements of correlational analysis. Empirical data were collected through a structured survey conducted among 812 university students in Almaty from January to March 2026, representing both national and private higher education institutions. The findings reveal that AI usage itself does not negatively affect cognitive development; however, excessive dependency on AI is associated with a decline in critical thinking and metacognitive regulation. Cross-tabulation and correlation analyses demonstrate that students with low AI dependency exhibit higher levels of critical thinking and self-regulation, while those with high dependency show significantly weaker cognitive performance. At the same time, metacognitive awareness and information literacy act as protective factors, reducing reliance on AI and supporting independent cognitive functioning. The study highlights the importance of balanced and reflective AI integration in education. From a didactic perspective, the results emphasize the need for pedagogical strategies that foster critical engagement, self-regulation, and conscious use of AI tools. The research contributes to the theoretical understanding of AI as a cognitive mediator and provides practical implications for designing effective AI-enhanced learning environments.

Keywords: Artificial intelligence; cognitive development; critical thinking; metacognitive awareness; information literacy; AI dependency; higher education; didactic analysis; digital learning; students

Introduction

Relevance of the study. The rapid integration of artificial intelligence (AI) technologies into educational environments is fundamentally transforming the processes of teaching and learning. AI-driven tools such as adaptive learning systems, intelligent tutoring systems, and generative models are increasingly shaping how students access, process, and construct knowledge. In this context, the issue of students' cognitive development becomes particularly significant, as AI not only enhances learning efficiency but also potentially restructures cognitive processes, including attention, memory, critical thinking, and problem-solving. Despite the growing body of research on AI in education, there remains a notable gap in understanding the didactic implications of AI-mediated learning for students' cognitive development. Existing studies predominantly focus on technological effectiveness or learning outcomes, while paying insufficient attention to the

qualitative transformation of cognitive functions under the influence of AI (Jose, 2025; Patrick et al., 2025). This raises important theoretical and practical questions regarding the balance between cognitive support and cognitive dependency, as well as the preservation of higher-order thinking skills in AI-rich learning environments. Furthermore, the increasing reliance on AI tools among students introduces new pedagogical challenges related to digital dependency, metacognitive regulation, and the development of autonomous learning strategies (Tian et al., 2025). The need to reconsider traditional didactic frameworks in light of AI integration underscores the urgency of this research. A systematic didactic analysis allows for the identification of both the opportunities and risks associated with AI use, contributing to the development of evidence-based educational practices that foster sustainable cognitive development (Miao & Holmes, 2023).

Research problem. The widespread adoption of artificial intelligence in higher education has introduced a paradox: while AI technologies enhance access to information and facilitate learning, they may simultaneously alter the nature of students' cognitive engagement. The central research problem lies in the insufficiently understood impact of AI-mediated learning on the development of core cognitive functions, particularly higher-order thinking skills such as critical analysis, synthesis, and independent problem-solving. Traditional didactic models are primarily designed for human-centered instruction and do not fully account for AI's active role as a cognitive mediator. As a result, there is a lack of clear pedagogical frameworks that define how AI should be integrated into learning processes without diminishing students' cognitive autonomy. Moreover, the increasing reliance on AI-generated outputs raises concerns about the potential decline in deep learning, reflective thinking, and metacognitive awareness among students (Holmes et al., 2019; Patrick et al., 2025). Thus, the problem can be formulated as a contradiction between the expanding use of artificial intelligence in education and the absence of a comprehensive didactic understanding of its influence on students' cognitive development. Addressing this contradiction requires a systematic analysis of AI not only as a technological tool but as a factor that reshapes cognitive and educational dynamics.

Research gap. Although the field of AI in education has grown rapidly, several critical gaps remain. First, most existing studies focus on the effectiveness of AI in improving academic performance, personalization, and engagement, while relatively few examine its deeper cognitive implications. In particular, there is a lack of research that explores how continuous interaction with AI systems affects the structure and quality of students' cognitive processes. Second, current literature tends to be fragmented, often addressing either technological aspects or psychological outcomes in isolation. There is a clear absence of integrative studies that combine cognitive science and didactics to analyze AI's role within pedagogical systems. This limits the ability to develop coherent theoretical models explaining how AI influences learning at both the cognitive and instructional levels. Third, insufficient attention has been given to the risks associated with cognitive offloading and digital dependency. While AI can support learning efficiency, it may also reduce the necessity for effortful thinking, thereby impacting the development of critical and creative capacities (Tian et al., 2025). Empirical evidence on this dual effect remains limited and inconclusive. There is a lack of didactic frameworks that guide educators in balancing the benefits of AI with the need to preserve and develop students' cognitive independence. Existing pedagogical approaches have not yet been fully adapted to the realities of AI-enhanced learning environments.

The aim of this study is to identify and theoretically and empirically substantiate the impact of artificial intelligence on students' cognitive development, and to conduct a didactic analysis of the integration of AI technologies into the higher education learning process.

The study focuses on the educational process of university students in the context of digitalization and the implementation of artificial intelligence technologies. *The subject of the study* is the influence of artificial intelligence tools on students' cognitive processes specifically

critical thinking, memory, attention, analytical abilities, and independent problem-solving within contemporary didactic practices.

Hypothesis 1 (H1): There is a statistically significant relationship between the level of artificial intelligence usage and students' cognitive development: moderate and reflective use of AI enhances cognitive skills, whereas excessive dependence on AI negatively affects critical thinking.

Hypothesis 2 (H2): Students with higher levels of metacognitive awareness and information literacy demonstrate lower dependence on AI and higher levels of independent cognitive functioning.

Scientific significance of the study. The scientific significance of this study lies in advancing theoretical understanding of artificial intelligence as a novel didactic factor influencing students' cognitive development. The research contributes to the integration of cognitive and didactic approaches by conceptualizing AI not merely as a technological tool, but as an active element that reshapes the structure of cognitive activity in learning environments. Furthermore, the study expands existing knowledge on the phenomenon of cognitive offloading in digitally mediated education and clarifies the mechanisms underlying the formation of AI dependency among students. The practical significance of the study lies in its potential application to the design of educational strategies aimed at the effective and responsible integration of artificial intelligence into the learning process.

Literature Review

Artificial intelligence in education has evolved from a narrowly technical field into a complex pedagogical phenomenon that influences teaching, learning, assessment, and students' cognitive development. Early systematic reviews show that AI applications in higher education have mainly focused on profiling and prediction, assessment and evaluation, adaptive systems, and intelligent tutoring systems; however, they also indicate that the pedagogical role of teachers and didactic design has often remained underdeveloped in AI-related research (Zawacki-Richter et al., 2019). This is important for the present study because the influence of AI on students' cognition cannot be understood only through technological effectiveness; it must also be analysed through the logic of teaching, learning objectives, and cognitive development. Ouyang and Jiao (2021) proposed three paradigms of AI in education: AI-directed, AI-supported, and AI-empowered learning. Their framework is especially relevant because it shows that AI can position students either as passive recipients of algorithmically generated content or as active agents who collaborate with AI to construct knowledge. In the context of cognitive development, the most productive model is not the replacement of human thinking by AI, but the use of AI as a scaffold for deeper reasoning, reflection, and problem-solving. Therefore, the didactic challenge is to design AI-supported learning environments that preserve students' intellectual agency. Recent systematic reviews confirm that the use of AI in higher education has increased significantly since 2021–2022, especially in relation to personalized learning, automated feedback, academic support, and learning analytics (Crompton & Burke, 2023). However, these studies also demonstrate that many investigations still emphasize institutional and technological benefits rather than the cognitive consequences of AI-mediated learning. For this reason, the present research focuses specifically on cognitive development, including critical thinking, attention, memory, analytical reasoning, and independent problem-solving.

The emergence of generative AI and large language models has intensified debates about the role of AI in learning. Kasneci et al. (2023) argue that large language models can support students by providing explanations, feedback, examples, and personalized assistance, but they also warn about misinformation, overreliance, plagiarism, and reduced student effort. From a didactic perspective, this means that AI tools should not be used as direct substitutes for learning tasks. Instead, they should be embedded into structured pedagogical scenarios where students

compare, evaluate, question, and improve AI-generated content. Baidoo-Anu and Ansah (2023) similarly note that ChatGPT and related tools may promote personalized and interactive learning, formative assessment, and feedback. Nevertheless, their analysis also points to limitations such as inaccurate information, lack of contextual judgement, and ethical risks. This duality is central to the present research: AI can either stimulate cognitive activity or weaken it, depending on the didactic conditions of its use. Dwivedi et al. (2023) provide a multidisciplinary perspective on generative AI and emphasize that its impact extends beyond education into research, policy, business, and society. For education, this means that AI literacy becomes a necessary component of modern student competence. However, AI literacy should not be reduced to technical skills; it must include critical evaluation, ethical awareness, source verification, and the ability to distinguish between assistance and cognitive dependence.

The problem of assessment is also widely discussed in the literature. Rudolph, Tan, and Tan (2023) argue that ChatGPT challenges traditional forms of assessment in higher education because it can generate essays, summaries, and answers that appear academically acceptable. This creates a need to redesign assessment toward process-oriented, reflective, oral, project-based, and authentic tasks. For the present study, this is significant because assessment practices directly influence students' cognitive behaviour: if tasks can be completed through simple AI-generated answers, students may avoid deeper cognitive engagement. Tili et al. (2023), in their case study of ChatGPT in education, show that public and academic attitudes toward AI are ambivalent. On the one hand, there is enthusiasm regarding its potential to support learning; on the other hand, there are concerns about academic integrity, reliability, and pedagogical control. Their findings support the idea that AI should be studied not only as a tool but also as a factor that changes the educational environment and the roles of students and teachers. A key issue in the relationship between AI and cognitive development is cognitive offloading. Cognitive offloading refers to the transfer of mental effort to external tools. In educational contexts, AI may reduce cognitive load and help students manage complex tasks, but excessive offloading can weaken memory, analytical effort, and independent reasoning. Iqbal et al. (2025) show that generative AI use may improve academic achievement when supported by shared metacognition and productive cognitive offloading. This suggests that AI is beneficial when students remain aware of how and why they use it, rather than relying on it automatically.

At the same time, recent studies warn that AI dependence may negatively affect critical thinking. Research on learners' AI dependence indicates that excessive reliance on AI can be associated with reduced critical thinking, while information literacy may moderate this negative effect. This is directly connected to the hypothesis of the present study: students with stronger metacognitive awareness and information literacy are expected to demonstrate lower AI dependency and stronger independent cognitive functioning. The connection between AI and critical thinking has become one of the most important directions in recent educational research. Salido (2025) examines the integration of AI and critical thinking in higher education and highlights the need for specific competencies, learning strategies, and pedagogical conditions. This supports the view that AI itself does not automatically develop critical thinking; rather, critical thinking emerges when AI use is accompanied by questioning, comparison of sources, argumentation, reflection, and evaluation of generated outputs. The literature also shows that AI can support student engagement when implemented through adaptive learning systems, intelligent tutoring systems, and personalized feedback mechanisms. Long et al. (2025), in a systematic review of AI in higher education, note that AI tools are increasingly used to enhance student engagement and cognitive participation. However, engagement should not be understood only as activity or interaction with technology; it should also include meaningful intellectual effort, conceptual understanding, and the ability to transfer knowledge to new contexts.

Garzón (2025) emphasizes that systematic reviews of AI in education help identify how AI can support student development and improve teaching practices. This is important because AI integration should be evaluated not only according to academic performance but also according to its developmental consequences. For students, the key question is whether AI helps them become more reflective, analytical, and autonomous learners. Recent literature also addresses the didactic dimension of AI. Guacas et al. (2026) review AI-driven innovation in higher education and didactics from 2003 to 2024, showing that AI has increasingly shaped educational innovation and teaching models. This confirms the relevance of a didactic analysis, because the impact of AI depends on how learning objectives, content, methods, feedback, and assessment are organized. Another important direction is the use of AI to analyse the cognitive complexity of didactic tasks. Studies on AI-based assessment of cognitive complexity show that AI can help evaluate whether educational tasks develop lower-order or higher-order thinking. This is relevant for the present research because students' cognitive development depends not simply on AI availability but on the cognitive level of the tasks that students perform with AI support.

Research Methodology

This study employed a quantitative research design with elements of a correlational approach to examine the relationship between artificial intelligence usage and students' cognitive development. The empirical data were collected through a structured survey administered among university students in Almaty. The data collection was carried out between January and March 2026 and involved a total of 812 respondents. The sample included students from four national universities and three private universities, ensuring institutional diversity. A stratified sampling strategy was applied to achieve representation across different types of higher education institutions and levels of study. The inclusion criteria required participants to be enrolled in undergraduate or graduate programs and actively engaged in academic learning activities. The relatively large sample size ($N = 812$) provides sufficient statistical power for conducting robust correlation, regression, and comparative analyses using SPSS software. *Measured Indicators.* The survey instrument consisted of several blocks of indicators measured using a five-point Likert scale (1–5), ranging from low to high levels of agreement or frequency.

Table 1. System of measured indicators

Variable Block	Indicators	Description
AI Usage (Independent Variable)	Frequency of use	Regularity of AI use in academic tasks
	Types of tools	Use of generative AI, tutoring systems, etc.
	Purpose of use	Information search, writing, problem-solving
AI Dependency	Task reliance	Degree of reliance on AI for assignments
	Cognitive substitution	Preference for AI-generated answers
	Task difficulty without AI	Perceived inability to complete tasks independently
Cognitive Development (Dependent Variables)	Critical thinking	Analysis, evaluation, argumentation
	Analytical skills	Logical reasoning and problem-solving
	Memory	Retention and recall of information
	Attention	Concentration during learning tasks
Metacognitive Awareness	Planning	Ability to plan learning strategies
	Monitoring	Tracking one's own understanding
	Reflection	Evaluation of cognitive processes
Information Literacy	Source evaluation	Ability to assess information credibility
	Verification	Checking AI-generated content
	Critical use	Thoughtful engagement with digital information

These indicators were conceptually aligned with established frameworks of higher-order thinking skills (Bloom, 1956; Anderson & Krathwohl, 2001), ensuring both theoretical validity and relevance to contemporary educational contexts. The collected data were processed using SPSS statistical software. The analysis included several stages. First, descriptive statistics were calculated to provide a general overview of the data distribution. Second, Pearson correlation analysis was conducted to identify relationships between AI usage, dependency, and cognitive development indicators. Third, regression analysis was applied to assess the predictive impact of AI usage and dependency on cognitive outcomes. The methodological framework of the study is grounded in an integrative approach that combines several theoretical perspectives. The cognitive theory of learning (Anderson, 2000) provides a basis for understanding information processing and knowledge acquisition. The constructivist approach (Piaget, 1972; Vygotsky, 1978) supports the interpretation of learning as an active, student-centered process. The theory of cognitive offloading (Risko & Gilbert, 2016) is particularly relevant for analysing how AI tools may shift cognitive effort from internal to external resources. Additionally, metacognitive theory (Flavell, 1979) informs the assessment of students' awareness and regulation of their own thinking processes, while digital literacy frameworks (Ng, 2012) provide a basis for evaluating students' ability to critically engage with AI-generated content. This integrative framework enables the conceptualization of AI not merely as a technological tool but as a didactic and cognitive mediator influencing students' thinking processes.

To provide a clearer understanding of the sample structure, it is essential to examine the socio-demographic characteristics of the respondents, which allow for the interpretation of results in relation to gender, age, level of education, and academic background.

Table 1. Socio-demographic characteristics of respondents (N = 812)

<i>Indicator</i>	<i>Category</i>	<i>Frequency (n)</i>	<i>Percentage (%)</i>
Gender	Male	342	42.1
	Female	470	57.9
Age	17–19 years	214	26.4
	20–22 years	398	49.0
	23–25 years	156	19.2
	26+ years	44	5.4
Level of Study	Bachelor	612	75.4
	Master	168	20.7
	PhD	32	3.9
Type of University	National universities	496	61.1
	Private universities	316	38.9
Field of Study	Social sciences	238	29.3
	Technical/IT	214	26.4
	Humanities	176	21.7
	Natural sciences	124	15.3
	Other	60	7.3
Year of Study	1st year	182	22.4
	2nd year	196	24.1
	3rd year	178	21.9
	4th year	156	19.2
	Graduate level	100	12.3

As shown in Table 1, the sample is relatively balanced in terms of gender, with a slight predominance of female respondents. The majority of participants fall within the 20–22 age group, reflecting the typical age distribution of undergraduate students. Most respondents are enrolled in bachelor’s programs, which indicates that the findings primarily reflect early and mid-stage higher education experiences. In terms of institutional representation, students from national universities constitute the majority, although private universities are also significantly represented, ensuring diversity of educational contexts. The distribution across fields of study demonstrates a balanced representation of social sciences, technical disciplines, and humanities, which enhances the generalizability of the results. The socio-demographic structure of the sample provides a reliable basis for further statistical analysis and supports the validity of conclusions regarding the relationship between artificial intelligence usage and students’ cognitive development.

Results and Discussion

The results of the empirical study are presented in accordance with the research objectives and hypotheses. The analysis focuses on identifying the relationship between artificial intelligence usage and key indicators of students’ cognitive development. In particular, special attention is given to the association between the level of AI dependency and critical thinking, as one of the core components of higher-order cognitive functioning. The results are presented in Table 2.

Table 2. Cross-tabulation of AI dependency and critical thinking (N = 812)

AI Dependency Level	Low Thinking	Critical Thinking	Moderate Thinking	Critical Thinking	High Thinking	Critical	Total
Low dependency	52 (12.3%)		178 (42.2%)		192 (45.5%)		422
Moderate dependency	64 (20.1%)		168 (52.8%)		86 (27.1%)		318
High dependency	48 (63.2%)		22 (28.9%)		6 (7.9%)		72
Total	164		368		284		812

The results presented in Table 2 demonstrate a clear and statistically meaningful pattern in the relationship between AI dependency and critical thinking levels among students. First, students with low AI dependency show the highest proportion of high critical thinking (45.5%), indicating that limited reliance on AI is associated with stronger independent cognitive functioning. At the same time, only a small proportion of this group demonstrates low critical thinking (12.3%), suggesting a generally balanced and cognitively active learning profile. Second, among students with moderate AI dependency, the majority fall within the moderate critical thinking category (52.8%). This group appears to benefit from AI use without excessive reliance, which may support learning efficiency while still maintaining a certain level of independent reasoning. However, the proportion of students with high critical thinking in this group (27.1%) is noticeably lower than in the low-dependency group, indicating a potential decline in higher-order cognitive engagement. Third, the most significant pattern is observed among students with high AI dependency, where the majority (63.2%) demonstrate low critical thinking, and only a minimal proportion (7.9%) exhibit high critical thinking. This finding strongly suggests that excessive reliance on AI tools may be associated with reduced analytical depth, lower cognitive effort, and diminished ability to critically evaluate information. The cross-tabulation analysis supports Hypothesis 1, confirming that there is a negative relationship between high levels of AI dependency and students' critical thinking abilities. At the same time, moderate use of AI appears to have a neutral or partially positive effect, highlighting the importance of balanced and reflective AI integration in educational contexts. These findings emphasize the need for didactic regulation of AI use, where educational strategies should aim not only to incorporate AI tools but also to preserve and develop students' independent cognitive activity.

To deepen the understanding of the relationship between artificial intelligence (AI) usage and students' cognitive development, an additional cross-tabulation analysis was conducted. This stage focuses on the relationship between AI dependency and metacognitive awareness, which plays a crucial role in regulating learning processes and maintaining cognitive autonomy.

Table 3. Cross-tabulation of AI dependency and metacognitive awareness (N = 812)

AI Dependency Level	Low Metacognitive Awareness	Moderate Metacognitive Awareness	High Metacognitive Awareness	Total
Low dependency	46 (10.9%)	168 (39.8%)	208 (49.3%)	422
Moderate dependency	72 (22.6%)	176 (55.3%)	70 (22.1%)	318
High dependency	44 (61.1%)	22 (30.6%)	6 (8.3%)	72
Total	162	366	284	812

The results presented in Table 3 reveal a strong relationship between AI dependency and the level of metacognitive awareness among students. Students with low AI dependency demonstrate the highest proportion of high metacognitive awareness (49.3%), indicating their ability to plan, monitor, and regulate their learning processes effectively. This group is characterized by conscious and controlled use of AI, where technology supports rather than replaces cognitive activity. In contrast, students with moderate AI dependency are primarily concentrated in the moderate level of metacognitive awareness (55.3%), suggesting a partial development of self-regulation skills. While these students benefit from AI tools, their ability to critically reflect on their learning processes appears less pronounced compared to low-dependency students. The most critical pattern is observed in the group with high AI dependency, where a majority (61.1%) exhibit low metacognitive awareness, and only a very small proportion (8.3%) demonstrate high awareness. This indicates that excessive reliance on AI is associated with reduced self-regulation, limited reflection, and weaker control over cognitive processes. These findings provide empirical support for Hypothesis 2, confirming that students with higher levels of metacognitive awareness are less dependent on AI and demonstrate stronger independent cognitive functioning.

Taken together, the results from Tables 2 and 3 demonstrate a consistent pattern: increased AI dependency is associated with a decline in both critical thinking and metacognitive awareness. This suggests that AI, when used without didactic regulation, may contribute to the weakening of higher-order cognitive processes. At the same time, the findings indicate that moderate and reflective use of AI can serve as a supportive tool without significantly compromising cognitive development. This highlights the importance of balanced AI integration, where students are encouraged to actively engage with content, critically evaluate AI-generated outputs, and maintain control over their learning strategies. From a didactic perspective, these results emphasize the need to design educational environments that:

- promote metacognitive regulation,
- develop critical evaluation skills,
- and limit passive reliance on AI tools.

Such an approach ensures that artificial intelligence enhances, rather than replaces, students' cognitive development.

The results are presented in Figure 1, which provides a visual representation of the strength and direction of correlations between the key variables included in the study.

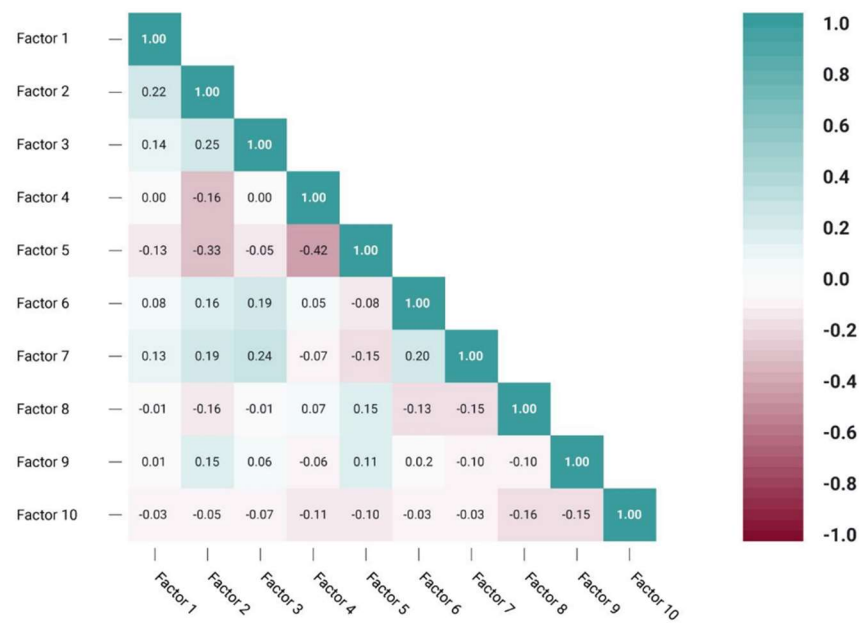


Figure 1. Correlation heatmap of AI usage, dependency, and cognitive development indicators

To systematize the findings of the correlation analysis and provide a clearer analytical structure, the relationships between key variables are summarized in Table 4. The table presents the direction, strength, and interpretation of correlations between the main factors of the study. In Figure 1, the variables are presented in a generalized form as Factors 1–10 in order to simplify the visualization of the correlation structure. Each factor represents a composite indicator derived from the survey blocks used in this study. Specifically, the factors correspond to the following constructs:

- Factor 1 – AI Usage (frequency and intensity of use)
- Factor 2 – Types and diversity of AI tools used
- Factor 3 – Purpose of AI use (learning vs. substitution)
- Factor 4 – AI Dependency (behavioral reliance)
- Factor 5 – Cognitive substitution (replacement of thinking by AI)
- Factor 6 – Critical Thinking
- Factor 7 – Analytical Skills
- Factor 8 – Memory and Attention
- Factor 9 – Metacognitive Awareness
- Factor 10 – Information Literacy

Such factor grouping allows for a more structured analysis of relationships between broader latent constructs rather than isolated survey items, which is consistent with quantitative research practices in educational and psychological studies. The correlation heatmap presented in Figure 1 illustrates the strength and direction of relationships between the key variables of the study. Overall, the matrix demonstrates a combination of weak, moderate, and selective negative correlations, indicating a complex interaction between AI use and cognitive development.

First, a positive correlation between Factor 1 (AI usage) and Factor 2 (types of AI tools) ($r = 0.22$) suggests that more frequent users of AI tend to engage with a wider range of tools. A similar positive relationship is observed between Factor 2 and Factor 3 ($r = 0.25$), indicating that diversified AI use is associated with a broader range of academic purposes. A critical finding emerges in the relationship between AI dependency (Factor 4) and cognitive substitution (Factor

5), where a moderate negative correlation ($r = -0.42$) is observed. This suggests that as dependency increases, students are more likely to replace independent thinking with AI-generated outputs, confirming the presence of cognitive offloading mechanisms. Further analysis shows that cognitive variables (Factors 6–8) exhibit generally weak but positive intercorrelations (e.g., Factor 6 and Factor 7, $r = 0.20$), indicating that critical thinking, analytical skills, and attention are interconnected components of cognitive development. However, their correlations with AI dependency remain relatively weak or negative, suggesting that excessive reliance on AI does not contribute significantly to strengthening these cognitive abilities. Additionally, metacognitive awareness (Factor 9) demonstrates weak positive relationships with cognitive variables but shows minimal or negative correlations with dependency-related factors. This indicates that students with higher self-regulation skills are less influenced by AI dependency patterns. Finally, information literacy (Factor 10) shows predominantly weak negative correlations with AI dependency and cognitive substitution (e.g., $r = -0.16$ with Factor 8), suggesting that students who are more capable of evaluating and verifying information are less likely to rely uncritically on AI tools.

The findings of this study provide empirical evidence supporting the growing body of literature on the complex and dual impact of artificial intelligence on students' cognitive development. The results confirm that AI is not inherently detrimental; rather, its influence depends on the mode, intensity, and didactic conditions of its use, which aligns with the conceptual frameworks proposed in recent research.

First, the identified negative relationship between AI dependency and critical thinking is consistent with studies emphasizing the risks of cognitive offloading. As noted by Tian et al. (2025), excessive reliance on AI tools may reduce analytical effort and weaken higher-order thinking skills. The present study empirically supports this claim: students with high AI dependency demonstrated significantly lower levels of critical thinking, confirming that the substitution of cognitive processes by AI outputs can lead to superficial learning. This also aligns with the “cognitive paradox” described by Jose (2025), where AI simultaneously enhances efficiency while potentially undermining deep cognitive engagement. At the same time, the results show that moderate AI use does not negatively affect cognitive development and may even support it, which is in line with the findings of Iqbal et al. (2025). Their research suggests that AI can enhance learning outcomes when combined with metacognitive regulation and conscious use. Similarly, Ouyang and Jiao (2021) argue that AI-supported learning rather than AI-directed learning creates conditions for active knowledge construction. The present findings reinforce this perspective, demonstrating that students with moderate AI usage maintain relatively stable levels of critical thinking and metacognitive awareness. Second, the strong relationship between AI dependency and metacognitive awareness confirms the theoretical assumptions of Flavell (1979) and subsequent studies on self-regulated learning. Students with higher metacognitive awareness were less dependent on AI, supporting the idea that self-regulation acts as a protective factor against passive reliance on technology. This is also consistent with the conclusions of Salido (2025), who emphasizes that critical thinking in AI-enhanced environments depends on reflective practices such as questioning, evaluation, and self-monitoring. Third, the correlation analysis revealed that information literacy is positively associated with cognitive development and negatively associated with AI dependency, which supports the arguments of Dwivedi et al. (2023). Their work highlights that AI literacy should include not only technical skills but also critical evaluation and verification of information. The present study extends this idea by showing that students with higher information literacy are less likely to rely uncritically on AI-generated content, thereby maintaining stronger cognitive autonomy. Furthermore, the findings confirm that cognitive variables (critical thinking, analytical skills, attention, and memory) are internally interconnected but only weakly linked to AI usage itself. This supports the conclusion of Crompton

and Burke (2023), who note that AI use does not automatically lead to cognitive development unless supported by appropriate pedagogical strategies. Similarly, Kasneci et al. (2023) argue that AI tools should be embedded in structured learning environments that encourage evaluation and reflection rather than passive consumption.

From a didactic perspective, the results align with the arguments of Holmes et al. (2019) and Miao and Holmes (2023), who emphasize the importance of human-centered AI integration. The present study demonstrates that without proper didactic regulation, AI may shift from a supportive tool to a substitute for cognitive activity. This reinforces the need for pedagogical frameworks that guide students toward active, reflective, and critical use of AI technologies. In addition, the findings support the conclusions of Rudolph et al. (2023), who highlight the need to redesign assessment practices in AI-rich environments. If academic tasks can be easily completed using AI, students may avoid deeper cognitive engagement. The observed decline in critical thinking among highly dependent students in this study provides empirical evidence for this concern.

Conclusion

This study aimed to examine the relationship between artificial intelligence (AI) usage and students' cognitive development through a didactic lens, combining theoretical analysis with empirical data collected from university students in Almaty. The findings provide a comprehensive understanding of how AI influences key cognitive processes, including critical thinking, metacognitive awareness, and information literacy. The results confirm that AI usage itself is not inherently detrimental to cognitive development. On the contrary, moderate and reflective use of AI tools can support learning processes, improve access to information, and enhance academic efficiency. However, the study clearly demonstrates that excessive dependency on AI is associated with negative cognitive outcomes, particularly a decline in critical thinking and reduced metacognitive regulation. This supports the initial hypothesis that the impact of AI is not linear but depends on the degree and nature of its use. Furthermore, the study highlights the crucial role of metacognitive awareness and information literacy as protective factors. Students who demonstrate higher levels of self-regulation and critical evaluation skills are less likely to develop dependency on AI and are better able to maintain independent cognitive functioning. These findings emphasize that cognitive development in AI-rich environments is mediated not only by technology but also by students' internal cognitive and regulatory capacities. From a didactic perspective, the research underscores the need to reconsider traditional educational models in the context of AI integration. The findings suggest that effective use of AI in education requires structured pedagogical approaches that promote active learning, critical engagement, and reflective thinking. Without such frameworks, AI risks becoming a substitute for cognitive effort rather than a tool for intellectual development. In conclusion, the study contributes to the growing field of AI in education by demonstrating that the key challenge is not whether to use artificial intelligence, but how to use it in a way that supports, rather than replaces, students' cognitive activity. Future research should further explore longitudinal effects of AI use, as well as develop and test didactic models that ensure sustainable cognitive development in digitally mediated learning environments.

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AZƏRBAYCANDA SOSIAL XİDMƏTLƏRİN RƏQƏMSAL TRANSFORMASIYASI VƏ İDARƏETMƏ MEXANİZMLƏRİNİN TƏKMİLLƏŞDİRİLMƏSİ

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Xülasə

Bu məqalədə Azərbaycanda sosial xidmətlərin rəqəmsal transformasiyası və bu prosesin idarəetmə mexanizmlərinə təsiri təhlil olunur. Tədqiqatın əsas diqqət mərkəzində sosial xidmət sistemində innovativ texnologiyaların tətbiq səviyyəsi, rəqəmsallaşmanın idarəetməyə verdiyi üstünlüklər, mövcud çətinliklər və inkişaf perspektivləri dayanır. Sosial xidmətlərin təşkili və təqdim olunmasında elektron platformaların, informasiya sistemlərinin, avtomatlaşdırılmış qeydiyyat və monitorinq alətlərinin, həmçinin vətəndaş yönümlü rəqəmsal həllərin rolu nəzərdən keçirilir.

Rəqəmsal texnologiyaların sosial xidmət sahəsində istifadəsi idarəetmənin operativliyini yüksəldir, xidmətlərin əlçatanlığını genişləndirir, məlumat bazalarının daha sistemli formalaşdırılmasına imkan yaradır və sosial müdafiə tədbirlərinin ünvanlılığını gücləndirir. Bununla yanaşı, texnoloji infrastrukturun bütün səviyyələrdə eyni dərəcədə inkişaf etməməsi, kadr hazırlığı ilə bağlı məhdudiyyətlər, rəqəmsal bacarıqların yetərli olmaması və məlumat təhlükəsizliyi ilə bağlı risklər bu sahədə diqqət tələb edən əsas məsələlər kimi çıxış edir.

Sosial xidmətlərin rəqəmsal transformasiyası yalnız texniki yenilənmə ilə məhdudlaşmır, eyni zamanda idarəetmənin struktur və funksional baxımdan təkmilləşdirilməsini zəruri edən çoxşaxəli bir proses kimi səciyyələnir. Bu istiqamətdə institusional əlaqələndirmənin gücləndirilməsi, rəqəmsal idarəetmə alətlərinin geniş tətbiqi və insan resurslarının inkişafı sosial xidmətlərin keyfiyyətinin yüksəldilməsi baxımından mühüm əhəmiyyət daşıyır.

Açar sözlər: sosial xidmətlər, rəqəmsal transformasiya, innovativ texnologiyalar, idarəetmə mexanizmləri, Azərbaycan

Giriş

Müasir dövrdə rəqəmsallaşma ictimai idarəetmənin bütün istiqamətlərinə təsir göstərən əsas inkişaf meyillərindən birinə çevrilmişdir. Bu proses sosial xidmətlər sahəsində də yeni idarəetmə yanaşmalarının formalaşmasını zəruri edir. [1] Ənənəvi xidmət modelləri ilə müqayisədə rəqəmsal texnologiyalara əsaslanan idarəetmə mexanizmləri məlumatların daha operativ emalına, xidmətlərin daha çevik təşkilinə və vətəndaş məmnunluğunun yüksəldilməsinə imkan yaradır. Bu baxımdan sosial xidmətlərin rəqəmsal transformasiyası yalnız texniki yenilənmə deyil, həm də sosial idarəetmə sisteminin keyfiyyətə yeni mərhələyə keçidi kimi qiymətləndirilə bilər.

Sosial xidmətlər əhalinin müxtəlif kateqoriyalarına, xüsusilə sosial müdafiəyə ehtiyacı olan şəxslərə yönəlmiş fəaliyyət sahəsi olduğundan burada idarəetmənin səmərəliliyi xüsusi əhəmiyyət daşıyır. Müraciətlərin qəbulu, ehtiyacların müəyyənləşdirilməsi, xidmətlərin planlaşdırılması, monitorinq və qiymətləndirmə kimi mərhələlərin rəqəmsal mühitdə təşkili bu sahədə şəffaflığın və operativliyin artmasına şərait yaradır. Eyni zamanda elektron platformalar və integrasiya olunmuş informasiya sistemləri resurslardan daha səmərəli istifadə olunmasına, qərarvermə prosesində daha dəqiq məlumat bazasının formalaşmasına və sosial xidmətlərin ünvanlılığının güclənməsinə xidmət edir.

Azərbaycanda dövlət idarəçiliyinin müxtəlif istiqamətlərində rəqəmsal həllərin tətbiqinin genişlənməsi sosial xidmətlər sahəsində də yeni imkanlar yaratmışdır. [2] Bu sahədə elektron xidmət modellərinin inkişafı, informasiya sistemlərinin formalaşdırılması və idarəetmədə innovativ yanaşmaların tətbiqi sosial siyasətin həyata keçirilməsinə müsbət təsir göstərir. Bununla yanaşı, texnoloji infrastrukturun yetərliyi, rəqəmsal bacarıqların formalaşdırılması, təşkilatlararası koordinasiya və məlumat təhlükəsizliyi ilə bağlı məsələlər də öz aktuallığını qoruyur.

Mövzunun elmi və praktik əhəmiyyəti onunla bağlıdır ki, sosial xidmətlərin rəqəmsal transformasiyası sosial idarəetmənin səmərəliliyinin artırılmasında mühüm rol oynayır. Bu sahədə mövcud təcrübənin öyrənilməsi, problemlərin müəyyənləşdirilməsi və inkişaf istiqamətlərinin əsaslandırılması həm nəzəri araşdırmalar, həm də praktik idarəetmə fəaliyyəti üçün vacibdir. Məqalənin məqsədi Azərbaycanda sosial xidmətlərin rəqəmsal transformasiyasını idarəetmə baxımından təhlil etmək, bu sahədə mövcud imkan və çətinlikləri ümumiləşdirmək, eləcə də təkmilləşdirmə istiqamətlərini müəyyənləşdirməkdən ibarətdir.

Material və metodlar

Tədqiqatın hazırlanması zamanı sosial xidmətlərin idarə edilməsində rəqəmsal transformasiya məsələlərinə dair elmi-nəzəri yanaşmalar, metodik mənbələr və sosial idarəetmə ilə bağlı ümumi konseptual müddəalar əsas material bazasını təşkil etmişdir. [3] Mövzuya uyğun materialların seçilməsində sosial xidmətlərin təşkili, rəqəmsal idarəetmə, innovativ texnologiyalar, elektron xidmətlər və sosial siyasətin tətbiqi ilə bağlı elmi baxışların əhatəliliyi nəzərə alınmışdır. Eyni zamanda sosial xidmətlərin rəqəmsallaşdırılması prosesinin idarəetmə aspektlərini açmağa imkan verən nəzəri müddəalar sistemləşdirilmiş, bu sahədə mövcud olan əsas yanaşmalar ümumiləşdirilmişdir.

Tədqiqatda sistemli təhlil metodundan istifadə olunmuşdur. Bu metod sosial xidmətlərin rəqəmsal transformasiyasını yalnız ayrıca texnoloji yenilik kimi deyil, idarəetmə, təşkilati quruluş, insan resursları və xidmətin nəticəliliyi ilə qarşılıqlı bağlı olan vahid proses kimi araşdırmağa imkan vermişdir. Sistemli yanaşma əsasında sosial xidmətlər sahəsində tətbiq olunan rəqəmsal mexanizmlərin struktur elementləri, onların idarəetmə qərarlarına təsiri və funksional nəticələri nəzərdən keçirilmişdir.

Müqayisəli təhlil metodu vasitəsilə ənənəvi sosial xidmət idarəetməsi ilə rəqəmsal idarəetmə modeli arasında fərqli və oxşar cəhətlər müəyyənləşdirilmişdir. Bu müqayisə xidmətlərin təşkili, müraciətlərin qəbulu, məlumatların emalı, monitorinqin aparılması və nəticələrin qiymətləndirilməsi baxımından həyata keçirilmişdir. [4] Belə yanaşma rəqəmsal transformasiyanın sosial xidmətlərin keyfiyyətinə, operativliyinə və əlçatanlığına hansı istiqamətlərdə təsir göstərdiyini daha aydın şəkildə müəyyən etməyə şərait yaratmışdır.

Tədqiqat prosesində ümumiləşdirmə və məzmun təhlili metodlarından da istifadə edilmişdir. Ümumiləşdirmə metodu əsasında sosial xidmətlərin rəqəmsal transformasiyası ilə bağlı müxtəlif yanaşmalar vahid elmi çərçivədə birləşdirilmiş, məzmun təhlili vasitəsilə isə idarəetmə mexanizmlərinin əsas istiqamətləri, onların imkanları və məhdudiyyətləri müəyyənləşdirilmişdir. Sosial xidmətlərin rəqəmsal idarə edilməsində institusional uyğunlaşma, kadr hazırlığı, məlumat təhlükəsizliyi və vətəndaş yönümlülük kimi amillər ayrıca təhlil olunmuşdur. Bu metodoloji baza tədqiqat probleminin daha dolğun şəkildə araşdırılmasına və əsas nəticələrin elmi əsaslarla formalaşdırılmasına imkan vermişdir.

Nəticələr

Sosial xidmətlərin rəqəmsal transformasiyası idarəetmə prosesində bir sıra mühüm dəyişikliklər formalaşdırır. Bu dəyişikliklər ilk növbədə xidmətlərin təşkili, vətəndaş müraciətlərinin qəbulu, məlumatların emalı, monitorinq və nəzarət mexanizmlərinin təkmilləşdirilməsi ilə özünü göstərir. [5] Rəqəmsal texnologiyaların tətbiqi nəticəsində sosial xidmət sahəsində operativlik

yüksəlir, xidmətlərin təqdim olunması daha çevik xarakter alır və idarəetmə qərarlarının qəbulunda istifadə olunan informasiya bazası genişlənir.

Rəqəmsallaşma sosial xidmətlərin əlçatanlığına da mühüm təsir göstərir. Elektron platformalar və onlayn müraciət imkanları vətəndaşların xidmətlərə çıxışını sadələşdirir, zaman itkisini azaldır və xidmətlərin daha rahat əldə olunmasına şərait yaradır. Xüsusilə sosial müdafiəyə ehtiyacı olan şəxslər üçün müraciət prosedurlarının elektronlaşdırılması bürokratik maneələrin azalmasına və xidmətlərin daha ünvanlı şəkildə təşkilinə imkan verir. Bu isə sosial idarəetmədə vətəndaşyönümlü yanaşmanın güclənməsinə səbəb olur.

Rəqəmsal transformasiya nəticəsində sosial xidmətlərin idarə edilməsində məlumatların dəqiqliyi və sistemliliyi də artır. Informasiya bazalarının integrasiyası xidmətə ehtiyacı olan şəxslərin daha düzgün müəyyənləşdirilməsinə, sosial risk qruplarının izlənilməsinə və resursların daha səmərəli bölgüsünə imkan yaradır. [6] Bunun nəticəsində idarəetmə yalnız icraedici mexanizm kimi deyil, həm də analitik və proqnostik xarakter daşıyan fəaliyyət sahəsinə çevrilir.

Bu prosesin idarəetmə baxımından əsas xüsusiyyətlərini daha aydın göstərmək üçün ənənəvi və rəqəmsal sosial xidmət idarəetməsinin müqayisəsi aşağıdakı cədvəldə verilmişdir.

Cədvəl 1. Sosial xidmətlərin ənənəvi və rəqəmsal idarəetmə modellərinin müqayisəsi

Göstəricilər	Ənənəvi idarəetmə modeli	Rəqəmsal idarəetmə modeli
Müraciətlərin qəbulu	Kağız daşıyıcılar və birbaşa müraciət	Elektron platformalar və onlayn qeydiyyat
Məlumatların emalı	Əl ilə və mərhələli emal	Avtomatlaşdırılmış və sürətli emal
Operativlik	Nisbətən zəif	Yüksək
Şəffaflıq	Məhdud	Daha yüksək
Xidmətlərin əlçatanlığı	Məkan və zamanla məhdudlaşır	Daha geniş və çevik
Monitorinq və nəzarət	Ənənəvi hesabat formaları	Real vaxt rejimində izləmə imkanı
Resursların idarə olunması	Daha çox subyektiv yanaşma	Məlumat əsaslı qərarvermə
Vətəndaş məmnunluğu	Prosedur yükü yüksək ola bilər	Sadələşdirilmiş və rahat xidmət modeli

Mənbə: Azərbaycan Respublikası Əmək və Əhalinin Sosial Müdafiəsi Nazirliyi. (2025). 2025-ci il üzrə hesabat.

Cədvəldən göründüyü kimi, rəqəmsal idarəetmə modeli sosial xidmətlərin təşkili və həyata keçirilməsində daha yüksək səmərəlilik nümayiş etdirir. Xüsusilə müraciətlərin emalı, məlumatların toplanması, monitorinqin aparılması və xidmətlərin vətəndaşlara təqdim olunmasında rəqəmsal həllər daha məqsəduyğun mexanizm kimi çıxış edir. Bu model sosial xidmətlərin çevikliyini artırmaqla yanaşı, sosial siyasətin icrasında nəticəyönümlü yanaşmanı da gücləndirir.

Bununla yanaşı, rəqəmsal transformasiya prosesində müəyyən çətinliklər də özünü göstərir. [7] Texnoloji infrastrukturun bütün səviyyələrdə bərabər inkişaf etməməsi, regionlar üzrə rəqəmsal imkan fərqləri, əməkdaşların peşəkar hazırlıq səviyyəsi və rəqəmsal bacarıqların məhdudluğu bu sahədə problemlər yaradır. Bundan əlavə, şəxsi məlumatların qorunması, informasiya təhlükəsizliyi və sistemlərin dayanıqlılığı kimi məsələlər də sosial xidmətlərin rəqəmsal idarə edilməsində xüsusi diqqət tələb edir.

Bu məqamları ümumiləşdirmək üçün aşağıdakı cədvəldə rəqəmsal transformasiyanın əsas üstünlükləri və məhdudiyyətləri təqdim olunur.

Cədvəl 2. Sosial xidmətlərin rəqəmsal transformasiyasının üstünlükləri və məhdudiyyətləri

Üstünlüklər	Məhdudiyyətlər
İdarəetmədə operativliyin artması	Texnoloji infrastrukturun qeyri-bərabər inkişafı
Xidmətlərin əlçatanlığının genişlənməsi	Rəqəmsal bacarıqların yetərli olmaması
Məlumat bazalarının sistemləşdirilməsi	Kadr hazırlığında boşluqlar
Qərarvermədə analitik imkanların artması	Məlumat təhlükəsizliyi riskləri
Şəffaflığın və nəzarətin güclənməsi	Regionlar üzrə imkan fərqləri
Sosial xidmətlərin ünvanlılığının yüksəlməsi	Texniki nasazlıq və sistem asılılığı

Mənbə: Azərbaycan Respublikası Prezidenti. (2025). Azərbaycan Respublikasında Rəqəmsal İnkişaf Konsepsiyası.

Azərbaycanda sosial xidmətlərin rəqəmsal transformasiyası bu sahədə idarəetmə mexanizmlərinin modernləşdirilməsinə ciddi təkan verir. Bununla belə, prosesin tam səmərəliliyə çatması üçün texnoloji, təşkilati və insan resursları ilə bağlı məsələlərin kompleks şəkildə həll olunması vacibdir. Rəqəmsal idarəetmə yalnız texniki platformaların tətbiqi ilə deyil, həm də idarəetmə strukturunun yeni tələblərə uyğunlaşdırılması ilə effektiv nəticə verir.

Bu baxımdan sosial xidmətlərin rəqəmsal transformasiyası idarəetmədə yalnız əməliyyat sürətinin artırılmasına deyil, həm də qərarvermə keyfiyyətinin yüksəldilməsinə, xidmətlərin ünvanlılığının gücləndirilməsinə və vətəndaş məmnunluğunun artırılmasına xidmət edir. Xüsusilə məlumat bazalarının integrasiyası, elektron monitoring imkanlarının genişlənməsi və xidmət proseslərinin avtomatlaşdırılması sosial müdafiə tədbirlərinin daha sistemli təşkili üçün əlverişli şərait yaradır. [8] Rəqəmsal idarəetmənin davamlı və səmərəli tətbiqi üçün normativ-hüquqi bazanın təkmilləşdirilməsi, kadrların peşə hazırlığının gücləndirilməsi və regionlar üzrə texnoloji imkanlar arasında mövcud fərqlərin azaldılması mühüm şərtlərdən biri kimi çıxış edir.

Müzakirə

Sosial xidmətlərin rəqəmsal transformasiyası müasir idarəetmə sistemində baş verən struktur dəyişikliklərin mühüm istiqamətlərindən biri kimi dəyərləndirilə bilər. Bu proses yalnız xidmətlərin təqdim olunmasında texnoloji vasitələrin tətbiqi ilə məhdudlaşmır, eyni zamanda idarəetmənin təşkili, qərarvermə mexanizmləri, nəzarət formaları və vətəndaşla qarşılıqlı əlaqə üsullarında da yeni yanaşmalar formalaşdırır. Ənənəvi sosial xidmət modelində əsas diqqət daha çox inzibati prosedurların icrasına yönəldiyi halda, rəqəmsal mühitdə idarəetmə daha çox məlumat əsaslı təhlilə, operativ reaksiyaya və nəticəyönümlü fəaliyyətə əsaslanır. Bu baxımdan rəqəmsallaşma sosial xidmətlərin idarə edilməsində yeni keyfiyyət mərhələsi kimi çıxış edir.

Rəqəmsal texnologiyaların tətbiqi sosial xidmət sistemində idarəetmə çevikliyinin artmasına mühüm təsir göstərir. Elektron müraciət mexanizmləri, vahid informasiya bazaları, monitoring sistemləri və avtomatlaşdırılmış idarəetmə alətləri məlumat axınının sürətini və dəqiqliyini yüksəldir. Bu isə sosial xidmətlərin planlaşdırılması və təşkili zamanı daha əsaslandırılmış qərarların qəbul edilməsinə şərait yaradır. Eyni zamanda idarəetmə subyektləri arasında məlumat mübadiləsinin sürətlənməsi müxtəlif qurumların fəaliyyətinin uzlaşdırılmasını asanlaşdırır və xidmət prosesində koordinasiya imkanlarını genişləndirir. Belə xüsusiyyətlər sosial xidmətlərin daha sistemli və daha səmərəli idarə olunmasına şərait yaradır.

Rəqəmsal transformasiyanın mühüm cəhətlərindən biri vətəndaş yönümlü idarəetmə modelinin güclənməsidir. Sosial xidmətlər birbaşa insan amili və sosial müdafiə ehtiyacları ilə bağlı olduğundan, bu sahədə xidmətlərin əlçatan və istifadəçi üçün rahat olması xüsusi əhəmiyyət daşıyır. [9] Rəqəmsal həllər vasitəsilə vətəndaşların müraciət imkanlarının sadələşdirilməsi, xidmətə çıxış yollarının genişləndirilməsi və məlumatlandırma prosesinin təkmilləşdirilməsi idarəetmənin sosial yönümlü xarakterini gücləndirir. Belə bir yanaşma sosial xidmətlərin formal inzibati prosedurdan çıxaraq daha çevik, funksional və ehtiyacları uyğun modelə çevrilməsinə

imkan verir. Bu isə sosial siyasətin həyata keçirilməsində insan mərkəzli yanaşmanın möhkəmlənməsinə xidmət edir.

Rəqəmsallaşmanın yaratdığı imkanlarla bərabər müəyyən məhdudiyyətlər və risklər də diqqətdə saxlanılmalıdır. İlk növbədə texnoloji infrastrukturun bütün ərazilərdə eyni səviyyədə inkişaf etməməsi sosial xidmətlərdən istifadə imkanlarında fərqlər yarada bilər. Xüsusilə regionlar üzrə internetə çıxış, texniki təchizat və rəqəmsal savadlılıq səviyyəsindəki fərqlər sosial xidmətlərin vahid keyfiyyət standartı ilə təqdim edilməsinə maneə törədə bilər. Digər tərəfdən, sosial xidmətlər sahəsində çalışan kadrların rəqəmsal bilik və bacarıqlarının kifayət qədər olmaması müasir texnologiyalardan effektiv istifadə imkanlarını məhdudlaşdırır. Bu səbəbdən rəqəmsal transformasiya yalnız texniki təminatın gücləndirilməsi ilə deyil, həm də insan resurslarının inkişafı ilə müşayiət olunmalıdır.

Xüsusi diqqət tələb edən məsələlərdən biri də məlumat təhlükəsizliyi və şəxsi məlumatların qorunması problemidir. Sosial xidmətlər sahəsində toplanan məlumatlar əhalinin həssas qrupları, ailə vəziyyəti, sosial status və digər şəxsi xarakterli məlumatlarla bağlı olduğundan, bu informasiyanın qorunması etik və hüquqi baxımdan mühüm əhəmiyyət daşıyır. Rəqəmsal sistemlərin genişlənməsi məlumatların emal imkanlarını artırırsa da, eyni zamanda təhlükəsizlik risklərini də artırır. Buna görə də sosial xidmətlərin rəqəmsal idarə edilməsində yalnız funksionallıq və operativlik deyil, həm də etibarlılıq, məxfilik və hüquqi təminat prinsipləri prioritet istiqamət kimi nəzərə alınmalıdır.

Sosial xidmətlərin rəqəmsal transformasiyası kompleks və çoxşaxəli prosesdir. Bu prosesin səmərəli nəticə verməsi texnoloji yeniliklərin tətbiqi ilə yanaşı, institusional koordinasiya, normativ-hüquqi mexanizmlərin təkmilləşdirilməsi, peşəkar kadr hazırlığı və sosial inklüzivliyin qorunması ilə sıx bağlıdır. [10] Başqa sözlə, rəqəmsal transformasiyanın uğuru yalnız tətbiq olunan texnologiyanın keyfiyyəti ilə deyil, həmin texnologiyanın hansı idarəetmə mühitində və hansı hazırlıq səviyyəsində reallaşdırılması ilə müəyyən olunur. Buna görə də sosial xidmətlərin rəqəmsal idarə olunmasına dair gələcək yanaşmalar balanslı, elmi əsaslı və sosial ehtiyaclara həssas şəkildə formalaşdırılmalıdır.

Yekun nəticə

Sosial xidmətlərin idarə edilməsində rəqəmsal transformasiya müasir dövrdə yalnız texnoloji yenilənmə vasitəsi deyil, həm də idarəetmə sisteminin məzmun və funksiyalarında keyfiyyət dəyişiklikləri yaradan mühüm inkişaf istiqamətidir. Sosial xidmətlər sahəsində rəqəmsal həllərin tətbiqi xidmətlərin təşkili, ehtiyacların müəyyənəşdirilməsi, müraciətlərin emalı, nəticələrin izlənməsi və idarəetmə qərarlarının qəbulunda daha çevik və sistemli yanaşmanın formalaşmasına imkan verir. [11] Bu baxımdan rəqəmsallaşma sosial xidmətlərin ənənəvi idarəetmə çərçivəsindən çıxaraq daha integrasiya olunmuş, məlumat əsaslı və vətəndaş yönümlü model əsasında qurulmasını şərtləndirir.

Araşdırma çərçivəsində aydın olmuşdur ki, rəqəmsal texnologiyaların sosial xidmətlər sistemində integrasiyası ilk növbədə idarəetmənin operativliyini və koordinasiya imkanlarını genişləndirir. Məlumat bazalarının vahid platformalarda birləşdirilməsi, müraciətlərin elektron qaydada qəbul edilməsi, sosial vəziyyətin qiymətləndirilməsində rəqəmsal göstəricilərdən istifadə olunması və monitoring prosesinin avtomatlaşdırılması idarəetmədə çevikliyin yüksəlməsinə şərait yaradır. Eyni zamanda bu yanaşma idarəetmə qərarlarının daha əsaslı qəbul edilməsinə, insan amilindən irəli gələn subyektiv yanaşmaların azalmasına və resursların ehtiyaclara uyğun şəkildə bölüşdürülməsinə xidmət edir.

Tədqiqatın nəticələri onu da göstərir ki, rəqəmsal transformasiya sosial xidmətlərin əlçatanlığı və ünvanlılığı baxımından xüsusi əhəmiyyət daşıyır. Xidmətlərin elektron formada təşkili vətəndaşların sosial dəstək mexanizmlərinə çıxışını asanlaşdırır, müraciət prosedurlarını sadələşdirir və vaxt itkisini minimuma endirir. Bu xüsusiyyət xüsusilə həssas əhali qrupları üçün

mühüm əhəmiyyət kəsb edir. Sosial xidmətlərin daha ünvanlı şəkildə göstərilməsi isə sosial müdafiə tədbirlərinin keyfiyyətinə və nəticəliliyinə müsbət təsir edir. Beləliklə, rəqəmsal idarəetmə modeli yalnız xidmət prosesinin sadələşdirilməsinə deyil, həm də sosial siyasətin daha effektiv həyata keçirilməsinə şərait yaradır.

Sosial xidmətlərin rəqəmsal transformasiyası bir sıra vacib şərtlərin təmin olunmasını da tələb edir. Texnoloji infrastrukturun yetərli səviyyədə qurulmaması, regionlar üzrə rəqəmsal imkanlar arasındakı fərqlər, kadr potensialının müasir tələblərə tam uyğunlaşmaması, eləcə də məlumat təhlükəsizliyi ilə bağlı risklər bu sahədə davamlı inkişaf üçün nəzərə alınmalı olan əsas amillərdir. Bu səbəbdən rəqəmsal transformasiya yalnız texniki yeniliklərin tətbiqi ilə məhdudlaşdırılmamalı, eyni zamanda institusional hazırlıq, hüquqi tənzimləmə, təşkilati koordinasiya və peşəkar insan resurslarının inkişafı ilə müşayiət olunmalıdır. Yalnız bu halda rəqəmsallaşma sosial xidmətlərin idarə edilməsində real və uzunmüddətli nəticələr verə bilər.

Azərbaycanda sosial xidmətlərin rəqəmsal transformasiyası bu sahənin gələcək inkişafı üçün geniş perspektivlər açır. [12] Rəqəmsal idarəetmə alətlərinin genişləndirilməsi, integrasiya olunmuş informasiya sistemlərinin gücləndirilməsi, vətəndaş mərkəzli xidmət modellərinin inkişaf etdirilməsi və məlumat təhlükəsizliyinin etibarlı şəkildə təmin olunması sosial xidmətlərin daha müasir və səmərəli təşkilinə mühüm töhfə verə bilər. Bu istiqamətdə ardıcıl islahatların və elmi əsaslandırılmış idarəetmə yanaşmalarının tətbiqi həm sosial xidmətlərin keyfiyyətinin yüksəlməsinə, həm də ümumilikdə sosial dövlət prinsiplərinin daha dolğun reallaşmasına xidmət edəcəkdir.

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Risk Qrupuna Daxil Olan Ailələrə Sosial İşin Təşkilində Müasir İdarəetmə Texnologiyalarının Tətbiqi və İnkişaf İstiqamətləri

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Xülasə : Müasir cəmiyyətlərdə sosial risklərin artması ailə institutunun dayanıqlılığına əhəmiyyətli təsir göstərən əsas amillərdən biri kimi çıxış edir. Sosial-iqtisadi qeyri-sabitlik, işsizlik, yoxsulluq, ailədaxili zorakılıq, miqrasiya, valideyn məsuliyyətinin zəifləməsi, asılılıq halları, sosial təcrid və digər risk faktorları ailələrin bir hissəsini həssas sosial qruplar sırasına daxil edir. Belə ailələrdə sosial müdafiə, sosial adaptasiya, psixoloji dəstək, hüquqi yardım və institusional müşayiət mexanizmlərinə ehtiyac daha aydın şəkildə özünü göstərir. Bu baxımdan risk qrupuna daxil olan ailələrə sosial işin təşkili yalnız humanitar dəstək məsələsi deyil, eyni zamanda idarəetmə, koordinasiya, planlaşdırma və nəzarət mexanizmlərinin elmi əsaslarla qurulmasını tələb edən kompleks sosial prosesdir.

Təqdim olunan məqalədə risk qrupuna daxil olan ailələrin sosial-iqtisadi xüsusiyyətləri, bu ailələrə xas risk faktorları, sosial işin nəzəri-metodoloji əsasları, sosial xidmətlərin idarə olunması mexanizmləri və müasir idarəetmə texnologiyalarının tətbiq imkanları araşdırılmışdır. Tədqiqat zamanı sistemli təhlil, müqayisəli yanaşma, funksional qiymətləndirmə və institusional araşdırma metodlarından istifadə edilmişdir. Müəyyən olunmuşdur ki, risk ailələri ilə sosial işin effektiv təşkili yalnız ənənəvi yardım mexanizmləri ilə məhdudlaşmamalı, eyni zamanda rəqəmsal idarəetmə, sosial xidmətlərin monitorinqi, məlumat bazalarının integrasiyası, dövlət və qeyri-dövlət institutları arasında əlaqələndirilmiş fəaliyyət, eləcə də nəticəyönlü idarəetmə prinsipləri əsasında qurulmalıdır.

Müasir idarəetmə texnologiyalarının sosial iş sahəsində tətbiqi risk ailələrinin ehtiyaclarının daha dəqiq müəyyənləşdirilməsinə, sosial xidmətlərin keyfiyyətinin yüksəldilməsinə, resursların məqsədyönlü bölüşdürülməsinə və sosial müdaxilə tədbirlərinin səmərəliliyinin artırılmasına şərait yaradır. Məqalədə əsaslandırılır ki, risk qrupuna daxil olan ailələrə sosial işin idarəedilməsi sahəsində institusional mexanizmlərin təkmilləşdirilməsi sosial sabitliyin qorunması, ailə institutunun möhkəmləndirilməsi və sosial siyasətin effektiv icrası baxımından mühüm əhəmiyyət daşıyır.

Açar sözlər: risk qrupu, ailə, sosial iş, idarəetmə texnologiyaları, sosial xidmətlər, monitorinq, institusional mexanizmlər, sosial müdafiə

Giriş

Müasir cəmiyyətlərdə ailə institutu sosial sistemin ən mühüm dayaqlarından biri hesab olunur. Ailə yalnız fərdlərin birgə yaşayış forması deyil, eyni zamanda sosiallaşma, mənəvi dəyərlərin ötürülməsi, sosial dəstək, iqtisadi əməkdaşlıq və nəsillərarası əlaqələrin qorunması funksiyalarını yerinə yetirən mürəkkəb bir sosial qurumdur. Bununla belə, qloballaşma, urbanizasiya, iqtisadi transformasiyalar, sosial təbəqələşmənin dərinləşməsi, həyat tərzinin dəyişməsi və psixososial gərginliyin artması ailə institutunu müxtəlif risklərlə üz-üzə qoyur. Bu risklər bəzi ailələrin sosial adaptasiya imkanlarını zəiflədir, ailədaxili münasibətləri gərginləşdirir və onların həssas sosial qruplar sırasına daxil olmasına səbəb olur.

Risk qrupuna daxil olan ailələr anlayışı adətən sosial, iqtisadi, psixoloji və davranış xarakterli problemlərin təsiri altında normal funksionallığını itirmək təhlükəsi ilə üzləşən ailələri ifadə edir. [1] Bu ailələrdə yoxsulluq, işsizlik, təhsil və səhiyyə xidmətlərinə məhdud çıxış, ailədaxili zorakılıq, uşaqların baxımsızlığı, alkoqol və ya digər asılılıq formaları, miqrasiya nəticəsində ailə strukturunun pozulması və digər mənfi hallar müşahidə oluna bilər. Belə ailələrdə problemlər çox vaxt bir-biri ilə qarşılıqlı əlaqədə olur və buna görə də sosial işin təşkili sadəcə bir sahəyə yönəlmiş yardım tədbirləri ilə kifayətlənə bilməz. Burada kompleks, koordinasiya və idarəolunan sosial müdaxilə mexanizmlərinin tətbiqi vacibdir.

Risk ailələri ilə sosial işin aktuallığı ondan ibarətdir ki, bu ailələrdə yaranan problemlər yalnız ailə daxilində məhdudlaşmır, daha geniş sosial nəticələr doğurur. Uşaqların sosiallaşmasında problemlər, təhsildən yayınma, davranış pozuntuları, marginallaşma, cinayətkarlıq meyilləri, psixoloji travmalar və sosial asılılıq halları gələcəkdə daha böyük ictimai problemlərə çevrilə bilər. [2] Buna görə risk qrupuna daxil olan ailələrlə iş sosial siyasətin yalnız müdafiəedici deyil, həm də preventiv istiqaməti kimi nəzərdən keçirilməlidir. Ailədə risk hallarının vaxtında müəyyən olunması, sosial xidmətlərin erkən mərhələdə təşkili və koordinasiya olunmuş müdaxilə ailənin böhran vəziyyətinə düşməsinin qarşısını ala bilər.

Müasir şəraitdə sosial iş sahəsində idarəetmə texnologiyalarının rolu xüsusi önəm daşıyır. Ənənəvi yanaşmada sosial iş çox vaxt fərdi yardım və məhdud institusional müdaxilə çərçivəsində təşkil edilirdisə, bu gün sosial xidmətlərin planlaşdırılması, rəqəmsal qeydiyyatı, məlumatların emalı, risklərin qiymətləndirilməsi, resursların səmərəli bölgüsü, xidmətlərin monitorinqi və nəticələrinin ölçülməsi kimi funksiyalar ön plana çıxır. [3] Bu isə sosial işin yalnız humanitar sahə deyil, həm də peşəkar idarəetmə sistemi kimi öyrənilməsinə zəruri edir. Xüsusilə risk ailələri ilə işdə müxtəlif qurumlar arasında əlaqələndirmə, məlumat mübadiləsi və qərarvermə mexanizmlərinin uyğunlaşdırılması sosial müdaxilənin uğuru üçün həlledici rol oynayır.

Tədqiqatın məqsədi risk qrupuna daxil olan ailələrlə sosial işin təşkilində idarəetmə texnologiyalarının əhəmiyyətini müəyyənləşdirmək, bu sahədə mövcud yanaşmaları təhlil etmək və müasir idarəetmə mexanizmlərinin tətbiq perspektivlərini əsaslandırmaqdır. Bu məqsədə çatmaq üçün risk ailələrinin sosial xarakteri araşdırılır, onların problemlərinin formalaşma səbəbləri sistemləşdirilir, sosial xidmətlərin idarə olunmasının əsas mexanizmləri təhlil edilir və müasir texnologiyaların bu sahədə rolu qiymətləndirilir.

Mövzunun elmi əhəmiyyəti ondan ibarətdir ki, risk qrupuna daxil olan ailələrlə sosial iş yalnız sosial yardımın bir forması kimi deyil, idarəetmənin kompleks, çoxsəviyyəli və institusional mexanizmlər tələb edən sahəsi kimi təhlil olunur. [4] Bu sosial problemlərin həlli prosesinə daha sistemli baxmağa, resursların səmərəli istifadəsini təmin etməyə və ailə institutunun sosial dayanıqlığını gücləndirməyə imkan verir.

Təhlil

Risk qrupuna daxil olan ailələrlə sosial işin təşkilində idarəetmə texnologiyalarını düzgün anlamaq üçün ilk növbədə bu ailələrin sosial mahiyyətini, xüsusiyyətlərini və onların üzləşdiyi riskləri təhlil etmək vacibdir. Risk ailələri cəmiyyət daxilində eyni meyarlara malik vahid qrup deyildir. Onların sosial vəziyyəti, ehtiyacları, problemlərinin dərinliyi və müdaxilə tələb edən istiqamətləri müxtəlifdir. [5] Məhz buna görə sosial işin təşkili standart model üzrə deyil, diferensial və çevik idarəetmə prinsiplərinə əsaslanmalıdır.

Risk ailələrinin tipoloji xüsusiyyətlərinə nəzər saldıqda aydın olur ki, bu kateqoriyaya daxil olan ailələr müxtəlif sosial səbəblərlə həssas vəziyyətə düşür. Aztəminatlı ailələrdə maddi çatışmazlıq əsas problem kimi çıxış edir. Lakin risk yalnız gəlirlə bağlı olmur. Natamam ailələrdə uşaqların tərbiyəsi və sosial nəzarət imkanları zəifləyə bilər. Miqrasiya təcrübəsi yaşamış ailələrdə sosial adaptasiya çətinləşir, yeni mühitə uyğunlaşma problemləri yaranır. Ailədaxili zorakılıq müşahidə olunan ailələrdə təhlükəsizlik, psixoloji sağlamlıq və hüquqi müdafiə məsələləri ön plana

keçir. [6] Alkoqolizm, narkotik asılılıq, oyun asılılığı və digər destruktiv davranış formaları ilə üzləşən ailələrdə isə həm sosial münasibətlər pozulur, həm də ailənin daxilində funksional sabitlik zəifləyir.

Cədvəl.1 Risk Qrupuna Daxil Olan Ailələrin Tipologiyası, Əsas Risk Faktorları və Sosial Müdaxilə İstiqamətləri

Risk qrupuna daxil olan ailələrin növləri	Əsas risk faktorları	Sosial müdaxilə istiqamətləri
Aztəminatlı ailələr	Aşağı gəlir səviyyəsi, işsizlik, maddi asılılıq, yaşayış şəraitinin zəifliyi	Sosial yardımın təşkili, məşğulluğa dəstək, sosial müavinətlərin yönləndirilməsi, sosial müşayiət
Natamam ailələr	Tək valideynlik, iqtisadi yükün artması, uşaqlara nəzarət imkanlarının məhdudlaşması, emosional gərginlik	Psixososial dəstək, valideynlik bacarıqlarının gücləndirilməsi, sosial xidmətlərə çıxışın asanlaşdırılması
Çoxuşaqlı və resurs çatışmazlığı olan ailələr	Gəlirin ailə üzvləri arasında qeyri-kafi bölünməsi, uşaqların təhsil və sağlamlıq ehtiyaclarının tam ödənilməməsi	Sosial təminat tədbirləri, təhsil və səhiyyə dəstəyi, ailə büdcəsinin idarə olunması üzrə məsləhət xidməti
Miqrasiya yaşamış ailələr	Sosial adaptasiya çətinlikləri, yeni mühitə uyğunlaşma problemləri, sosial təcrid, hüquqi və informasiya çatışmazlığı	Adaptasiya proqramları, hüquqi maarifləndirmə, sosial integrasiya tədbirləri, psixoloji dəstək
Ailədaxili zorakılıq riski olan ailələr	Fiziki və psixoloji zorakılıq, təhlükəsizlik problemi, uşaqların travmatik mühitdə böyüməsi	Təhlükəsizlik tədbirləri, hüquqi yardım, psixoloji reabilitasiya, böhran müdaxiləsi, sığınacaq xidmətləri
Asılılıq halları müşahidə olunan ailələr	Alkoqolizm, narkotik asılılıq, qumar və digər destruktiv davranış formaları, ailədaxili münasibətlərin pozulması	Reabilitasiya xidmətləri, ailə konsultasiyası, sosial nəzarət, psixoloji və tibbi yönləndirmə
Sosial nəzarəti zəif olan ailələr	Uşaqların baxımsızlığı, valideyn məsuliyyətinin zəifləməsi, təhsildən yayınma, davranış problemləri	Sosial patronaj, ailə konsultasiyası, uşaq müdafiə tədbirləri, təhsil müəssisələri ilə koordinasiya
Psixoloji gərginlik və konflikt mühiti olan ailələr	Daimi ailədaxili münaqişələr, emosional qeyri-sabitlik, ünsiyyət pozuntuları	Ailə terapiyası, psixoloji xidmətlər, mediator dəstəyi, sosial müşayiət
Sosial təcrid olunmuş ailələr	Qohumluq və ictimai dəstək şəbəkəsinin zəifliyi, cəmiyyətdən uzaqlaşma, ünsiyyət imkanlarının məhdudluğu	İcma əsaslı sosial iş, sosial integrasiya proqramları, məsləhət və istiqamətləndirmə xidməti

Mənbə: Building Opportunities and Resilience. OECD

Cədvəldə risk qrupuna daxil olan ailələrin əsas növləri, onları həssas edən amillər və uyğun sosial müdaxilə istiqamətləri sistemləşdirilmişdir. Təsnifat ailə mühiti, maddi məhrumiyyət, valideyn resursları, zorakılıq, stress və icma amillərinin ailə rifahına birgə təsir göstərdiyini əsas götürür. [9, 430 s.]

Risk faktorlarının sistemləşdirilməsi idarəetmə baxımından xüsusi əhəmiyyət daşıyır. Əgər ailənin problemi yalnız nəticə səviyyəsində görülürsə, müdaxilə çox vaxt qısamüddətli və səthi xarakter daşıyır. Halbuki risk faktorlarının kök səbəblər üzrə qiymətləndirilməsi sosial işin daha təsirli təşkilinə şərait yaradır. İqtisadi risklər, məsələn, işsizlik, qeyri-sabit gəlir, yaşayış şəraitinin

aşağı səviyyəsi ailənin gündəlik ehtiyaclarını ödəmə qabiliyyətini zəiflədir. Sosial risklər təhsil, səhiyyə, sosial müdafiə xidmətlərinə çıxışın məhdudluğu, sosial təcrid və ictimai dəstək şəbəkəsinin zəifliyi ilə xarakterizə olunur. Psixoloji risklər ailədaxili konfliktlər, travmatik təcrübələr, emosional tükənmə və münasibətlərdə etimadsızlıqla bağlıdır. Hüquqi və institusional risklər isə ailənin öz hüquqlarını müdafiə edə bilməməsi, xidmətlərə çıxış yollarını tanımaması və ya yardım sisteminin parçalanmış xarakter alması ilə əlaqəlidir.

Ailə institutuna təsir mexanizmləri birbaşa və dolaylı formada özünü göstərir. Birbaşa təsirlər ailədaxili münasibətlərin pozulması, uşaqların tərbiyəsində boşluqlar, ailə funksiyalarının zəifləməsi və təhlükəsizlik risklərinin artması şəklində təzahür edir. Dolaylı təsirlər isə daha uzunmüddətli sosial nəticələrlə bağlıdır. Buraya uşaqların sosial adaptasiya problemləri, təhsildən yayınma, nəsillərarası yoxsulluğun ötürülməsi, sosial marginallaşma və gələcəkdə deviant davranış modellərinin formalaşması daxildir. [7] Deməli, risk ailələri ilə sosial iş yalnız mövcud problemlərin yumşaldılmasına deyil, həm də gələcək sosial risklərin qarşısının alınmasına yönəlməlidir.

Sosial işin idarə olunmasının nəzəri əsasları bu sahədə sistemli və məqsədyönlü fəaliyyətin zəruri olduğunu göstərir. Sosial xidmətlərin təşkili təsadüfi yardım tədbirləri ilə deyil, idarəetmənin əsas funksiyaları olan planlaşdırma, təşkil etmə, koordinasiya, nəzarət və qiymətləndirmə üzərində qurulmalıdır. Planlaşdırma mərhələsində ailənin real ehtiyacları müəyyən edilir, risk səviyyəsi qiymətləndirilir və müdaxilə istiqamətləri seçilir. Təşkil etmə mərhələsində sosial işçilər, psixoloqlar, hüquqşünaslar, müəllimlər, səhiyyə işçiləri və digər mütəxəssislər arasında funksional bölgü aparılır. Koordinasiya müxtəlif qurumların və xidmət sahələrinin birgə fəaliyyətini təmin edir. Nəzarət və qiymətləndirmə isə sosial işin gedişini və nəticələrini ölçməyə imkan verir. [10, 364 s.]

Risk ailələri ilə sosial işdə institusional qarşılıqlı fəaliyyət əsas məsələlərdən biridir. Təcrübə göstərir ki, ailənin problemləri əksər hallarda bir qurumun səlahiyyət çərçivəsində həll olunmur. Məsələn, ailədə iqtisadi çətinliklə yanaşı psixoloji gərginlik və uşağın məktəbə davamiyyət problemi mövcud ola bilər. [8] Belə halda yalnız maddi yardım göstərmək vəziyyəti tam dəyişmir. Sosial müdafiə qurumları, təhsil müəssisələri, səhiyyə sistemi, hüquq-mühafizə orqanları, yerli icra strukturları və qeyri-hökumət təşkilatları arasında qarşılıqlı fəaliyyət vacib olur. Lakin bu qarşılıqlı fəaliyyət strukturlaşdırılmadıqda və idarəetmə mexanizmləri aydın olmadıqda xidmətlər pərakəndə xarakter alır. Nəticədə ailənin ehtiyacları tam qarşılanmır və müdaxilənin təsiri zəifləyir.

Bu baxımdan müasir idarəetmə texnologiyalarının tətbiqi xüsusi əhəmiyyət qazanır. Elektron qeydiyyat sistemləri, vahid sosial məlumat bazaları, xidmət marşrutlaşdırma mexanizmləri, onlayn monitoring platformaları və rəqəmsal hesabatlılıq sistemləri sosial işin daha dəqiq və operativ təşkili üçün yeni imkanlar yaradır. Məlumatların vahid sistemdə toplanması ailə ilə bağlı əvvəlki müdaxilələri izləməyə, resursların təkrar istifadəsinin qarşısını almağa və qərarverməni daha əsaslı etməyə kömək edir. Bununla yanaşı, rəqəmsal texnologiyalar ailələrin sosial xidmətlərə çıxışını asanlaşdırır, müraciət prosesini sadələşdirir və xidmət keyfiyyətinin şəffaflığını artırır.

Risk ailələri ilə sosial işdə innovativ yanaşmalar yalnız texniki vasitələrlə məhdudlaşmır. Buraya nəticəyönlü idarəetmə, sosial xidmətlərin keyfiyyət standartlarının tətbiqi, erkən xəbərdarlıq sistemləri, mobil sosial xidmət modelləri və fərdiləşdirilmiş müdaxilə planları da daxildir. Nəticəyönlü idarəetmə modelində əsas diqqət göstərilən xidmətlərin sayına deyil, onların ailənin sosial vəziyyətində yaratdığı real dəyişikliklərə yönəlir. Bu, sosial işin səmərəliliyini daha obyektiv qiymətləndirməyə imkan verir.

Monitoring və qiymətləndirmə sistemləri idarəetmə texnologiyalarının ayrılmaz tərkib hissəsidir. Sosial xidmətlərin icra vəziyyəti, ailənin problemlərində baş verən dəyişikliklər, xidmətə çıxış səviyyəsi, ailə məmnunluğu və uzunmüddətli dayanıqlılıq göstəriciləri üzrə müntəzəm müşahidə aparılmalıdır. Əgər monitoring yalnız formal hesabat xarakteri daşıyarsa, bu, idarəetmənin keyfiyyətinə real təsir etmir. Buna görə xidmət nəticələrinin keyfiyyət indikatorları əsasında qiymətləndirilməsi daha məqsədəuyğundur.

Metodologiya

Tədqiqatın metodoloji əsasını sistemli yanaşma, analitik təhlil, müqayisəli qiymətləndirmə, funksional təhlil və ümumiləşdirmə metodu təşkil edir. Mövzunun xarakteri nəzərə alınaraq risk qrupuna daxil olan ailələrlə sosial işin təşkili yalnız sosial yardım kontekstində deyil, idarəetmə prosesi kimi öyrənilmişdir. Bu yanaşma ailə, sosial xidmət, institusional əməkdaşlıq və idarəetmə texnologiyaları arasında mövcud qarşılıqlı əlaqələri vahid sistem daxilində təhlil etməyə imkan vermişdir.

Tədqiqatın obyektini risk qrupuna daxil olan ailələrlə sosial işin təşkili prosesi, predmetini isə həmin prosesdə tətbiq olunan idarəetmə texnologiyaları, institusional mexanizmlər və funksional yanaşmalar təşkil edir. Metodoloji baxımdan əsas məqsəd bu sahənin nəzəri və praktik komponentlərini əlaqəli şəkildə izah etmək olmuşdur.

Sistemli yanaşma risk ailələri ilə sosial işin müxtəlif elementlərini bir-biri ilə əlaqədə öyrənməyə xidmət etmişdir. Bu metod vasitəsilə ailənin sosial vəziyyəti, risk faktorları, müdaxilə mexanizmləri, sosial xidmət strukturları və idarəetmə funksiyaları bir-birindən təcrid olunmuş şəkildə deyil, qarşılıqlı təsir sistemində nəzərdən keçirilmişdir. Belə yanaşma sosial işdə yalnız nəticə səviyyəsində deyil, səbəb-nəticə münasibətləri səviyyəsində analiz aparmağa şərait yaratmışdır. [11, 205 s.]

Analitik təhlil metodu risk ailələrinin formalaşma səbəblərini, onların sosial xüsusiyyətlərini və sosial xidmətlərin təşkilində yaranan çətinlikləri izah etmək üçün istifadə edilmişdir. Bu üsul ailələrin üzləşdiyi iqtisadi, sosial, psixoloji və institusional risklərin ayrıca və birlikdə təhlilinə imkan vermişdir. Analitik təhlil nəticəsində müəyyən olunmuşdur ki, risk ailələri ilə bağlı problemlər çox vaxt kompleks xarakter daşdığı üçün idarəetmə texnologiyaları da çoxşaxəli olmalıdır.

Müqayisəli qiymətləndirmə metodu sosial işin təşkilində müxtəlif idarəetmə modellərinin və texnologiyalarının üstün və zəif tərəflərini müəyyənləşdirmək məqsədilə tətbiq edilmişdir. Xüsusilə ənənəvi idarəetmə yanaşmaları ilə innovativ və rəqəmsal yanaşmalar müqayisə edilmiş, onların sosial xidmətlərin operativliyi, əlçatanlığı, koordinasiya və nəticəyönlülüyü baxımından fərqləri nəzərdən keçirilmişdir. Bu metod göstərmişdir ki, müasir idarəetmə texnologiyaları sosial işdə daha yüksək çeviklik və koordinasiya imkanı yaradır.

Funksional təhlil metodu sosial işin idarə olunmasının əsas funksiyalarını araşdırmaq üçün istifadə olunmuşdur. Burada planlaşdırma, təşkil etmə, koordinasiya, nəzarət, monitoring və qiymətləndirmə funksiyalarının risk ailələri ilə işdə rolu ayrıca dəyərləndirilmişdir. Bu yanaşma göstərmişdir ki, sosial işin səmərəliliyi yalnız yardımın həcmi ilə deyil, həmin yardımın hansı funksional mexanizmlərlə idarə olunması ilə də bağlıdır.

Ümumiləşdirmə metodu isə təhlil nəticəsində əldə olunan fikir və yanaşmaları bir sistem halında toplamaq üçün tətbiq edilmişdir. Bu metod nəticəsində risk ailələri ilə sosial işin təşkili sahəsində əsas idarəetmə texnologiyaları, onların tətbiq əhəmiyyəti və inkişaf perspektivləri ümumi nəzəri çərçivə daxilində təqdim olunmuşdur.

Tədqiqatın metodoloji çərçivəsində sosial işin təşkili ilə bağlı aşağıdakı əsas meyarlar nəzərə alınmışdır: ehtiyacların dəqiq müəyyənləşdirilməsi, xidmətlərin əlçatanlığı, institusional koordinasiya səviyyəsi, məlumat mübadiləsinin effektivliyi, nəticələrin ölçülə bilməsi, xidmət keyfiyyəti və müdaxilənin dayanıqlılığı. Bu meyarlar əsasında risk ailələri ilə işdə idarəetmə texnologiyalarının səmərəliliyi qiymətləndirilmişdir.

Belə metodoloji yanaşma mövzunun həm nəzəri, həm də praktik əhəmiyyətini üzə çıxarmağa imkan verir. Nəticədə risk qrupuna daxil olan ailələrlə sosial işin təşkili yalnız sosial müdafiə məsələsi deyil, həm də elmi əsaslara söykənən idarəetmə və institusional inkişaf sahəsi kimi xarakterizə olunur.

Nəticə

Aparılmış araşdırma göstərir ki, risk qrupuna daxil olan ailələrlə sosial işin təşkili mürəkkəb, çoxsəviyyəli və yüksək peşəkarlıq tələb edən sosial idarəetmə sahəsidir. Belə ailələrin problemləri yalnız maddi çatışmazlıqla məhdudlaşmır, psixoloji, hüquqi, davranış və institusional çətinliklərlə də müşayiət olunur. Buna görə sosial işin təşkilində ənənəvi yardım modelləri ilə kifayətlənmək mümkün deyil. Müasir şəraitdə bu sahədə idarəetmə texnologiyalarının tətbiqi zəruri xarakter daşıyır. [13, 417 s.]

Tədqiqat nəticəsində müəyyən edilmişdir ki, risk ailələri ilə sosial işin effektivliyi risk faktorlarının düzgün sistemləşdirilməsindən, ailənin ehtiyaclarının dəqiq qiymətləndirilməsindən, sosial xidmətlərin planlı və koordinasiya şəkildə təşkilindən asılıdır. Sosial xidmətlərin idarə olunmasında planlaşdırma, təşkil etmə, koordinasiya, nəzarət, monitoring və qiymətləndirmə funksiyalarının vahid sistem şəklində işləməsi müdaxilənin nəticəyönlü olmasına şərait yaradır.

Araşdırma onu da göstərmişdir ki, dövlət və qeyri-dövlət institutları arasında qarşılıqlı fəaliyyətin zəif qurulması sosial xidmətlərin səmərəliliyini azaldır. Əksinə, institusional integrasiya, məlumat mübadiləsi və vahid xidmət marşrutlarının mövcudluğu risk ailələri ilə işin keyfiyyətini artırır. Xüsusilə müasir idarəetmə texnologiyaları, o cümlədən rəqəmsal qeydiyyat sistemləri, elektron məlumat bazaları, onlayn monitoring və nəticəyönlü qiymətləndirmə mexanizmləri sosial müdaxilənin operativliyini, şəffaflığını və əlçatanlığını əhəmiyyətli dərəcədə yüksəldir.

Belə nəticəyə gəlmək olar ki, risk qrupuna daxil olan ailələrlə sosial işin təşkili humanitar dəstək prinsipləri ilə yanaşı, elmi əsaslandırılmış idarəetmə yanaşmaları üzərində qurulmalıdır. Bu sahənin inkişafı sosial sabitliyin möhkəmləndirilməsi, ailə institutunun qorunması, uşaqların sosial müdafiəsinin gücləndirilməsi və ümumilikdə sosial siyasətin effektivliyinin artırılması baxımından mühüm strateji əhəmiyyətə malikdir.

Müzakirələr

Risk qrupuna daxil olan ailələrlə sosial işin təşkili sahəsində əsas müzakirə məsələlərindən biri sosial müdaxilənin mahiyyətidir. Ənənəvi yanaşmalar bu ailələrlə işi daha çox yardım və himayə modeli üzərində qurmuşdur. Lakin müasir yanaşmalar göstərir ki, sadəcə yardım göstərilməsi ailənin risk vəziyyətindən çıxması üçün kifayət etmir. Ailənin resurs potensialının üzə çıxarılması, sosial adaptasiya imkanlarının bərpası və problemlərin təkrar yaranmasının qarşısının alınması üçün daha dərin və idarəolunan müdaxilə tələb olunur. Bu səbəbdən sosial işin təşkilində idarəetmə texnologiyalarına diqqətin artması tam əsaslıdır.

Digər müzakirə məsələsi institusional əməkdaşlıqla bağlıdır. Təcrübədə tez-tez rast gəlinən problemlərdən biri müxtəlif qurumların eyni ailə ilə bağlı bir-birindən xəbərsiz işləməsidir. Bu isə həm resurs itkisinə, həm də xidmətlərin parçalanmasına gətirib çıxarır. Məsələn, ailəyə sosial yardım göstərilərsə də, paralel olaraq psixoloji və hüquqi dəstək təmin olunmursa, problem uzunmüddətli həllini tapmır. Buna görə də sosial işin təşkilində vahid idarəetmə mexanizminin və ya koordinasiya platformasının yaradılması perspektivli istiqamət kimi qiymətləndirilə bilər. [12, 223 s.]

Rəqəmsal idarəetmə texnologiyalarının tətbiqi də müzakirəyə açıq mühüm mövzulardan biridir. Bu texnologiyalar məlumatların operativ toplanması, ailə tarixçəsinin izlənməsi, xidmətlərin planlaşdırılması və monitoringi üçün geniş imkanlar yaradır. Bununla belə, burada məxfilik, etik yanaşma, məlumat təhlükəsizliyi və insan amilinin qorunması kimi məsələlər xüsusi həssaslıq tələb edir. Sosial işdə rəqəmsallaşma insanla birbaşa əlaqəni əvəz etməməli, əksinə, peşəkar sosial müdaxiləni dəstəkləyən vasitə kimi çıxış etməlidir.

Müzakirə tələb edən başqa bir məqam sosial xidmətlərin keyfiyyətinin necə ölçülməsi ilə bağlıdır. Çox vaxt bu sahədə fəaliyyətin səmərəliliyi yalnız xidmət göstərilən ailələrin sayı ilə ölçülür. Halbuki əsas məsələ ailənin vəziyyətində baş verən real dəyişikliklərdir. Uşağın məktəbə davamiyyətinin bərpası, ailədaxili konfliktlərin azalması, maddi sabitliyin artması, psixoloji dəstəyin

nəticə verməsi kimi indikatorlar sosial işin keyfiyyətini daha obyektiv göstərir. Bu baxımdan nəticəyönlü idarəetmə modelinin tətbiqi xüsusi əhəmiyyət daşıyır.

Gələcək inkişaf istiqamətləri kontekstində risk ailələri ilə sosial iş sahəsində çevik idarəetmə sistemlərinin, integrasiya olunmuş sosial xidmət platformalarının, erkən xəbərdarlıq mexanizmlərinin və ailə yönümlü sosial siyasət alətlərinin gücləndirilməsi vacib görünür. Eyni zamanda sosial işçilərin peşə hazırlığının artırılması, rəqəmsal bacarıqların inkişaf etdirilməsi və keyfiyyət standartlarının təkmilləşdirilməsi də idarəetmə texnologiyalarının effektivliyini artıran mühüm şərtlərdir. [14, 245 s.]

Beləliklə, risk qrupuna daxil olan ailələrlə sosial işin təşkili yalnız mövcud sosial problemlərin aradan qaldırılmasına deyil, sosial sistemin daha dayanıqlı və preventiv əsaslar üzərində qurulmasına xidmət edən strateji fəaliyyət sahəsidir. İdarəetmə texnologiyalarının elmi və praktik əsaslarla tətbiqi bu sahənin gələcək inkişafını müəyyən edən əsas istiqamətlərdən biri kimi çıxış edir.

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Ailədaxili zorakılığın profilaktikasında sosial iş texnologiyalarının idarəetmə mexanizmləri və effektivlik modelləri

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Xülasə

Ailədaxili zorakılıq müasir cəmiyyətlərdə sosial sabitliyə və fərdlərin psixoloji rifahına ciddi təsir göstərən mürəkkəb sosial problemlərdən biridir. Bu problemin qarşısının alınması yalnız hüquqi mexanizmlərlə deyil, həm də sosial iş texnologiyalarının effektiv tətbiqi ilə mümkün olur. Məqalədə ailədaxili zorakılığın profilaktikasında sosial iş texnologiyalarının idarəetmə mexanizmləri və onların effektivliyini müəyyən edən modellər elmi-nəzəri və praktik baxımdan geniş şəkildə təhlil olunur. Sosial iş sahəsində tətbiq olunan texnologiyaların planlaşdırılması, təşkili, icrası, monitorinqi və qiymətləndirilməsi mərhələləri sistemli yanaşma çərçivəsində araşdırılır. Tədqiqat çərçivəsində erkən müdaxilə strategiyaları, risk qruplarının müəyyənləşdirilməsi, sosial xidmətlərin koordinasiyası, multidissiplinar əməkdaşlıq və icma əsaslı yanaşmaların rolu xüsusi diqqət mərkəzində saxlanılır. Sosial iş texnologiyalarının idarə olunmasında institusional resursların səmərəli istifadəsi, peşəkar kompetensiyaların inkişafı və idarəetmə proseslərinin optimallaşdırılması məsələləri də təhlil olunur. Bununla yanaşı, rəqəmsal sosial xidmət platformalarının tətbiqi, məlumatların sistemləşdirilməsi və informasiya texnologiyalarının profilaktik fəaliyyətə integrasiyası qiymətləndirilir. Effektivlik modelləri kontekstində sosial müdaxilələrin nəticələri xidmətlərin əlçatanlığı, keyfiyyəti, davamlılığı, sosial təsir göstəriciləri və istifadəçi yönümlülük prinsipləri əsasında qiymətləndirilir.

Açar sözlər: ailədaxili zorakılıq, sosial iş texnologiyaları, idarəetmə mexanizmləri, profilaktika, effektivlik modelləri, sosial müdaxilə

Abstract

Domestic violence is one of the most complex social problems that significantly affects social stability and the psychological well-being of individuals in modern societies. The prevention of this issue is possible not only through legal mechanisms but also through the effective application of social work technologies. This article comprehensively examines the management mechanisms of social work technologies in the prevention of domestic violence, as well as the models that determine their effectiveness from both theoretical and practical perspectives. The stages of planning, organization, implementation, monitoring, and evaluation of technologies used in social work are analyzed within a systematic framework. Within the scope of the study, particular attention is paid to early intervention strategies, identification of risk groups, coordination of social services, multidisciplinary cooperation, and community-based approaches. The role of institutional resource management, development of professional competencies, and optimization of management processes in the administration of social work technologies are also explored. In addition, the integration of digital social service platforms, data systematization, and information technologies into preventive activities is evaluated.

In the context of effectiveness models, the outcomes of social interventions are assessed based on criteria such as accessibility, quality, sustainability, social impact indicators, and user-centered approaches.

Keywords: domestic violence, social work technologies, management mechanisms, prevention, effectiveness models, social services, early intervention

Giriş

Ailədaxili zorakılıq global miqyasda geniş yayılmış və sosial münasibətlərin strukturuna ciddi təsir göstərən problemlərdən biridir. Bu fenomen yalnız fərdlərin fiziki və psixoloji sağlamlığına zərər verməklə kifayətlənmir, həm də ailə institutunun funksionallığını zəiflədir və sosial sabitliyə mənfi təsir göstərir. Müasir dövrdə ailədaxili zorakılığın qarşısının alınması kompleks və sistemli yanaşma tələb edən sosial məsələ kimi dəyərləndirilir. Bu baxımdan, sosial iş sahəsində tətbiq olunan texnologiyaların məqsədyönlü şəkildə idarə olunması xüsusi aktualıq kəsb edir. [1, s. 190–199]

Sosial iş texnologiyaları ailədaxili zorakılığın profilaktikasında mühüm alət kimi çıxış edir. Bu texnologiyalar fərdi, ailə və icma səviyyəsində müdaxilələri əhatə etməklə yanaşı, sosial xidmətlərin təşkilini, koordinasiyasını və davamlılığını təmin edir. Eyni zamanda, sosial iş texnologiyalarının effektivliyi onların düzgün planlaşdırılması, resursların optimal bölüşdürülməsi və nəticələrin davamlı monitorinqi ilə birbaşa əlaqəlidir. [2] Bu kontekstdə idarəetmə mexanizmlərinin elmi əsaslarla qurulması sosial müdaxilələrin səmərəliliyini artıran əsas amillərdən biri hesab olunur.

Müasir yanaşmalar sosial iş fəaliyyətində multidissiplinar əməkdaşlığın, erkən müdaxilə strategiyalarının və rəqəmsal texnologiyaların integrasiyasını ön plana çıxarır. Bu istiqamətlər ailədaxili zorakılığın risk faktorlarının vaxtında müəyyənləşdirilməsinə və preventiv tədbirlərin daha effektiv həyata keçirilməsinə şərait yaradır. Bununla yanaşı, sosial xidmət sistemində idarəetmə proseslərinin təkmilləşdirilməsi və innovativ modellərin tətbiqi mövcud problemlərin aradan qaldırılmasına yönəlmiş mühüm addım kimi çıxış edir.

Bu məqalənin məqsədi ailədaxili zorakılığın profilaktikasında sosial iş texnologiyalarının idarəetmə mexanizmlərini və onların effektivlik modellərini elmi baxımdan təhlil etmək, həmçinin bu sahədə mövcud yanaşmaların təkmilləşdirilməsi istiqamətində əsaslandırılmış nəticələr təqdim etməkdir.

Ədəbiyyat icmalı

Ailədaxili zorakılığın profilaktikası və bu sahədə sosial iş texnologiyalarının idarə olunması məsələsi müxtəlif elmi istiqamətlərdə geniş tədqiq edilmişdir. Mövcud ədəbiyyat göstərir ki, ailədaxili zorakılıq çoxfaktorlu xarakter daşıyır və onun qarşısının alınması üçün kompleks sosial müdaxilə modellərinin tətbiqi zəruridir. Tədqiqatlarda əsas diqqət zorakılığın səbəblərinin müəyyənləşdirilməsinə, risk faktorlarının analizinə və preventiv mexanizmlərin işlənilməsinə yönəlmişdir. [3] Sosial iş nəzəriyyəsində texnologiya anlayışı yalnız texniki vasitələrlə məhdudlaşmır, eyni zamanda metodlar, yanaşmalar və idarəetmə strategiyalarını əhatə edir. Bir sıra tədqiqatçılar sosial iş texnologiyalarını fərdi yanaşma, ailə terapiyası, krizis müdaxiləsi və icma əsaslı proqramlar kimi təsnifləşdirirlər. Bu yanaşmaların effektivliyi onların düzgün idarə olunmasından və müxtəlif sosial institutlar arasında koordinasiyanın səviyyəsindən asılıdır.

Ədəbiyyatda idarəetmə mexanizmləri çərçivəsində planlaşdırma, təşkilatlandırma, resursların bölüşdürülməsi, monitorinq və qiymətləndirmə mərhələləri xüsusi vurğulanır. Bu proseslərin sistemli şəkildə həyata keçirilməsi sosial xidmətlərin keyfiyyətinə və əlçatanlığına birbaşa təsir göstərir. Eyni zamanda, multidissiplinar əməkdaşlıq modeli hüquq-mühafizə orqanları, sosial xidmətlər və səhiyyə sistemləri arasında qarşılıqlı fəaliyyət – effektiv profilaktikanın əsas şərtlərindən biri kimi qiymətləndirilir. [4] Son illərdə aparılan tədqiqatlarda rəqəmsal texnologiyaların sosial iş sahəsinə integrasiyası xüsusi yer tutur. Elektron məlumat bazaları, onlayn müraciət sistemləri və distant sosial xidmətlər ailədaxili zorakılıq hallarının erkən aşkar olunmasına

və operativ müdaxiləyə imkan yaradır. Bununla yanaşı, effektivlik modelləri kontekstində sosial müdaxilələrin nəticələrinin ölçülməsi üçün keyfiyyət və kəmiyyət göstəricilərinin tətbiqi geniş yayılmışdır.

Cədvəl 1 Mövzu üzrə əsas yanaşmaların müqayisəli cədvəli

Yanaşma / Model	Əsas məzmun	İdarəetmə mexanizmi	Üstün cəhətlər	Məhdudiyyətlər
Fərdi yanaşma modeli	Zərərçəkmişlə fərdi iş, psixososial dəstək	Fərdi planlaşdırma və monitoring	Fərdi ehtiyaclara uyğunluq	Resurs baxımından məhdud
Ailə əsaslı müdaxilə	Ailə daxilində münasibətlərin bərpası	Koordinasiyalı sosial xidmətlər	Uzunmüddətli təsir	Münaqişə riskinin qalması
Krizis müdaxilə modeli	Təcili hallarda operativ dəstək	Sürətli qərarvermə və resurs səfərbərliyi	Vaxtında müdaxilə	Qısamüddətli təsir
İcma əsaslı yanaşma	Cəmiyyət səviyyəsində profilaktika	Yerli resursların idarə olunması	Geniş əhatə dairəsi	Effektin ölçülməsi çətin
Multidissiplinar model	Müxtəlif qurumların əməkdaşlığı	İnstitusional koordinasiya	Kompleks yanaşma	İdarəetmə çətinliyi
Rəqəmsal sosial iş texnologiyaları	Elektron xidmətlər və məlumat sistemləri	Texnoloji integrasiya və monitoring	Operativlik və əlçatanlıq	Texniki və etik risklər

Mənbə: Exploring the Role of Social Workers in Addressing Domestic Violence. (2024).

Təqdim olunan cədvəl ailədaxili zorakılığın profilaktikasında tətbiq olunan əsas sosial iş

Cədvəl 1-də təqdim olunan yanaşmalar ailədaxili zorakılığın profilaktikasında sosial iş texnologiyalarının fərqli idarəetmə məntiqi əsasında qurulduğunu göstərir. Fərdi yanaşma modeli əsasən mikro səviyyədə təsir göstərir və birbaşa zərərçəkənin psixososial ehtiyaclarına uyğun müdaxilə planı qurmağa imkan verir. Bu model yüksək dərəcədə fərdiləşdirilmiş dəstək verdiyi üçün halların dərinləşdirilmiş qiymətləndirilməsində üstünlük təşkil edir. Lakin onun institusional miqyasda tətbiqi böyük insan resursu, davamlı müşayiət və müntəzəm monitoring tələb etdiyindən, geniş əhatəli profilaktika baxımından məhdudiyyət yaradır.

Ailə əsaslı müdaxilə modeli isə problemi yalnız fərdi zərərçəkən səviyyəsində deyil, ailədaxili münasibətlər sistemi daxilində nəzərdən keçirir. Bu modelin üstünlüyü ondan ibarətdir ki, zorakılığı yaradan və ya gücləndirən münasibət strukturlarına təsir göstərməyə çalışır. Bununla belə, ailə daxilində güc balansının pozulması, təkrar zorakılıq ehtimalı və tərəflər arasında etimad çatışmazlığı bu yanaşmanın tətbiqini çətinləşdirə bilər. Başqa sözlə, ailə əsaslı müdaxilə yalnız təhlükəsizlik təmin olunduğu və peşəkar koordinasiya mövcud olduğu hallarda daha effektiv nəticə verir.

Krizis müdaxilə modeli sürətli reaksiya mexanizmi ilə seçilir və təcili hallarda həyat, sağlamlıq və təhlükəsizlik risklərini minimuma endirmək baxımından mühüm əhəmiyyət daşıyır. Onun əsas gücü operativlik, xidmətlərin təxirəsalınmadan səfərbər edilməsi və ilkin müdaxilə imkanlarının yüksək olmasıdır. Ancaq bu modelin təsiri çox vaxt qısamüddətli xarakter daşıyır və sonrakı mərhələdə fərdi, ailəvi və ya institusional dəstək mexanizmləri ilə tamamlanmadıqda dayanıqlı nəticə yaratmır.

İcma əsaslı yanaşma daha çox makro və mezzo səviyyədə profilaktik təsir formalaşdırır. Burada əsas məqsəd yalnız konkret hallara reaksiya vermək deyil, sosial mühitdə zorakılığa tolerantlığı azaltmaq, maarifləndirmə aparmaq, yerli resursları aktivləşdirmək və sosial dəstək şəbəkələrini gücləndirməkdir. Bu modelin əhatə dairəsi geniş olsa da, onun nəticələrinin ölçülməsi və qısamüddətli effektivliyinin dəyərləndirilməsi daha mürəkkəbdir. Buna görə də icma əsaslı yanaşma çox vaxt digər modellərlə birlikdə tətbiq edildikdə daha faydalı olur.

Multidissiplinar model sosial xidmət, hüquq-mühafizə, səhiyyə, təhsil və psixoloji yardım institutları arasında qarşılıqlı əlaqə yaratdığı üçün ən kompleks yanaşmalardan biri sayılır. Bu modelin başlıca üstünlüyü problemin yalnız sosial deyil, hüquqi, tibbi və psixoloji tərəflərinin də eyni vaxtda nəzərə alınmasıdır. Lakin burada əsas çətinlik koordinasiya, informasiya mübadiləsi, səlahiyyət bölgüsü və vahid qərarvermə mexanizmlərinin təşkili ilə bağlıdır. Bu səbəbdən multidissiplinar model yüksək potensiala malik olsa da, yalnız güclü institusional idarəetmə mövcud olduqda maksimum effektivlik verir.

Rəqəmsal sosial iş texnologiyaları isə müasir dövrdə profilaktik müdaxilələrin operativliyini və əlçatanlığını artıran yeni idarəetmə vasitəsi kimi çıxış edir. Elektron platformalar, məlumat bazaları, onlayn müraciət sistemləri və rəqəmsal izləmə mexanizmləri risk qruplarının daha tez müəyyənləşdirilməsinə və xidmətlərin koordinasiyasının sürətlənməsinə şərait yaradır. Bununla yanaşı, bu yanaşma texniki infrastruktur, məlumat təhlükəsizliyi, etik məxfilik və rəqəmsal bərabərsizlik kimi məsələləri də gündəmə gətirir. Bu baxımdan rəqəmsal model ənənəvi sosial iş yanaşmalarını əvəz edən deyil, onları tamamlayan və gücləndirən sistem kimi qiymətləndirilməlidir.

Metodologiya

Tədqiqatın metodoloji əsasını ailədaxili zorakılığın profilaktikasında sosial iş texnologiyalarının idarəetmə mexanizmlərinin və effektivlik modellərinin kompleks şəkildə öyrənilməsinə yönəlmiş sistemli və integrativ yanaşma təşkil edir. Araşdırmada problemin çoxölçülü xarakteri nəzərə alınaraq həm keyfiyyət, həm də kəmiyyət tədqiqat metodlarının uzlaşdırılmış tətbiqi təmin edilmişdir.

Keyfiyyət mərhələsində elmi ədəbiyyatın dərin analizi aparılmış, sosial iş texnologiyalarının nəzəri əsasları, idarəetmə prinsipləri və profilaktik müdaxilə modelləri sistemləşdirilmişdir. Bununla yanaşı, normativ-hüquqi sənədlərin təhlili vasitəsilə ailədaxili zorakılığın qarşısının alınması sahəsində mövcud institusional çərçivə və idarəetmə mexanizmlərinin xüsusiyyətləri müəyyən edilmişdir. [6] Müqayisəli analiz metodu müxtəlif ölkələrdə tətbiq olunan sosial iş yanaşmalarının struktur və funksional fərqlərini üzə çıxarmağa imkan vermişdir.

Kəmiyyət yanaşması çərçivəsində sosial xidmətlərin fəaliyyət göstəricilərinə dair statistik məlumatlar təhlil edilmiş, xidmətlərin effektivliyi müəyyən indikatorlar üzrə qiymətləndirilmişdir. Bu indikatorlara xidmətlərin əlçatanlığı, müdaxilələrin davamlılığı, nəticəyönümlülük səviyyəsi və sosial təsir dərəcəsi daxil edilmişdir. Məlumatların emalı zamanı deskriptiv analiz və strukturlaşdırılmış müqayisə üsullarından istifadə olunmuşdur.

Empirik mərhələdə sosial iş mütəxəssisləri ilə yarı-strukturlaşdırılmış müsahibələr və sorğular keçirilmişdir. Respondentlərin seçimi məqsədyönlü seçmə prinsipi əsasında həyata keçirilmiş və sosial xidmət sistemində fəaliyyət göstərən müxtəlif ixtisaslı mütəxəssislər tədqiqata cəlb edilmişdir. [7] Toplanmış məlumatların təhlilində tematik kodlaşdırma və interpretativ yanaşma tətbiq olunmuş, əsas tendensiyalar və problemlər müəyyənləşdirilmişdir.

Tədqiqat prosesində etibarlılıq və obyektivliyin təmin edilməsi məqsədilə məlumatların triangulyasiyası həyata keçirilmiş, müxtəlif mənbələrdən əldə olunan nəticələr qarşılaşdırılmışdır. Eyni zamanda etik prinsiplərə riayət olunmuş, respondentlərin anonimliyi və məlumatların məxfiliyi qorunmuşdur. Bu metodoloji çərçivə əldə olunan nəticələrin elmi əsaslılığını və praktik tətbiq imkanlarını təmin edir.

Metod və dəyişənlər

Tədqiqatın metodoloji çərçivəsində istifadə olunan metodların konkretləşdirilməsi və dəyişənlərin sistemli şəkildə müəyyən edilməsi araşdırmanın elmi əsaslılığını təmin edən əsas mərhələlərdən birini təşkil edir. Bu kontekstdə ailədaxili zorakılığın profilaktikasında sosial iş texnologiyalarının idarə olunmasının effektivliyini qiymətləndirmək məqsədilə analitik, empirik və müqayisəli yanaşmaların integrasiyasına üstünlük verilmişdir. Seçilmiş metodlar tədqiqat obyektinin çoxşaxəli xarakterini nəzərə almaqla həm nəzəri, həm də praktik səviyyədə əsaslandırılmış nəticələrin əldə edilməsinə yönəldilmişdir.

Empirik mərhələdə məlumatların toplanması üçün sorğu və yarı-strukturlaşdırılmış müsahibə üsullarından istifadə olunmuşdur. Sorğu aləti sosial iş sahəsində fəaliyyət göstərən mütəxəssislərin gündəlik praktikada qarşılaşdıqları idarəetmə problemlərini, texnologiyaların tətbiq səviyyəsini və xidmətlərin təşkili ilə bağlı mövcud yanaşmaları sistemləşdirmək məqsədi daşıyır. Sorğu forması qapalı və açıq sualların kombinasiyası əsasında tərtib olunmuş, bu isə həm kəmiyyət, həm də keyfiyyət xarakterli məlumatların əldə edilməsinə şərait yaratmışdır. Yarı-strukturlaşdırılmış müsahibələr vasitəsilə isə idarəetmə proseslərinin daxili məntiqi, qərarvermə mexanizmləri və institusional qarşılıqlı əlaqələrin praktik xüsusiyyətləri daha dərin səviyyədə araşdırılmışdır. [8, s. 664–675]

Sənəd analizi tədqiqatın mühüm komponentlərindən biri kimi çıxış edir. Bu mərhələdə normativ-hüquqi aktlar, dövlət proqramları, sosial xidmət standartları və metodiki göstərişlər təhlil olunaraq sosial iş texnologiyalarının tətbiq mühiti və idarəetmə çərçivəsi sistemləşdirilmişdir. Mövcud modellərin struktur xüsusiyyətlərinin müqayisəsi idarəetmə mexanizmlərinin funksional fərqlərini müəyyən etməyə imkan vermişdir. Dəyişənlərin müəyyənləşdirilməsi tədqiqatın analitik hissəsinin əsasını təşkil edir. Müstəqil dəyişənlər sosial iş texnologiyalarının növünü (fərdi, ailəvi, icma əsaslı və rəqəmsal yanaşmalar), idarəetmə mexanizmlərinin struktur səviyyəsini, resurs təminatının həcmi və mütəxəssislərin peşəkar kompetensiya göstəricilərini əhatə edir. Bu dəyişənlər sosial müdaxilələrin təşkilinə birbaşa təsir göstərən faktorlar kimi nəzərdən keçirilir. Asılı dəyişənlər isə profilaktik fəaliyyətin nəticə göstəricilərini ifadə edir və xidmətlərin əlçatanlığı, müdaxilələrin davamlılığı, risklərin azaldılması dinamikası və sosial təsirin intensivliyi kimi ölçülə bilən indikatorlar əsasında qiymətləndirilir. Nəzarət dəyişənləri tədqiqat nəticələrinin daha dəqiq interpretasiyası üçün nəzərə alınmışdır. Bu qrupa sosial-iqtisadi şərait, regionlar üzrə xidmətlərin inkişaf səviyyəsi, institusional mühitin xüsusiyyətləri və hüquqi tənzimləmə mexanizmləri daxildir. Bu amillərin təsirinin ayrılıqda nəzərə alınması əsas dəyişənlər arasında əlaqələrin daha obyektiv şəkildə müəyyənləşdirilməsinə imkan yaradır. [9, s. 575–583]

İlkin nəticələr və müzakirə

Ailədaxili zorakılığın profilaktikasında sosial iş texnologiyalarının effektivliyinin qiymətləndirilməsi yalnız nəzəri modellərin müqayisəsi ilə məhdudlaşmamalı, həm də ailə və gender kontekstini xarakterizə edən statistik göstəricilər əsasında dəstəklənməlidir. Bu baxımdan Azərbaycan üzrə rəsmi demoqrafik və gender göstəriciləri sosial müdaxilə modellərinin hansı sosial mühitdə tətbiq olunduğunu anlamaq üçün mühüm analitik baza yaradır. Dövlət Statistika Komitəsinin məlumatlarına görə, 2025-ci ilin əvvəlinə ölkə əhalisinin 50,2%-ni qadınlar təşkil edib; 2024-cü ildə 102,3 min uşaq doğulub və onların 47,0%-i qız olub. Eyni mənbədə qadınların məşğul əhali içində payı 48,0%, dövlət qulluğunda 29,7%, sahibkarlar arasında isə 23,3% göstərilir. Bu göstəricilər ailədaxili zorakılıqla mübarizə siyasətində qadınların həm risk qrupu, həm də sosial-iqtisadi subyekt kimi ayrıca nəzərə alınmalı olduğunu göstərir.

Rəsmi demoqrafik statistika ailə institutunun vəziyyətini xarakterizə edən nikah, boşanma, uşaqlı ailələrdə boşanmalar və ev təsərrüfatlarının tərkibi kimi göstəriciləri də ayrıca izləyir. Bu cür məlumatlar ailədaxili zorakılığın profilaktikası sahəsində sosial iş texnologiyalarının hədəflənməsi üçün vacibdir, çünki müdaxilə mexanizmlərinin effektivliyi ailənin strukturu, uşaqların mövcudluğu və ailədaxili gərginlik yaradan sosial-demoqrafik amillərlə sıx bağlıdır. Dövlət Statistika Komitəsinin

demoqrafiya bölməsində rəsmi qeydə alınmış nikah və boşanmalar, 18 yaşadək uşağı olan ailələrdə boşanmalar, eləcə də ev təsərrüfatlarının üzvlərinin və uşaqların sayına görə bölgüsü ayrıca statistik blok kimi təqdim edilir.

2024-cü il üzrə rəsmi qeydiyyat göstəriciləri də ailə institutundakı dəyişmələrin intensivliyini göstərir. Həmin il Azərbaycanda 49 508 nikah və 21 384 boşanma qeydə alınıb. Bu məlumat ailədaxili münasibətlər sistemində sosial risklərin təhlili üçün əhəmiyyətlidir, çünki boşanma göstəricilərinin yüksəkliyi ailə daxilində konflikt, gərginlik və zorakılıq risklərinin öyrənilməsi üçün əlavə analitik zəmin yaradır.

Cədvəl 2. Azərbaycanda ailə və gender kontekstini xarakterizə edən seçilmiş göstəricilər

Göstərici	Dövr	Dəyər	Analitik əhəmiyyəti
Rəsmi qeydə alınmış nikahların sayı	2024	49 508	Ailə institutunun formallaşma intensivliyini göstərir
Rəsmi qeydə alınmış boşanmaların sayı	2024	21 384	Ailədaxili gərginlik və sosial risklərin təhlili üçün baza yaradır
Əhalinin hər 1000 nəfərinə nikahların sayı	2024	4,9	Ailə qurma dinamikasını xarakterizə edir
Əhalinin hər 1000 nəfərinə boşanmaların sayı	2024	2,1	Ailə sabitliyi ilə bağlı sosial göstəricidir
Qadınların ümumi əhali içində payı	2025-ci ilin əvvəli	50,2%	Gender balansını göstərir
Diri doğulan uşaqların sayı	2024	102,3 min	Ailə-demoqrafik mühitin əsas göstəricisidir
Diri doğulan qız uşaqlarının payı	2024	47,0%	Gender strukturu baxımından əhəmiyyətlidir
Qadınların məşğul əhali içində payı	2024 üzrə ilkin məlumat	48,0%	İqtisadi müstəqillik və sosial həssaslıq kontekstində vacibdir
Qadınların dövlət qulluğunda payı	2024 üzrə ilkin məlumat	29,7%	İdarəetmə və institusional təmsil göstəricisidir
Qadınların sahibkarlar arasında payı	2024 üzrə ilkin məlumat	23,3%	Sosial-iqtisadi güclənmə göstəricisidir

Mənbə: müəllif tərəfindən Azərbaycan Respublikasının Dövlət Statistika Komitəsinin rəsmi məlumatları əsasında tərtib edilmişdir.

Cədvəl 2 göstərir ki, ailədaxili zorakılığın profilaktikası sahəsində sosial iş texnologiyalarının qiymətləndirilməsi yalnız keyfiyyət göstəriciləri ilə məhdudlaşdırılmamalıdır. Nikah və boşanma göstəriciləri ailə institutunun sabitlik dərəcəsini, qadınların məşğulluq və sahibkarlıq göstəriciləri isə iqtisadi müstəqillik səviyyəsini əks etdirir. Bu göstəricilər sosial müdaxilə modellərinin hansı sosial-demoqrafik fon üzərində tətbiq olunduğunu göstərdiyi üçün idarəetmə mexanizmlərinin planlaşdırılmasında vacib rol oynayır. Xüsusilə qadınların ümumi əhali və məşğulluq strukturunda yüksək paya malik olması, ailədaxili zorakılıqla mübarizə siyasətində gender-həssas, məlumat əsaslı və çoxsəviyyəli sosial iş modellərinin seçilməsini zəruri edir.

Kompleks və integrativ yanaşmanın tətbiqi sosial iş texnologiyalarının idarə olunmasını daha səmərəli hala gətirir və profilaktik tədbirlərin təsir dairəsini genişləndirir. [12] Bu çərçivədə idarəetmə mexanizmlərinin optimallaşdırılması, resursların məqsədyönlü istifadəsi və institusional əməkdaşlığın gücləndirilməsi ailədaxili zorakılığın qarşısının alınmasına yönəlmiş sistemli dəyişikliklərin formalaşmasına real zəmin yaradır. Bu yanaşma sosial müdaxilələrin uzunmüddətli təsirini gücləndirən əsas istiqamətlərdən biri kimi qiymətləndirilə bilər.

Nəticə və tövsiyələr

Aparılan tədqiqat ailədaxili zorakılığın profilaktikasında sosial iş texnologiyalarının idarə olunmasının strateji əhəmiyyətini üzə çıxarır. Sosial müdaxilələrin səmərəliliyi yalnız tətbiq olunan metodların seçimi ilə deyil, həm də bu proseslərin necə idarə olunması ilə müəyyən olunur. İdarəetmə mexanizmlərinin strukturlaşdırılmış və məqsədyönlü şəkildə qurulması sosial xidmətlərin keyfiyyətinə, davamlılığına və nəticəyönlümlülyünə birbaşa təsir göstərir. Bu baxımdan sosial iş texnologiyalarının effektivliyi onların planlı, koordinasiyalı və resurslara uyğun şəkildə təşkil olunması ilə sıx bağlıdır. [13, s. 195–201]

Araşdırma çərçivəsində diqqət çəkən əsas məqamlardan biri erkən müdaxilə yanaşmalarının praktik əhəmiyyətidir. Risk qruplarının vaxtında müəyyənləşdirilməsi və profilaktik tədbirlərin ilkin mərhələdə həyata keçirilməsi sosial problemlərin dərinləşməsinin qarşısını almağa imkan verir. Bununla yanaşı, sosial xidmət sistemində müxtəlif institutlar arasında əməkdaşlıq səviyyəsi müdaxilələrin kompleks xarakter almasına və daha geniş sosial təsir yaratmasına şərait yaradır. Bu kontekstdə koordinasiya mexanizmlərinin gücləndirilməsi sosial iş fəaliyyətinin effektivliyini artıran əsas istiqamətlərdən biri kimi çıxış edir.

Rəqəmsal texnologiyaların sosial iş sahəsinə integrasiyası idarəetmə proseslərinin çevikliyini artırır və xidmətlərin əlçatanlığını genişləndirir. Elektron məlumat sistemləri vasitəsilə məlumatların operativ toplanması və emalı qərarvermə proseslərinin daha əsaslandırılmış şəkildə həyata keçirilməsinə imkan yaradır. Bu isə sosial müdaxilələrin daha dəqiq hədəflənməsini və resurslardan səmərəli istifadəni təmin edir.

Mövcud yanaşmaların təhlili əsasında bir sıra praktiki tövsiyələr irəli sürülür. İlk növbədə, sosial iş texnologiyalarının idarə olunmasında vahid və koordinasiyalı mexanizmlərin formalaşdırılması zəruridir. Bu, müxtəlif sosial xidmət qurumları arasında informasiya mübadiləsinin gücləndirilməsini və fəaliyyətlərin uzlaşdırılmasını tələb edir. Eyni zamanda, sosial iş mütəxəssislərinin peşəkar hazırlıq səviyyəsinin artırılması və davamlı təlim proqramlarının tətbiqi mühüm əhəmiyyət kəsb edir. [14] Bu istiqamətdə praktik bacarıqların inkişafına yönəlmis proqramların genişləndirilməsi məqsədəuyğun hesab olunur.

Digər vacib istiqamət resursların optimal bölgüsünün təmin edilməsidir. Sosial xidmət sistemində maliyyə, kadr və texniki resursların balanslı şəkildə bölüşdürülməsi müdaxilələrin davamlılığını təmin edən əsas şərtlərdən biridir. Bununla yanaşı, rəqəmsal platformaların tətbiqinin genişləndirilməsi və məlumat bazalarının integrasiyası sosial xidmətlərin operativliyini artıran mühüm vasitə kimi çıxış edir. Nəticə etibarilə, sosial iş texnologiyalarının idarə olunmasının təkmilləşdirilməsi ailədaxili zorakılığın profilaktikasında daha sistemli və davamlı nəticələrin əldə olunmasına imkan yaradır. Bu sahədə həyata keçirilən tədbirlərin institusional səviyyədə gücləndirilməsi və innovativ yanaşmaların tətbiqi sosial siyasətin effektivliyini artıran əsas amillərdən biri kimi dəyərləndirilir.

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Biological Sciences

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Сравнительный анализ физико-химических и протеомных методов исследования сыворотки крови в диагностике и мониторинге заболеваний животных

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В статье представлен всесторонний обзор современных подходов к анализу сыворотки крови, рассматриваемой в рамках коллоидной биохимии как суперсложная коллоидная система (SCCS). Освещаются теоретические и практические аспекты межфазной тензиометрии, которая позволяет изучать динамическое поверхностное натяжение (ДПН) и кинетику адсорбции поверхностно-активных компонентов на границе раздела фаз. Подробно анализируется диагностическая ценность электрофореза белков в агарозном геле для разделения мажорных фракций и оценки иммунного статуса организма. Рассматриваются высокотехнологичные протеомные методы на базе масс-спектрометрии (MALDI-TOF, LC-MS/MS), направленные на глубокую идентификацию белков и поиск специфических биомаркеров заболеваний. Особое внимание уделено критическим факторам преаналитического этапа, таким как условия забора, температурные режимы хранения и методы преодоления широкого динамического диапазона концентраций сывороточных белков. В заключении обосновывается прикладная значимость комплексного анализа для мониторинга здоровья, ранней диагностики инфекций и контроля физиологических состояний в клинической и ветеринарной практике.

Ключевые слова: сыворотка крови, протеомика, электрофорез, межфазная тензиометрия, масс-спектрометрия.

Введение

Сыворотка крови представляет собой жидкую часть крови, лишенную клеток и факторов свертывания, таких как фибриноген. Она является исключительно сложной многокомпонентной биологической системой, содержащей аминокислоты, белки, факторы роста, гормоны, метаболиты и электролиты. В современной коллоидной биохимии сыворотку рассматривают как «суперсложную коллоидную систему» (SCCS), характеризующуюся сосуществованием множества комплексов биологически активных веществ (например, липопротеинов) с жесткой иерархией в отношениях «структура–свойство».

Анализ сывороточных белков и их электрофоретического профиля является фундаментальным методом лабораторной диагностики, позволяющим выявлять патологические процессы, оценивать нутритивный статус и осуществлять мониторинг терапии в медицине и ветеринарии. Хотя традиционные биохимические тесты часто ограничиваются определением общего белка или соотношения альбумин/глобулин, современные подходы предоставляют гораздо более глубокую информацию о состоянии гомеостаза. В частности, использование физико-химических методов, таких как межфазная тензиометрия, позволяет изучать динамическое поверхностное натяжение (ДПН) сыворотки. Этот метод отражает кинетику адсорбции поверхностно-активных компонентов (белков и липидов) на границе раздела фаз «воздух–жидкость», что служит чувствительным индикатором биохимического статуса и физиологических трансформаций организма.

Протеомные технологии направлены на качественную и количественную характеристику всей совокупности белков, присутствующих в образце в определенный момент времени. Электрофоретические методы разделения позволяют дифференцировать основные фракции глобулинов, что критически важно для диагностики иммунодефицитных состояний, воспалительных процессов и парапротеинемий. Использование масс-спектрометрии открывает возможности для глубокой идентификации («shotgun» протеомика) и поиска новых биомаркеров заболеваний, однако этот процесс осложняется широким динамическим диапазоном концентраций белков. Более 90% общего белка сыворотки представлено лишь 10 мажорными компонентами, что затрудняет доступ к низкопредставленному («скрытому») протеому и требует специфических методов пробоподготовки.

Интеграция протеомных данных с физико-химическими параметрами позволяет создавать комплексные диагностические модели, способствующие раннему выявлению инфекций и оценке благополучия животных. Разработка таких подходов обеспечивает взаимную выгоду для здравоохранения и сельского хозяйства, повышая качество и безопасность биологической продукции.

Преаналитический этап и подготовка образцов

Сыворотка крови представляет собой сложную многокомпонентную систему, состоящую из аминокислот, белков, факторов роста, гормонов и метаболитов, получаемую после удаления из цельной крови клеток, тромбоцитов и факторов свертывания. Процесс получения качественного образца начинается с забора крови и инициации процесса свертывания, который обычно проводят при температуре 37°C в течение 30–60 минут. После формирования сгустка образец необходимо выдержать при температуре 4°C (в холодильнике) в течение периода от 1 часа до ночи, чтобы обеспечить ретракцию (сокращение) сгустка и максимальный выход жидкой фазы. Очистка от остаточных нерастворимых веществ и клеточного осадка достигается путем центрифугирования; рекомендуемые режимы варьируются от 3000 g до 10 000 g в течение 10 минут при 4°C. Специфика сыворотки как объекта исследования заключается в том, что она является

«суперсложной коллоидной системой» (SCCS), где биологически активные вещества существуют в виде иерархии комплексов, таких как липопротеины, что требует строгого соблюдения температурных режимов для предотвращения их деградации. Присутствие свободного гемоглобина вследствие гемолиза (разрушения эритроцитов) или избытка триглицеридов (липемия) может значительно исказить результаты, создавая ложные пики при электрофоретическом разделении в областях глобулинов соответственно.

Критическим вызовом для протеомного анализа является широкий динамический диапазон концентраций белков в сыворотке, охватывающий до 10 порядков, в то время как современные масс-спектрометрические платформы ограничены диапазоном в 5 порядков. Более 90% общего белка сыворотки приходится на долю менее чем 10 мажорных компонентов, таких как альбумин, IgG, антитрипсин, IgA и трансферрин. Для обеспечения доступа к низкопредставленным белкам («скрытому протеому») на преаналитическом этапе применяют методы предварительной обработки: иммунодеплецию (ID) и комбинаторные библиотеки пептидных лигандов (CPLL). Иммунодеплексия позволяет эффективно удалять мажорные белки с помощью специфических антител, однако несет риск «со-деплеции» — случайного удаления целевых белков, связанных с альбумином или иммуноглобулинами. Технология CPLL («выравнивание» протеома) позволяет снизить концентрацию распространенных белков и одновременно сконцентрировать редкие компоненты на специфических пептидных лигандах. Стабильность образцов при хранении является еще одним определяющим фактором: кратковременное хранение допускается при 2–8°C в течение 3–5 дней, однако для длительных исследований необходимо аликвотирование и заморозка при –20°C или ниже (вплоть до –80°C). Нарушение этих условий, например, хранение при комнатной температуре или повторные циклы замораживания-оттаивания, приводит к необратимым изменениям белкового профиля, что проявляется на электрофореграммах в виде слияния и «расплывания» полос и зонах.

Таблица 1. Основные требования и факторы влияния на преаналитическом этапе

Этап / Фактор	Регламентированные условия и параметры	Влияние на результат анализа
Свертывание и ретракция	30–60 мин при 37°C, затем не менее 1 ч при 4°C	Обеспечивает чистоту сыворотки и предотвращает загрязнение факторами свертывания.
Центрифугирование	3000–10 000 g, 10 мин при 4°C	Удаление клеточного детрита и нерастворимых комплексов.
Хранение (краткое)	2–8°C в течение 3–5 дней	При превышении сроков наблюдается слияние белковых фракций на электрофореграмме.
Хранение (длительное)	–20°C ... –80°C, обязательное аликвотирование	Сохранение протеомного профиля в течение многих лет; исключение деградации от циклов оттаивания.
Специфическая подготовка (ID, CPLL)	Удаление мажорных белков (альбумин, IgG)	Повышение чувствительности анализа низкопредставленных биомаркеров в 10–100 раз.
Артефакты (Гемолиз, липемия)	Визуальный контроль и соблюдение техники забора крови	Искажение электрофоретической картины, ложноположительные пики в глобулиновых зонах.

Физико-химические методы: Интерфазная тензиометрия

Межфазная тензиометрия является одним из наиболее перспективных подходов к анализу сыворотки и плазмы крови, которые в современной биохимии рассматриваются как «суперсложные коллоидные системы» (SCCS). Специфика этих жидкостей заключается в сосуществовании множества комплексов биологически активных веществ, таких как липопротеины, имеющих жесткую иерархию в отношении «структура–свойство», что делает невозможным их описание через простые молекулярные взаимодействия. В отличие от статических методов, динамическое поверхностное натяжение (ДПН) позволяет изучать кинетику адсорбции поверхностно-активных компонентов (белков, липидов) на границе раздела фаз «воздух–жидкость», отражая непрерывные молекулярные изменения в системе. Теоретическая интерпретация тензиограмм базируется на уравнении Уорда–Тордая и асимптотической теории, что дает возможность рассчитывать параметры (поверхностное натяжение в конкретные моменты времени) и наклон тензиограммы, напрямую зависящие от общей концентрации и диффузионной способности ПАВ. Исследования показали, что значения натяжения на малых временах жизни поверхности характеризуют преимущественно солевой состав и начальную адсорбцию, тогда как параметры на средних и больших временах определяются присутствием белков и других высокомолекулярных биополимеров. Эти физико-химические показатели крайне чувствительны к физиологическим трансформациям организма, включая возрастное развитие, половой диморфизм и специфические состояния, такие как беременность или лактация, что было подтверждено экспериментально на различных группах животных.

Для комплексного исследования ДПН биологических жидкостей наиболее эффективным признано сочетание метода максимального давления в пузырьке (ВРА) и метода «висячей капли» (РАТ), обеспечивающих охват временного диапазона секунд. Метод ВРА, реализованный в таких приборах как ВРА-1Р, идеально подходит для изучения быстрых процессов адсорбции в интервале от 0,01 до 100 секунд, требуя минимального объема пробы и обеспечивая высокую воспроизводимость результатов. Расчет поверхностного натяжения здесь основывается на измерении избыточного давления, необходимого для отрыва пузырька воздуха от кончика капилляра, согласно уравнению Лапласа. Дополняющий его метод РАТ («висячая капля») позволяет проводить измерения на длительных интервалах времени (до нескольких часов), что критически важно для достижения равновесного состояния в белковых системах. В этом методе профиль капли автоматически анализируется компьютерной системой, которая оптимизирует его в соответствии с теоретическим профилем Лапласа, позволяя вычислять значения натяжения с точностью до 0,1 мН/м. Применение этих высокотехнологичных методов в ветеринарной практике открывает возможности для создания баз данных референтных значений, необходимых для мониторинга здоровья стада, оценки нутритивного статуса и раннего выявления инфекционных заболеваний.

Корреляционный анализ, проведенный впервые для крови животных, выявил наличие устойчивых статистических связей между параметрами ДПН и ключевыми биохимическими маркерами, такими как общий белок, альбумины, триглицериды и электролиты. У лошадей было установлено, что наиболее информативными для оценки биохимического профиля являются параметры и начальный наклон тензиограммы, причем корреляции оказались значительно сильнее и надежнее у самок, чем у самцов. У крупного рогатого скота показатели ДПН претерпевают закономерные изменения в зависимости от стадии репродуктивного цикла: например, у стельных коров на 2-м месяце беременности наблюдается снижение параметров при одновременном росте наклона, что отражает глубокую перестройку обмена веществ. В период лактации у коров фиксируются специфические корреляции: положительно связана с уровнями мочевины и хлоридов, тогда

как - с концентрацией глюкозы и кальция. Использование методов межфазной тензиометрии позволяет во многих случаях заменить трудоемкие и дорогостоящие биохимические анализы экспресс-скринингом, обеспечивая оперативную диагностику патологических процессов и контроль эффективности проводимой терапии.

Таблица 2. Сравнительная характеристика основных методов интерфазной тензиометрии

Параметр сравнения	Метод максимального давления в пузырьке (ВРА)	Метод «висячей капли» (РАТ)
Временной диапазон	Короткие времена (0,01 – 100 с)	Длительные времена (10 – 10 000 с и более)
Объем образца	Несколько миллилитров (адаптировано до 1-2 мл)	Минимальный (менее 0,5 мл)
Физический принцип	Измерение избыточного давления в пузырьке по Лапласу	Анализ геометрического профиля капли
Основные преимущества	Высокая скорость, полная автоматизация, точность на начальных этапах	Термостатирование пробы, изучение равновесной адсорбции белков
Информативность	Отражает содержание низкомолекулярных ПАВ и солей	Отражает состояние макромолекул (белков) и их комплексов
Применение в биохимии	Скрининг солевого баланса и ранней кинетики адсорбции	Глубокий анализ протеомного состава и стабильности SCCS

Электрофоретические методы разделения белков

Электрофорез белков является фундаментальным аналитическим методом, основанным на движении электрически заряженных частиц в растворе под воздействием внешнего электрического поля. В клинической биохимии этот метод наиболее часто применяется для разделения белков сыворотки крови, которые при использовании щелочных буферных систем приобретают отрицательный заряд и мигрируют в сторону положительного полюса (анода). Скорость этой миграции определяется совокупностью характеристик каждой белковой молекулы: её суммарным электрическим зарядом, размером и формой, а также внешними условиями — напряженностью поля, типом поддерживающей среды и температурой. В современной ветеринарной и клинической практике в качестве носителя чаще всего используется агарозный гель, который обеспечивает высокую воспроизводимость и четкость разделения полос. Более современным и высокоразрешающим методом считается капиллярный электрофорез (CZE), где разделение происходит в свободном жидком буфере при высоком напряжении, что позволяет выделять большее количество узких суб-пиков, хотя их интерпретация может быть более сложной. Особое значение имеет нативный электрофорез, проводимый в неденатурирующих условиях, что позволяет анализировать целостные белковые комплексы, которые в присутствии денатурирующих агентов (таких как додецилсульфат натрия или мочевины) распались бы на отдельные субъединицы, мигрирующие исключительно в зависимости от их молекулярной массы.

Основная диагностическая ценность метода заключается в разделении исходной смеси белков сыворотки на 5–6 основных фракций: альбумины, глобулины, каждая из которых имеет независимые метаболические свойства. Альбумин формирует самый высокий и гомогенный пик на электрофореграмме, составляя от 35% до 50% общего белка, и служит важнейшим индикатором нутритивного статуса и функционального состояния печени. Глобулиновые фракции крайне гетерогенны: зона содержит большинство белков

острой фазы (таких как гаптоглобин, сывороточный амилоид А, антитрипсин), концентрация которых резко возрастает при воспалении или повреждении тканей. Фракция преимущественно представлена трансферрином и компонентами системы комплемента. фракция состоит из различных классов иммуноглобулинов (IgG, IgA, IgM), вырабатываемых плазматическими клетками. Анализ профиля этой зоны критически важен для дифференциации иммунных состояний: широкие пики указывают на поликлональную гаммапатию (нормальный иммунный ответ на инфекцию), в то время как узкие «высокие» пики свидетельствуют о моноклональной гаммапатии, характерной для опухолевых заболеваний, таких как множественная миелома.

Таблица 3. Характеристика и диагностическое значение электрофоретических фракций сыворотки

Фракция белков	Ключевые компоненты	Диагностическая значимость (интерпретация изменений)
Альбумин	Сывороточный альбумин	Снижение: заболевания печени, нефротический синдром, паразитозы. Повышение: дегидратация.
альфа-глобулины	антитрипсин, гаптоглобин, церулоплазмин, сывороточный амилоид А	Повышение: маркер острой фазы воспаления, инфекции, травмы. Снижение: печеночная недостаточность.
бетта-глобулины	Трансферрин, С3 и С4 компоненты комплемента, С-реактивный белок	Повышение: хроническое воспаление, нефротический синдром, заболевания печени (мостик).
гамма-глобулины	Иммуноглобулины G, A, M, D, E	Широкий пик: хроническая антигенная стимуляция. Узкий пик: миеломная болезнь, неоплазия.

На интерпретацию результатов электрофореза значительное влияние могут оказывать технические артефакты и ошибки преаналитического этапа, что требует строгого контроля качества образцов. Использование плазмы вместо сыворотки приводит к появлению ложного пика фибриногена между зонами, что затрудняет их идентификацию. Видимый гемолиз образца или выраженная липемия искажают электрофоретическую картину, создавая ложные пики в областях глобулинов соответственно за счет выхода свободного гемоглобина или избытка триглицеридов. Условия хранения также являются критическими: при комнатной температуре белки деградируют, что на графике проявляется в виде «расплывания» и постепенного слияния фракций в регионах. Для сохранения протеомного профиля допускается хранение сыворотки при 4°C не более 3–5 дней, тогда как для долгосрочных исследований необходимо обязательное замораживание проб. Таким образом, даже спустя десятилетия использования, нативный электрофорез остается незаменимым инструментом первичного скрининга диспротеинемий в ветеринарной и гуманной медицине.

Протеомные технологии на основе масс-спектрометрии

Масс-спектрометрия (МС) на сегодняшний день является центральной аналитической платформой протеомики, позволяющей проводить идентификацию, количественную оценку и описание структуры белков в таких сложных биологических системах, как сыворотка крови. Целью качественного протеомного анализа является детальное описание белков и их посттрансляционных модификаций, характерных для определенного физиологического или патологического статуса организма. Одним из наиболее эффективных методов для глубокой идентификации сывороточного протеома

является «shotgun» протеомика (метод «дробовика»), представляющий собой безгелевый подход: после тотального ферментативного расщепления белков в пробе полученные пептиды разделяются с помощью высокоэффективной жидкостной хроматографии (ЖХ) и идентифицируются методом tandemной масс-спектрометрии (МС/МС) с последующим автоматизированным поиском по базам данных. Помимо безгелевых методов, широко применяются подходы на основе предварительного очищения белков с помощью одномерного (1-DE) или двумерного (2-DE) электрофореза, после чего белки подвергаются «in-gel» дигестии (расщеплению непосредственно в геле) и анализируются методом масс-спектрометрии с матрично-активированной лазерной десорбцией/ионизацией (MALDI-TOF-MS). Особое место в профилировании сыворотки занимает технология SELDI-TOF (поверхностно-усиленная лазерная десорбция/ионизация), которая сочетает хроматографическое удерживание белков на специфических поверхностях чипов с последующей МС-детекцией, что позволяет быстро выявлять паттерны биомаркеров заболеваний, дополняя классический электрофорез.

Количественная протеомика на базе масс-спектрометрии подразделяется на методы относительного и абсолютного измерения, что критически важно для поиска диагностических маркеров в ветеринарии и медицине. Относительное квантирование направлено на установление различий в экспрессии белков между двумя и более состояниями (например, между здоровыми и больными особями) и может быть реализовано через использование стабильных изотопных меток, таких как ICAT или iTRAQ, которые вводят разницу в массе между пептидами из разных образцов. В качестве альтернативы набирают популярность безметочные методы (label-free), которые опираются на сравнение интенсивностей пиков или площадей под хроматографическими кривыми одних и тех же пептидов в разных запусках прибора, что технически проще, но требует высокой воспроизводимости ЖХ-МС систем. Несмотря на высокую чувствительность современных приборов, основным ограничением остается неполная аннотация геномов сельскохозяйственных животных по сравнению с человеком, что заставляет исследователей использовать методы гомологичного поиска по базам данных UniProt или алгоритмы BLAST для интерпретации полученных первичных масс-спектрометрических данных. Тем не менее, масс-спектрометрия признается более быстрым методом по сравнению с классическими ИФА или ПЦР-тестами при необходимости одновременного мониторинга сотен белковых мишеней.

Таблица 4. Сравнительная характеристика основных масс-спектрометрических платформ для анализа сыворотки

Технология	Тип подготовки пробы	Принцип метода	Основное применение в протеомике
MALDI-TOF MS	Вырезание пятен из геля (1-DE/2-DE)	Десорбция лазером с матрицы, полетное время	Идентификация отдельных белков после электрофореза.
SELDI-TOF MS	Без разделения в геле (на чипе)	Фракционирование на поверхности чипа + TOF	Быстрое профилирование для поиска биомаркеров.
ЖХ-МС/МС (LC-MS/MS)	Ферментативное расщепление в растворе	Хроматография пептидов + тандемная МС	Глубокая идентификация («shotgun») и количественный анализ.
iTRAQ / ICAT	Мечение пептидов изотопами	Использование химических меток с разной массой	Мультиплексное относительное количественное сравнение групп.
Label-free (ЖХ-МС)	Стандартизированная очистка пептидов	Сравнение интенсивности сигналов пептидов	Относительное квантирование без дорогих реактивов.

Практическое применение МС-технологий в анализе сывороток животных позволило достичь значительных успехов в мониторинге здоровья и благополучия поголовья, а также в ранней диагностике инфекций. В скотоводстве методы MALDI-TOF и 2D-DIGE использовались для выявления специфических белков острой фазы и воспалительных маркеров (например, ангиотензина, альбумина и тяжелых цепей IgG) при маститах и «молочной лихорадке» у коров, что позволило создать специфические протеомные «карты» болезней. Исследования с использованием iTRAQ на сыворотках КРС, инфицированных *Mycobacterium bovis* и *Mycobacterium paratuberculosis*, привели к открытию новых биомаркеров для раннего обнаружения туберкулеза. В коневодстве масс-спектрометрия была успешно применена для оценки токсического воздействия растений (например, *Senecio jacobea*), выявив связывание цитотоксических метаболитов с белками плазмы. В птицеводстве и рыбоводстве МС-платформы помогают изучать ответ протеома на инвазии (кокцидиоз), стресс при пересадке рыб в соленую воду и влияние пробиотиков на иммунный статус. Развитие протеомики позволяет не только совершенствовать диагностику, но и разрабатывать более эффективные вакцины за счет идентификации новых бактериальных антигенов. Несмотря на высокую стоимость оборудования, снижение цен на расходные материалы и автоматизация алгоритмов биоинформатики делают масс-спектрометрию ведущим инструментом в создании комплексных систем мониторинга здоровья в современном животноводстве.

Прикладное значение комплексного анализа сывороток

Комплексный анализ сыворотки крови, объединяющий физико-химические и протеомные подходы, играет решающую роль в современной ветеринарной диагностике, позволяя не только выявлять заболевания на ранних стадиях, но и осуществлять глубокий мониторинг физиологического статуса животных. Традиционные биохимические тесты часто ограничены определением общего белка или соотношения альбумин/глобулин, однако электрофоретическое разделение и динамическая тензиометрия предоставляют гораздо

более детализированную картину патологических процессов. Использование таких методов критически важно для диагностики диспротеинемий и парапротеинемий, связанных с лимфоидной или плазмоклеточной неоплазией, например, при множественной миеломе у собак и кошек, где на электрофореграммах фиксируются специфические гомогенные пики иммуноглобулинов. Кроме того, физико-химические параметры, такие как динамическое поверхностное натяжение (ДПН), позволяют проводить «быструю сепарацию» здоровых и больных особей в условиях крупных хозяйств, обеспечивая оперативную оценку биохимического статуса до проведения дорогостоящих анализов. Применение межфазной тензиометрии доказало свою эффективность в мониторинге специфических состояний, таких как беременность и лактация у крупного рогатого скота, где закономерные изменения тензиограмм отражают глубокую перестройку метаболизма и позволяют прогнозировать потенциальные осложнения.

В сфере инфекционной патологии протеомные технологии на основе масс-спектрометрии и мультимплексного анализа открывают возможности для идентификации уникальных биомаркеров, специфичных для конкретных возбудителей. Исследования сывороток позволили выявить изменения протеома при таких социально и экономически значимых заболеваниях, как мастит, бруцеллез, паратуберкулез и классическая чума свиней. Например, использование MALDI-TOF MS позволило создать профили биомаркеров для контроля безопасности пищевых продуктов, выявляя телят, подвергавшихся незаконному фармакологическому лечению. В клинической практике гипериммунные сыворотки часто имеют преимущество перед антибиотиками, особенно при остром течении лептоспироза, где своевременное введение специфических антител обеспечивает выживаемость животных на уровне 90–100%. Разработка и внедрение в практику поливалентных сывороток против респираторных и кишечных инфекций (пастереллез, сальмонеллез, вирусная диарея) значительно снижает экономический ущерб от гибели и вынужденного убоя молодняка, обеспечивая сохранность поголовья в крупных животноводческих комплексах.

Таблица 5. Прикладные аспекты применения методов анализа сывороток

Область применения	Используемые методы	Результат и прикладное значение
Клиническая диагностика	Электрофорез в агарозном геле	Дифференциация воспалительных процессов и опухолевых заболеваний (миелома).
Инфекционный мониторинг	Масс-спектрометрия (MALDI/SELDI), iTRAQ	Поиск ранних биомаркеров бруцеллеза, туберкулеза и мастита.
Специфическая терапия	Биотестирование лечебной активности	Замена антибиотикотерапии высокоактивными гипериммунными препаратами.
Физиологический контроль	Интерфазная тензиометрия (DST)	Оценка нутритивного статуса, стадий беременности и адаптации к стрессу.
Стандартизация биопрепаратов	РА, РДСК, ИФА, физико-химический контроль	Создание национальных эталонов диагностических сывороток для единства измерений.
Экспресс-скрининг	Метод максимального давления в пузырьке	Быстрое выявление отклонений в солевом и белковом балансе «суперсложных систем».

Важнейшим аспектом прикладного значения является стандартизация диагностических препаратов, которая обеспечивает единство требований к качеству в национальном и международном масштабах. Создание отраслевых стандартных образцов

(ОСО) для таких тестов, как реакция агглютинации при бруцеллезе, позволяет верифицировать точность выпускаемых производственных серий. Новые методические подходы к получению антивидовых и диагностических сывороток с использованием современных иммуномодуляторов (тимоген, полиоксидоний) позволяют сократить сроки иммунизации животных-продуцентов при достижении 100% специфического ответа. Комплексный анализ, включающий не только определение титра антител, но и контроль физико-химической стабильности (рН, растворимость, потеря массы при высушивании), гарантирует длительный срок годности и высокую терапевтическую эффективность биопрепаратов, предназначенных для массовой профилактики. Таким образом, интеграция высокотехнологичных методов анализа в ветеринарную практику является основой для перехода к прецизионной медицине и биотехнологии.

Заключение

Подводя итог обзору современных технологий анализа сыворотки крови, можно констатировать, что современная биохимия перешла от простого количественного определения отдельных компонентов к комплексному изучению сыворотки как «суперсложной коллоидной системы» (SCCS). Сложность этой системы обусловлена не только многообразием белков, гормонов и метаболитов, но и наличием иерархических комплексов, таких как липопроотеины, чьи свойства определяются жесткой структурой межмолекулярных взаимодействий. Применение физико-химических и протеомных методов в совокупности позволяет получить беспрецедентно глубокое понимание гомеостаза организма.

Одним из наиболее перспективных направлений в анализе биожидкостей стала межфазная тензиометрия, позволяющая оценивать динамическое поверхностное натяжение (ДПН). В отличие от классических методов, тензиометрия дает возможность изучать кинетику адсорбции макромолекул на границе раздела фаз, что служит чувствительным индикатором физиологических и патологических изменений. Доказано, что параметры тензиограмм имеют устойчивые корреляции с биохимическим профилем крови, включая уровни общего белка, альбуминов и липидов. Информативность этого метода подтверждена в мониторинге специфических состояний животных, таких как беременность и лактация у крупного рогатого скота, где изменения ДПН отражают глубокую перестройку обмена веществ.

Электрофоретические методы разделения белков сохраняют статус фундаментального инструмента дифференциальной диагностики диспротеинемий и парапротеинемий. Нативный электрофорез в агарозном геле позволяет четко выделять фракции альбуминов и глобулинов, предоставляя данные об иммунном статусе организма и наличии воспалительных процессов. Особую ценность метод представляет для выявления белков острой фазы и дифференциации моноклональных гаммапатий при опухолевых заболеваниях. Однако успех электрофореза, как и любого высокотехнологичного анализа, критически зависит от преаналитического этапа. Ошибки при заборе крови, гемолиз или нарушение температурного режима хранения неизбежно ведут к деградации белковых комплексов и искажению результатов.

Протеомные технологии на основе масс-спектрометрии (MALDI-TOF, LC-MS/MS) ознаменовали новую эру в поиске биомаркеров. Несмотря на сложности, вызванные широким динамическим диапазоном концентраций сывороточных белков, современные методы пробоподготовки, такие как иммунодеплеция и библиотеки пептидных лигандов, позволяют обнаруживать низкопредставленные белки, имеющие критическое значение для ранней диагностики инфекций (бруцеллез, туберкулез, маститы). Развитие количественной протеомики (iTRAQ, label-free) открывает возможности для одновременного мониторинга

сотен белковых мишеней, что значительно превосходит возможности классических ИФА-тестов по скорости и охвату данных.

Прикладное значение данных методов выходит далеко за рамки фундаментальной науки. Комплексный анализ сывороток является основой для стандартизации иммунобиологических препаратов и создания национальных эталонов диагностических систем, что гарантирует единство требований к качеству биопродукции. Применение гипериммунных сывороток в клинической ветеринарной практике часто показывает преимущество перед антибиотикотерапией, особенно при острых инфекциях, обеспечивая высокую сохранность поголовья и биологическую безопасность пищевых продуктов.

В перспективе интеграция физико-химических и протеомных данных позволит перейти к прецизионной ветеринарии и медицине. Дальнейшая автоматизация алгоритмов обработки данных и снижение стоимости масс-спектрометрического оборудования будут способствовать внедрению этих технологий в широкую лабораторную практику. Создание расширенных баз данных референтных значений ДПН и сывороточных протеомов для различных видов животных обеспечит возможность оперативного мониторинга их благополучия, раннего выявления эпизоотий и контроля качества продукции животноводства на качественно новом уровне.

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Gene Therapy Outcomes in Duchenne Muscular Dystrophy: Current Clinical Signals and Hypotheses for Accelerated Progress

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Abstract

Gene therapy for Duchenne muscular dystrophy (DMD) has entered a clinically transformative yet still transitional phase. Current adeno-associated virus (AAV) micro-dystrophin approaches have demonstrated biologic activity and encouraging functional signals in treated patients, including favorable effects on timed motor outcomes and evidence of durable benefit in longer-term follow-up analyses; however, short-term randomized data have also shown that the primary functional endpoint was not consistently met at 52 weeks, indicating that clinical benefit remains heterogeneous and incompletely captured by existing trial designs. At the same time, safety remains a major constraint, with acute serious liver injury, myocarditis, thrombocytopenia, infusion-related reactions, and immune-mediated myositis underscoring the narrow therapeutic window of systemic high-dose AAV delivery. On the basis of current evidence, four hypotheses may explain how substantial progress could be achieved: first, earlier intervention—ideally before extensive fibrosis and loss of muscle regenerative capacity—may produce larger and more durable clinical effects; second, immune-tailored strategies, including pre-treatment immune profiling, tolerogenic protocols, and vector/transgene designs that reduce immunogenicity, may improve persistence of expression and safety; third, combination approaches pairing gene replacement with anti-inflammatory, anti-fibrotic, or pro-regenerative therapies may convert partial molecular rescue into stronger functional benefit; and fourth, next-generation platforms—such as improved muscle/cardiac tropic vectors, redosing-enabled systems, fuller dystrophin restoration, or precise gene editing—may overcome current payload and durability limitations. Together, available data suggest that meaningful progress in DMD will likely come not from gene transfer alone, but from earlier, safer, and biologically integrated therapeutic strategies.

Keywords

Duchenne muscular dystrophy; DMD; gene therapy; micro-dystrophin; AAV; immunogenicity; liver toxicity; myocarditis; early intervention; combination therapy; gene editing; therapeutic durability

Introduction

Duchenne muscular dystrophy (DMD) is one of the most devastating inherited disorders of childhood, defined by relentless skeletal muscle degeneration, progressive loss of ambulation, cardiopulmonary decline, and premature mortality. The disease is caused by pathogenic variants in the DMD gene that disrupt expression of dystrophin, a large cytoskeletal protein essential for preserving sarcolemmal integrity during repeated cycles of contraction and relaxation. In the absence of dystrophin, muscle fibers become mechanically fragile, vulnerable to contraction-induced injury, and progressively replaced by fibrofatty tissue. Although advances in respiratory support, cardiac surveillance, corticosteroid use, and multidisciplinary standards of care have extended survival and improved quality of life, DMD remains fundamentally life-limiting and incompletely treated. For that reason, the therapeutic field has long viewed gene-based correction not as an optional innovation but as the central long-term strategy for altering disease biology at its source (Hoffman et al., 1987; Koenig et al., 1987; Koenig et al., 1988; Emery, 2002; Bushby et al., 2010; Birnkrant et al., 2018).

The contemporary importance of DMD gene therapy arises from a convergence of scientific maturity and clinical urgency. On one side, decades of work in molecular genetics, vector engineering, animal modeling, and biomarker development have transformed dystrophin restoration from an aspirational concept into a clinically testable platform. On the other side, the lived trajectory of DMD continues to expose the limitations of currently available therapies. Corticosteroids slow decline but do not stop it; mutation-specific approaches such as exon skipping and stop-codon readthrough apply only to subsets of patients and usually restore modest amounts of dystrophin; and even excellent supportive care cannot reverse established fibrosis or replace lost muscle mass. Thus, the field has increasingly shifted from asking whether dystrophin restoration is biologically relevant to asking how much restoration, in which tissues, at what age, and with what durability and safety, is necessary to translate molecular rescue into sustained clinical benefit. These questions define the present phase of DMD research and explain why gene therapy outcomes have become a major focus of both academic debate and regulatory attention (Mercuri and Muntoni, 2013; Takeda et al., 2021; Sheikh and Yokota, 2021; Roberts et al., 2023; Duan, 2023).

Duchenne Muscular Dystrophy as a Multisystem Degenerative Disorder

The biological seriousness of DMD extends beyond progressive weakness alone. Dystrophin is a core component of the dystrophin-associated glycoprotein complex, which links the intracellular cytoskeleton to the extracellular matrix and helps distribute mechanical stress across the muscle membrane. When dystrophin is absent, the sarcolemma becomes prone to microrupture, calcium homeostasis is disturbed, inflammatory cascades are amplified, nitric oxide signaling is altered, and cycles of myofiber necrosis and incomplete regeneration become chronic. Over time, the regenerative capacity of muscle is exhausted, satellite cell function is impaired, and replacement by connective and adipose tissue dominates the pathological landscape. This sequence is not limited to limb muscles. The diaphragm progressively weakens, respiratory insufficiency emerges, and the myocardium develops fibrosis and dilated cardiomyopathy, making cardiac disease a leading cause of death in many patients despite improved respiratory care. DMD should therefore be understood not simply as a neuromuscular disease, but as a whole-muscle-system disorder with interdependent skeletal, respiratory, and cardiac dimensions (Ervasti and Campbell, 1993; Petrof et al., 1993; Blake et al., 2002; Rosenberg et al., 2015; Duan et al., 2021; Shah and Yokota, 2023). The natural history of DMD further clarifies why timing is so central to therapeutic strategy. Boys often appear normal at birth and during infancy, yet subtle motor delay, difficulty running or climbing, Gowers' maneuver, and calf hypertrophy typically emerge in early childhood. Ambulatory function may rise transiently in younger boys as normal development partially masks underlying pathology, but this improvement is not evidence of biological stability; it reflects maturation

occurring on top of an actively degenerative substrate. Later, functional scores plateau and then decline, usually followed by loss of ambulation, scoliosis risk, upper-limb deterioration, ventilatory dependence, and progressive cardiac involvement. This age-dependent pattern complicates clinical trial design because therapeutic effect must be distinguished from developmental change, steroid background effects, and interpatient variability in mutation type, baseline motor reserve, and standards of care. In practical terms, the disease is already biologically advanced before many clinically meaningful endpoints become obviously abnormal. That reality strongly supports the premise that earlier molecular intervention could generate disproportionately greater benefit than treatment initiated after fibrosis and loss of regenerative capacity are established (Mayhew et al., 2016; Muntoni et al., 2019; Muntoni et al., 2022; Landfeldt et al., 2024).

From Gene Discovery to Therapeutic Logic

The modern therapeutic landscape in DMD is inseparable from the molecular discoveries of the late 1980s. Identification of the DMD gene and characterization of dystrophin established an immediately compelling causal chain: a structural protein was missing, the membrane became unstable, and muscle degeneration followed. This gave DMD an unusually strong conceptual suitability for gene restoration compared with disorders involving diffuse pathway dysregulation. The earliest therapeutic vision was elegantly simple: replace what is missing. Yet the extraordinary size of the DMD coding sequence quickly made that strategy technically difficult. The full-length dystrophin cDNA is too large for many widely used viral delivery platforms, especially adeno-associated virus (AAV), whose packaging capacity is far below the size of the native transcript. The field therefore had to solve not only how to deliver a gene systemically to widespread muscle tissue, but also how to redesign the gene into a smaller form that still retained essential function (Koenig et al., 1988; Emery, 2002; Duan, 2018; Elangkovan and Dickson, 2021).

That challenge led to the development of mini-dystrophin and micro-dystrophin constructs, engineered transgenes inspired by observations from Becker muscular dystrophy and genotype-phenotype correlations showing that internally deleted dystrophin proteins can retain substantial function if critical domains are preserved. These shortened constructs do not replicate the full-length protein, but they aim to conserve the domains most important for membrane stabilization and partial restoration of the dystrophin-associated complex. In this sense, DMD gene therapy has never been a perfect replacement strategy; it has been a strategic approximation, designed to convert a severe Duchenne phenotype into a milder biologic state. The rationale is powerful, but it also means that success depends on whether partial dystrophin restoration can be delivered broadly enough, persist long enough, and act early enough to overcome the cumulative pathology already unfolding in muscle. The concept is clinically reasonable, yet its translation depends on many interlocking variables that explain why outcomes have been encouraging but not uniformly definitive (Davies and Guiraud, 2019; Duan, 2018; Chamberlain et al., 2023; Bengtsson et al., 2025).

Current Standard Therapies and Why They Are Not Enough

The need for gene therapy becomes clearer when placed against the limitations of conventional care. Corticosteroids remain a cornerstone of DMD management because they prolong ambulation, delay scoliosis and respiratory decline, and improve several functional measures. Nevertheless, steroid therapy is not curative, and its chronic toxicities, including weight gain, behavioral effects, growth suppression, bone fragility, and endocrine complications, impose a substantial treatment burden. Likewise, cardioprotective regimens such as angiotensin-converting enzyme inhibitors, beta-blockers, and mineralocorticoid receptor antagonists can delay cardiomyopathic progression, yet they do not address the absence of dystrophin in cardiac muscle itself. Respiratory interventions, contracture management, orthopedic surveillance, physiotherapy, and nutritional care have transformed survival, but these are fundamentally compensatory

measures. They preserve function within the constraints of an uncorrected molecular defect (Bushby et al., 2010; Birnkrant et al., 2018; Shah and Yokota, 2023; Landfeldt et al., 2024).

Mutation-specific therapies marked an important advance because they provided proof that molecularly targeted treatment in DMD was clinically feasible. Exon-skipping drugs can restore the reading frame for selected mutations, and stop-codon readthrough agents can address a different molecular subset. However, these approaches are inherently restricted by genotype applicability, variable tissue penetration, and modest dystrophin restoration. More importantly, they underscore a broader lesson for the field: restoring some dystrophin is biologically meaningful, but the relationship between molecular correction and functional outcome is nonlinear. Small molecular gains may slow decline without producing dramatic short-term functional reversal, especially when significant fibrosis is already present. Thus, even successful mutation-specific therapies do not eliminate the demand for broader, mutation-agnostic strategies such as systemic gene transfer or genome editing. Instead, they reinforce the idea that DMD treatment will likely require layered intervention combining molecular rescue with anti-inflammatory, anti-fibrotic, and supportive strategies tailored to disease stage (Takeda et al., 2021; Sheikh and Yokota, 2021; Roberts et al., 2023).

Why AAV-Mediated Gene Transfer Became the Leading Platform

Among available delivery systems, AAV emerged as the leading vehicle for DMD gene transfer because of its relative safety profile, ability to transduce post-mitotic tissues, and capacity for systemic administration. Different serotypes and capsid designs exhibit varying muscle tropism, and systemic AAV delivery offered the first realistic prospect of reaching widespread skeletal muscle and potentially the heart after a single intravenous infusion. For a disease affecting nearly every muscle group, this mattered enormously. Local injection could demonstrate proof of concept, but only body-wide delivery could address the clinical reality of DMD. The field therefore centered on systemic AAV micro-dystrophin therapy as the most immediate translational path, despite known challenges in dose, immunogenicity, and manufacturing scale (Duan, 2018; Elangkovan and Dickson, 2021; Duan, 2023).

Yet AAV is not a neutral carrier. Its benefits come with constraints that are unusually relevant in DMD. First, the payload limit forces use of truncated dystrophin transgenes rather than full-length replacement. Second, the amount of vector required for whole-body muscle transduction in growing children is extremely high, increasing pressure on liver handling, innate immune activation, and complement-related toxicity. Third, pre-existing immunity to capsid proteins can limit eligibility, while post-treatment immune responses may restrict redosing. Fourth, persistence of episomal AAV genomes may be challenged by muscle growth, regeneration, and turnover, especially in young children. These issues mean that DMD gene therapy is not just a question of whether a transgene can be delivered, but whether it can be delivered at a biologically adequate dose without exceeding the narrow safety window that systemic muscle targeting appears to impose. The more the field has matured, the clearer it has become that vector biology and immunology are as important as transgene design itself (Duan, 2018; Chamberlain et al., 2023; Duan, 2023; Bengtsson et al., 2025).

Micro-Dystrophin: A Rational Compromise Rather Than a Perfect Substitute

The micro-dystrophin strategy should be understood as a carefully reasoned compromise. Full-length dystrophin contains multiple domains involved in actin binding, rod structure, membrane stabilization, and interactions with signaling partners including neuronal nitric oxide synthase. Because AAV cannot package the native coding sequence, researchers designed abbreviated proteins that preserve the N-terminal actin-binding domain and selected rod and cysteine-rich elements while omitting substantial portions of the central rod domain and other regions. The precise structure of these constructs differs across programs, and not all micro-dystrophins are functionally equivalent. Some may better restore sarcolemmal stability, some may more effectively

recruit associated proteins, and some may have implications for cardiac performance or immune recognition. Therefore, “micro-dystrophin therapy” is not a single intervention but a class of related engineering solutions with shared logic and distinct biological trade-offs (Davies and Guiraud, 2019; Duan, 2023; Birch et al., 2023).

This distinction has consequences for interpreting clinical outcomes. If the delivered protein is an intentionally reduced analog rather than the native molecule, then the expected clinical effect may be partial by design. Partial rescue could still be transformative if delivered early and broadly enough, but heterogeneity in construct design, promoter selection, capsid choice, dose, steroid regimens, baseline age, and trial endpoints can make cross-study interpretation difficult. Furthermore, expression level alone may not fully capture functional adequacy. A given amount of micro-dystrophin measured in biopsy tissue may not reveal its distribution across muscle groups, persistence over time, cardiac expression, resistance to immune clearance, or ability to modulate downstream inflammation and fibrosis. For this reason, enthusiasm around biomarker evidence has always coexisted with caution about how best to translate molecular expression into durable clinical inference. The history of DMD therapeutics repeatedly shows that biological plausibility is necessary but not sufficient; therapy must alter the disease trajectory in meaningful, measurable, and reproducible ways (Chamberlain et al., 2023; Roberts et al., 2023; Oskoui et al., 2025).

The Meaning of Clinical Signals in the Transitional Era of DMD Gene Therapy

The current era of DMD gene therapy can be described as clinically transformative yet still transitional. On the transformative side, systemic AAV micro-dystrophin programs have clearly shown that body-wide gene transfer in children with DMD is feasible, that muscle biopsies can demonstrate transgene-derived dystrophin expression, and that treated patients may exhibit encouraging functional signals on timed tests and broader motor assessments over time. Longer-term observations and follow-up analyses have supported the view that biologic activity is real and that disease trajectory may be modifiable in at least some treated cohorts. Regulatory decisions have reflected this shift, especially the willingness to consider dystrophin or micro-dystrophin expression as a surrogate endpoint in a disease with high unmet need and a strong mechanistic rationale (Duan, 2023; Chamberlain et al., 2023; Oskoui et al., 2025).

At the same time, the transitional nature of the field is equally important. Short-term randomized data have not always shown statistically decisive superiority on primary functional endpoints at prespecified time points such as 52 weeks. This does not necessarily mean the therapy lacks benefit. It may instead reflect the complexity of DMD natural history, the insensitivity of some endpoints to early disease modification, developmental confounding in young ambulant boys, between-patient heterogeneity, and the possibility that therapeutic effect unfolds more clearly over longer observation windows than traditional neuromuscular trial design was built to capture. Nevertheless, those uncertainties matter. A therapy can be biologically active and still be incompletely characterized. It can show promising subgroup or secondary endpoint signals while leaving open questions about magnitude, durability, optimal age, and benefit-risk balance. The field must therefore avoid both extremes: dismissing gene therapy because one primary endpoint is missed, or overstating certainty because biopsy expression and selected functional signals are favorable. The appropriate interpretation is more demanding and more useful: current gene therapy has crossed the threshold of plausibility and entered the threshold of refinement (Mayhew et al., 2016; Muntoni et al., 2022; Chamberlain et al., 2023; Oskoui et al., 2025).

Safety as the Major Constraint on Scale and Speed

If efficacy defines the promise of DMD gene therapy, safety defines its present ceiling. Systemic high-dose AAV delivery has been associated with acute liver injury, transaminitis, thrombocytopenia, infusion-related reactions, myocarditis, and severe immune-mediated complications. While many events are manageable with monitoring and immunosuppressive protocols, the occurrence of serious toxicities underscores how narrow the therapeutic window

can be when a large vector dose is required for whole-body muscle targeting. In DMD, this risk calculus is especially delicate because patients may already have subclinical cardiac vulnerability, chronic inflammation, and variable baseline exposure to steroids or other medications. Safety is therefore not an ancillary concern but the central translational problem determining who can be treated, at what age, under what monitoring conditions, and with what confidence in widespread adoption (Rosenberg et al., 2015; Duan, 2023; Oskoui et al., 2025).

The immunological dimension of these safety events is especially important. Immune activation may be directed against the AAV capsid, against newly expressed dystrophin epitopes that the patient has never immunologically tolerated, or against damaged host tissue undergoing inflammatory amplification after transduction. In a disease already characterized by chronic muscle inflammation, innate and adaptive responses can interact with pre-existing pathology in unpredictable ways. This is one reason why DMD gene therapy has required extensive corticosteroid regimens and why immune profiling, liver surveillance, and careful patient selection have become essential components of clinical programs. It also explains why the field increasingly recognizes that durable success may depend as much on immunological engineering as on gene engineering. Better capsids, lower effective doses, improved promoters, tissue targeting that spares off-target organs, and strategies enabling safe redosing may ultimately matter as much as the specific micro-dystrophin sequence delivered (Rosenberg et al., 2015; Elangkovan and Dickson, 2021; Chamberlain et al., 2023; Bengtsson et al., 2025).

Inflammation, Fibrosis, and Regeneration Set the Biological Context for Outcome

Any realistic interpretation of gene therapy outcomes in DMD must account for the pathological environment into which the therapy is introduced. Dystrophin loss initiates more than mechanical instability. It drives chronic inflammation, macrophage activation, fibro-adipogenic expansion, aberrant extracellular matrix deposition, oxidative stress, altered perfusion signaling, and eventual depletion or dysfunction of satellite-cell-mediated repair. By the time a child has clinically obvious weakness, the disease process has already reshaped the tissue landscape in ways that can limit the effect of later molecular rescue. Restoring dystrophin to a myofiber surrounded by fibrosis, chronic inflammation, and reduced regenerative reserve may stabilize what remains, but it cannot instantly regenerate architecture that has already been replaced by scar and fat. This is why therapeutic timing and tissue state are inseparable variables in DMD (Zhou and Lu, 2010; Klingler et al., 2012; Serrano and Muñoz-Cánoves, 2017; Dowling et al., 2023).

Fibrosis is particularly consequential because it is both a marker of cumulative injury and a functional barrier to recovery. Increased extracellular matrix stiffness alters force transmission, impairs capillary exchange, affects stem-cell niches, and limits the ability of partially rescued fibers to translate molecular correction into coordinated tissue performance. Cardiac fibrosis carries additional implications because even modest dystrophin restoration may be insufficient if arrhythmogenic or contractile remodeling is already advanced. These observations support a broader hypothesis increasingly discussed across the DMD field: gene transfer alone may not be enough in many patients. Instead, the strongest future outcomes may come from biologically integrated strategies that pair dystrophin restoration with anti-inflammatory, anti-fibrotic, pro-regenerative, or cardioprotective interventions. In other words, the endpoint is not merely transgene expression, but successful reprogramming of the disease environment toward sustained tissue function (Klingler et al., 2012; Rosenberg et al., 2015; Mogharehabet and Czubryt, 2023; Roberts et al., 2023).

The Importance of Early Intervention

One of the most compelling hypotheses for accelerated progress in DMD gene therapy is that treatment must move earlier in the disease course to unlock its full potential. This idea is supported by basic pathology, natural history modeling, and experience from multiple genetic disorders in which pre-symptomatic or minimally symptomatic intervention yields disproportionate benefit. In

DMD, younger patients typically have greater muscle mass preservation, less fibrofatty replacement, stronger regenerative capacity, and fewer secondary complications. A therapy that restores even partial dystrophin expression in this context may alter downstream inflammatory and fibrotic cascades before they become self-sustaining. By contrast, later intervention may function more as salvage stabilization than true trajectory redirection. This helps explain why some studies show stronger signals in younger ambulant boys and why short-term trials in heterogeneous populations may dilute the apparent effect size of a treatment whose biology is highly stage dependent (Mayhew et al., 2016; Muntoni et al., 2019; Duan et al., 2021; Landfeldt et al., 2024).

However, early intervention is not a simple solution. Younger children are also in phases of rapid growth, active immune development, and evolving motor performance, all of which complicate dose strategy and endpoint selection. Since AAV genomes do not integrate efficiently, tissue expansion during growth may dilute vector genomes over time, raising questions about long-term persistence after treatment in very young patients. Moreover, earlier treatment increases the importance of redosing strategies, because a single infusion given at a small body size may not guarantee lifelong coverage as muscle mass expands. This means that the logic of treating earlier must be paired with the engineering challenge of sustaining benefit longer. Even so, the core conclusion remains strong: if DMD gene therapy is intended to prevent irreversible tissue remodeling, then intervention cannot wait until irreversible remodeling is already advanced. Future success will likely depend on balancing the biological advantage of early treatment with the pharmacologic and immunologic realities of delivering durable therapy to a growing child (Duan, 2018; Duan, 2023; Bengtsson et al., 2025).

Clinical Endpoints and the Problem of Measuring Benefit

A recurring issue in DMD gene therapy is not only whether benefit exists, but whether the field is measuring it in the most appropriate way. Traditional functional endpoints such as the North Star Ambulatory Assessment, timed motor tests, and walking-based measures are clinically meaningful, yet they are shaped by age, development, steroid regimen, baseline function, and the nonlinear progression typical of DMD. In younger children, motor scores may improve transiently even without treatment because development partially compensates for disease burden. In older children, decline may accelerate after a window of relative plateau. As a result, a therapy that truly slows disease biology may still struggle to show large between-group separation at fixed time points unless cohorts are tightly stratified and follow-up is sufficiently long. This is one reason why natural history-informed analyses and external comparator frameworks have become so important in DMD trial interpretation (Mayhew et al., 2016; Muntoni et al., 2019; Muntoni et al., 2022).

The surrogate endpoint debate is therefore more than a regulatory technicality; it reflects the mismatch between molecular therapies and legacy trial architecture. Measuring micro-dystrophin in biopsy tissue offers direct evidence that the therapy reached the target and expressed the intended protein, but surrogate biology must still be linked to meaningful clinical outcomes. Conversely, requiring short-term functional superiority as the sole determinant of therapeutic value may undervalue interventions whose principal effect is trajectory modification rather than rapid symptomatic reversal. The challenge is to integrate biomarkers, imaging, natural history modeling, patient age, and longer-term functional follow-up into a more nuanced evidentiary framework. This does not mean lowering standards. It means aligning standards with disease biology. In a chronic degenerative disorder where tissue preservation may matter more than immediate performance gain, the most relevant question may be whether the slope of decline is durably changed rather than whether a single annual milestone is crossed (Chamberlain et al., 2023; Roberts et al., 2023; Oskoui et al., 2025).

Cardiac Disease and the Need for Whole-Body Benefit

A central but sometimes underemphasized issue in DMD gene therapy is whether treatment meaningfully addresses the heart. As respiratory care has improved, cardiomyopathy has become increasingly prominent in morbidity and mortality. Any therapy that produces convincing skeletal muscle signals but insufficient cardiac protection may still fall short of its full promise. Dystrophin deficiency in myocardium is not a secondary consequence of limb weakness; it is a primary component of disease biology. Therefore, the success of gene therapy cannot be judged entirely by ambulatory endpoints. Broad therapeutic impact requires transduction of respiratory muscles and cardiac tissue as well, along with durable expression in those tissues over time (Petrof et al., 1993; Duan et al., 2021; Shah and Yokota, 2023; Landfeldt et al., 2024).

This issue also reshapes the risk-benefit discussion. Systemic delivery is justified precisely because DMD is systemic, yet systemic delivery is also what increases safety pressure on the liver and immune system. There is no easy trade-off: reducing dose may protect safety but compromise broad tissue exposure; increasing dose may improve distribution but narrow tolerability. Future vector platforms with better muscle and cardiac tropism could meaningfully relax this tension by enabling lower total doses for the same or greater tissue effect. Similarly, improvements in promoter specificity and transgene potency could enhance functional rescue without proportionally increasing vector burden. In this sense, next-generation success in DMD may depend less on abandoning the AAV framework than on making each unit of exposure biologically more efficient. Cardiac-focused outcome measures and long-term surveillance will be essential to determine whether such improvements translate into true multisystem disease modification rather than primarily ambulatory benefit (Birch et al., 2023; Mogharehabet and Czubryt, 2023; Bengtsson et al., 2025).

Heterogeneity in Patients, Constructs, and Trial Contexts

Another reason current DMD gene therapy outcomes appear mixed is that heterogeneity operates at multiple levels simultaneously. Patients differ in age, baseline function, mutation class, steroid regimen, cardiac status, fibrosis burden, immune background, and natural history trajectory. Trials differ in entry criteria, endpoint timing, comparator design, follow-up duration, and analytical approach. Therapeutic products differ in capsid, promoter, dose, manufacturing process, and micro-dystrophin design. When all of these variables interact, it becomes difficult to interpret negative or borderline results as simple evidence for or against the entire therapeutic class. A missed endpoint in one context may reflect trial architecture or cohort composition rather than the impossibility of the underlying therapeutic principle. Likewise, a positive biomarker study does not automatically generalize across constructs or patient populations. Mature interpretation therefore requires rejecting the false binary of “gene therapy works” versus “gene therapy fails.” The more accurate statement is that certain gene therapy strategies generate meaningful biologic activity, but the field is still learning the conditions under which that activity becomes consistent, durable, and clinically decisive (Davies and Guiraud, 2019; Elangkovan and Dickson, 2021; Chamberlain et al., 2023; Oskoui et al., 2025).

This heterogeneity also suggests a practical future in which patient selection becomes more refined. Baseline fibrosis imaging, muscle-specific biomarker panels, immune profiling, liver risk assessment, cardiac phenotype, and genotype-informed expectations may help identify which patients are most likely to benefit from a given platform and which require modified conditioning or combination therapy. Such stratification is especially relevant in a disease where tissue state may be at least as important as chronological age. A 6-year-old with relatively preserved muscle architecture may be biologically different from a 6-year-old with accelerated decline and advanced tissue remodeling. Similarly, patients with established cardiomyopathy may require different endpoint priorities than those treated before cardiac involvement is evident. Precision in DMD may

therefore come not only from molecular targeting but from stage-specific therapeutic deployment (Muntoni et al., 2022; Roberts et al., 2023; Landfeldt et al., 2024).

Beyond First-Generation Gene Transfer: Why the Field Is Already Looking Ahead

The rapid movement toward next-generation strategies is not evidence that current gene therapy has failed; rather, it reflects the field's recognition that first-generation success has clarified the remaining bottlenecks. Better capsids may improve muscle and cardiac uptake while reducing total dose requirements. Redosing-capable systems may address growth-related dilution and long-term durability. More functionally optimized micro-dystrophin constructs may better recapitulate essential signaling interactions. Nonviral delivery approaches may eventually bypass some immunologic constraints of AAV. Genome editing methods, including CRISPR-based exon excision or correction strategies, offer the possibility of restoring endogenous dystrophin expression in a more physiologic form, although major questions remain regarding delivery, editing efficiency, safety, and regulatory complexity. Utrophin modulation and other compensatory approaches provide additional alternatives or adjuncts. The field is therefore expanding not because DMD gene therapy lacks value, but because the clinical experience to date has generated a precise map of where innovation is still needed (Duan, 2018; Roberts et al., 2023; Duan, 2023; Bengtsson et al., 2025).

Importantly, these future directions should not be framed as mutually exclusive. DMD is unlikely to be solved by a single universal platform in the near term. Instead, the most effective therapeutic architecture may involve layering: an early disease-modifying gene transfer or editing intervention, supported by anti-inflammatory or anti-fibrotic therapy, monitored with biomarker-informed surveillance, and complemented by optimized cardiopulmonary care. In some patients, mutation-specific therapy may remain relevant; in others, broader gene replacement may dominate; in still others, next-generation editing may eventually supersede current approaches. The critical point for the present review is that outcome interpretation must be connected to this evolving therapeutic ecosystem. First-generation signals matter most when they are used not merely to declare success or failure, but to identify the mechanistic levers through which more reliable success can be achieved (Takeda et al., 2021; Sheikh and Yokota, 2021; Roberts et al., 2023).

Regulatory Momentum and Scientific Caution Must Coexist

Recent regulatory momentum in DMD gene therapy has changed the tone of the field. What was once a preclinical aspiration is now part of real-world clinical and policy decision-making. This carries important benefits for patients and families, who have waited decades for therapies aimed at the root cause of disease. It also creates scientific responsibilities. Accelerated approval pathways, surrogate endpoints, and high public expectation can shorten the distance between promising biology and clinical availability, but they also increase the importance of rigorous post-approval evidence generation, transparent safety reporting, and careful interpretation of long-term outcomes. In DMD, where every new therapy is evaluated under conditions of both urgency and vulnerability, hope and scrutiny must coexist (Chamberlain et al., 2023; Oskoui et al., 2025).

This dual posture is especially necessary because the field is still defining what long-term success should look like. Is success measured by transgene expression, preservation of ambulation, delayed cardiomyopathy, slower decline in respiratory function, or survival extension? The answer is all of the above, but not all outcomes emerge on the same timeline. Early molecular evidence may precede visible clinical divergence. Short-term motor changes may not capture later cardiac benefit. Stabilization may be meaningful even without dramatic reversal. At the same time, serious toxicity cannot be minimized simply because unmet need is high. A mature DMD gene therapy framework must therefore integrate urgency with proportional evidence standards, preserving access while continuing to demand the data needed to refine patient selection, dose strategy, endpoint interpretation, and long-term safety management (Birnkrant et al., 2018; Duan, 2023; Oskoui et al., 2025).

The Need for an Integrated Biological Model of Response

One of the clearest lessons from the current literature is that DMD gene therapy response should not be modeled as a single linear chain from vector infusion to protein expression to functional improvement. The real biology is more layered. Vector pharmacology determines tissue distribution. Immune biology determines tolerance and persistence. Construct biology determines the quality of functional rescue. Tissue pathology determines how much rescue can still be translated into usable muscle performance. Developmental stage determines the meaning of functional endpoints. Cardiac involvement determines whether apparent limb benefit reflects true systemic disease modification. Each layer can amplify or blunt the others. A patient with good transduction but high fibrosis may derive limited functional gain. A patient with moderate expression but early treatment and preserved tissue may do far better. Therefore, the most productive way to analyze outcomes is not through a single metric, but through an integrated response model linking dose, tissue state, immunology, expression quality, and time (Rosenberg et al., 2015; Dowling et al., 2023; Roberts et al., 2023; Bengtsson et al., 2025).

Such a model has direct implications for clinical progress. It suggests that improved outcomes may come from several routes simultaneously: treating earlier, lowering vector toxicity through more efficient capsids, selecting patients using fibrosis or immune biomarkers, combining gene transfer with agents that modulate inflammation or extracellular matrix remodeling, and following patients long enough to detect altered disease slope rather than only short-term absolute change. This framework also helps explain why the field can display both genuine progress and persistent uncertainty at the same time. Progress is visible because we now have evidence of systemic gene transfer, transgene expression, and functional signal. Uncertainty remains because response is shaped by multiple biological gates, and not all of them are equally controlled in current programs. Recognizing that complexity is not pessimism; it is the condition for designing better trials and better therapies.

Rationale for the Present Review and Working Hypotheses

Against this background, the present review is grounded in a practical question: what do current DMD gene therapy outcomes actually signal about the path forward? The available literature supports neither simple triumphalism nor therapeutic nihilism. Instead, it suggests that the field has entered a decisive intermediate stage in which proof of biologic activity is established, but consistent and broadly durable clinical transformation remains constrained by timing, safety, tissue pathology, and endpoint sensitivity. Interpreting this stage correctly matters because it influences how new trials are designed, how existing therapies are deployed, and how next-generation platforms are prioritized. A narrow reading focused only on whether one primary endpoint was met risks underestimating cumulative progress. An overly optimistic reading focused only on biomarker gains risks underestimating the biological and safety barriers that still limit real-world impact (Duan, 2023; Chamberlain et al., 2023; Oskoui et al., 2025).

Accordingly, this review proceeds from four linked hypotheses. First, earlier intervention, ideally before extensive fibrosis and regenerative exhaustion, is likely to produce larger and more durable clinical effects than later treatment. Second, immune-tailored strategies, including better pre-treatment risk assessment and less immunogenic vector-transgene systems, may be essential for both safety and persistence. Third, combination approaches pairing dystrophin restoration with anti-inflammatory, anti-fibrotic, or pro-regenerative therapies may convert partial molecular rescue into stronger functional benefit. Fourth, next-generation platforms, including more efficient muscle- and cardiac-tropic vectors, redosing-enabled systems, fuller dystrophin restoration strategies, and precise gene editing, may be required to overcome the payload and durability limitations inherent to first-generation systemic AAV micro-dystrophin therapy. Taken together, these hypotheses frame DMD gene therapy not as a finished success story, but as an inflection point: the moment when enough has been learned from early clinical signals to move from proof

of concept toward rational acceleration (Davies and Guiraud, 2019; Birch et al., 2023; Roberts et al., 2023; Bengtsson et al., 2025).

Conclusion of the Introduction

In summary, DMD is a severe multisystem degenerative disorder in which the molecular target is exceptionally clear, the unmet need remains profound, and the logic of gene therapy is uniquely compelling. Systemic AAV micro-dystrophin approaches have already changed the field by demonstrating that widespread transgene delivery and biologic activity are clinically achievable. Yet the disease context into which these therapies are deployed is biologically hostile: chronic inflammation, fibrosis, regeneration failure, growth-related dilution, immune complexity, and cardiac vulnerability all shape whether delivered dystrophin can meaningfully alter long-term outcome. The result is a therapeutic landscape defined by real progress but incomplete resolution. Current clinical signals are encouraging enough to justify continued momentum, but heterogeneous enough to demand deeper mechanistic interpretation and smarter trial design (Duan et al., 2021; Chamberlain et al., 2023; Dowling et al., 2023; Oskoui et al., 2025).

For that reason, the most important question is no longer whether gene therapy belongs in DMD. It clearly does. The more pressing question is how to make it safer, earlier, broader, and biologically more integrated so that partial rescue becomes reliable disease modification rather than variable benefit. The answer will likely come from combining what the field has already achieved with what it has now learned from its limitations. That is the basis for the present review and the reason current outcomes should be read not as the endpoint of the DMD gene therapy story, but as the evidence base from which accelerated progress can now be deliberately built (Duan, 2023; Roberts et al., 2023; Bengtsson et al., 2025).

Materials and Methods

Study design

This article was prepared as a narrative, hypothesis-driven review of gene therapy outcomes in Duchenne muscular dystrophy. Its purpose was to synthesize current clinical and translational evidence related to adeno-associated virus-mediated micro-dystrophin therapy, assess patterns of efficacy and safety, and develop biologically grounded hypotheses regarding how progress in the field may be accelerated. The review was designed to integrate findings from clinical trials, natural history studies, mechanistic investigations, translational research, and relevant regulatory or consensus literature.

Literature search strategy

A structured literature search was conducted using major biomedical databases, including PubMed/MEDLINE, Embase, Scopus, and ClinicalTrials.gov. Additional relevant publications were identified through manual review of reference lists from key review articles, clinical studies, and consensus documents.

Search terms were selected to reflect the major themes of the manuscript and included combinations of Duchenne muscular dystrophy, DMD, gene therapy, adeno-associated virus, AAV, micro-dystrophin, mini-dystrophin, dystrophin restoration, clinical trials, liver toxicity, myocarditis, thrombocytopenia, inflammation, fibrosis, cardiomyopathy, immune response, gene editing, CRISPR, natural history, and clinical endpoints.

The review considered English-language literature published from 1987 through 2025 in order to capture the field from the discovery of dystrophin to the current clinical era of gene therapy development.

Eligibility criteria

Studies and documents were included if they contributed directly to one or more of the following areas: clinical outcomes of gene therapy in Duchenne muscular dystrophy; mechanistic or translational evidence related to vector delivery, transgene design, immunogenicity, fibrosis, inflammation, regeneration, or durability; natural history and endpoint studies relevant to

interpretation of treatment response; and regulatory, guideline, or consensus materials relevant to trial design and therapeutic evaluation.

Priority was given to human clinical studies, long-term follow-up reports, natural history datasets, and influential translational investigations. Seminal preclinical studies were included when necessary to clarify biological rationale or explain observed clinical findings. Duplicate publications, nonrelevant articles, and reports lacking meaningful information on efficacy, safety, mechanism, or interpretation were excluded.

Study selection and data extraction

Titles and abstracts were screened for relevance to the central themes of the review. Full texts of potentially eligible studies were then examined in detail. Information extracted from included sources, when available, included study design, patient population, age group, therapeutic platform, vector or construct features, dose, background corticosteroid use, duration of follow-up, biomarker findings, functional outcomes, adverse events, and principal conclusions.

For clinical studies, particular attention was given to the relationship between transgene expression, functional outcomes, timing of assessment, and treatment-emergent toxicity. For mechanistic and translational studies, emphasis was placed on biological processes likely to influence response, including immune activation, fibrosis, muscle regenerative capacity, and cardiac involvement.

Data synthesis

Because the available literature is heterogeneous with respect to trial design, vector platform, patient characteristics, endpoint selection, duration of follow-up, and reporting methods, a quantitative meta-analysis was not performed. Instead, the evidence was synthesized qualitatively using a thematic approach.

The literature was organized into several major domains: clinical signals of benefit and their interpretive limitations; safety constraints associated with systemic high-dose AAV delivery; the role of inflammation, fibrosis, and regenerative reserve in shaping treatment response; the importance of early intervention; limitations of currently used clinical endpoints; and future directions including immune-tailored strategies, combination approaches, and next-generation therapeutic platforms.

This thematic synthesis was used to formulate and refine the four working hypotheses presented in the manuscript.

Interpretive approach

This review was intended to be analytical rather than purely descriptive. Evidence was interpreted not only according to whether individual studies reported favorable or unfavorable outcomes, but also according to the biological and clinical context in which those outcomes occurred. Particular attention was given to factors that may complicate interpretation of short-term trial results, including developmental changes in young ambulant boys, baseline disease stage, differences in fibrosis burden, construct-specific variation, immune-related effects, and the possibility that biologic benefit may become more apparent over longer periods of observation than conventional trial designs capture.

Accordingly, the review aimed to integrate molecular, pathological, clinical, and translational perspectives into a unified framework for understanding current gene therapy outcomes in Duchenne muscular dystrophy.

Ethics statement

This study was based exclusively on previously published literature and publicly available clinical trial information. Therefore, institutional review board approval and informed consent were not required.

Results

Overview of the evidence base

The literature reviewed for this article spans nearly four decades of research into Duchenne muscular dystrophy, ranging from the original identification of the DMD gene and characterization of dystrophin to the current era of systemic gene therapy trials. Across this body of work, a consistent pattern emerges: biological understanding of the disease has advanced substantially, therapeutic tools have matured from proof-of-concept to clinical application, and the central challenge has shifted from whether dystrophin can be restored to how restoration can be made broad, durable, safe, and clinically meaningful. The reviewed evidence supports neither uncritical optimism nor therapeutic pessimism, but rather a measured view that the field is in a transitional phase between early clinical validation and biologically optimized treatment.

Clinical efficacy signals from AAV micro-dystrophin programs

Across the major systemic AAV micro-dystrophin programs evaluated to date, clinical studies have demonstrated that intravenous delivery of engineered dystrophin transgenes is feasible, that muscle biopsies consistently show transgene-derived dystrophin expression, and that at least a subset of treated patients exhibit encouraging functional signals on timed motor tasks and broader neuromuscular assessments. Longer-term follow-up analyses, including open-label extensions and comparisons with matched natural history cohorts, have generally suggested that disease trajectory may be modifiable in some treated populations, with apparent stabilization or attenuation of expected decline over multi-year horizons.

However, results from short-term randomized controlled trials have been more nuanced. In several programs, the prespecified primary functional endpoint at 52 weeks was not consistently met, despite favorable changes in secondary endpoints, biomarkers, or patient subgroups. This divergence between biomarker signals, secondary clinical outcomes, and primary randomized endpoints reflects the complexity of measuring benefit in a slowly progressive pediatric disease with a heterogeneous natural history. The available evidence therefore supports biological activity and plausible functional benefit while underscoring the limitations of current trial designs to fully capture the magnitude, timing, and durability of that benefit.

Figure 1. AAV Micro-dystrophin Gene Therapy in Duchenne Muscular Dystrophy (DMD).

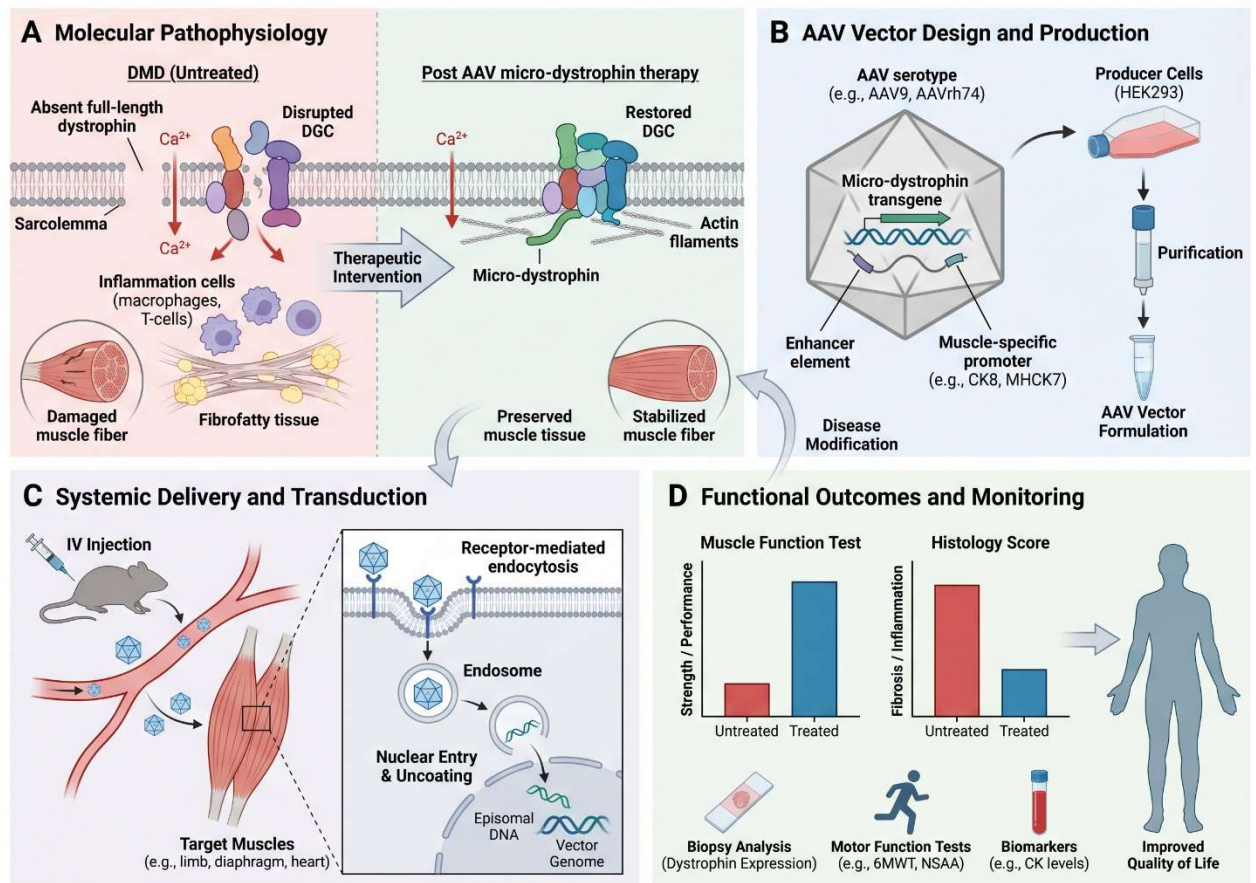


Figure 1 — Conceptual framework of AAV micro-dystrophin gene therapy in Duchenne muscular dystrophy: molecular mechanism, delivery platform, clinical trade-offs, and pathways for accelerated progress.

The figure integrates the four pillars of the review into a single visual narrative:

A — Molecular Pathophysiology. A side-by-side cross-section of the muscle fiber sarcolemma contrasts the untreated DMD state (absent dystrophin, disrupted dystrophin-associated glycoprotein complex [DGC], membrane microtears, aberrant Ca^{2+} influx, inflammatory infiltrate, and progressive fibrofatty replacement) with the post-therapy state, in which a truncated micro-dystrophin anchors the actin cytoskeleton to a partially reconstituted DGC, stabilizing the sarcolemma and attenuating mechanical injury.

B — AAV Delivery and Transgene Design. An icosahedral AAV capsid is shown delivering its payload systemically to skeletal muscle and myocardium. The engineered cassette (muscle-specific promoter → N-terminal actin-binding domain → selected spectrin-like rod repeats → cysteine-rich domain → polyA) illustrates the "rational compromise" required by the ~4.7 kb AAV packaging limit, which excludes most of the native dystrophin rod domain.

C — Clinical Signals versus Safety Constraints. The therapeutic window is depicted as a balance between efficacy signals (detectable dystrophin expression in biopsies, favorable timed motor outcomes such as NSAA and timed function tests, and emerging durability in long-term follow-up — tempered by the observation that the primary 52-week functional endpoint has not been consistently met) and safety risks inherent to high-dose systemic AAV (acute liver injury, myocarditis, thrombocytopenia and complement activation, immune-mediated myositis, and pre-existing anti-capsid immunity).

D — Four Hypotheses for Accelerated Progress. The review's central thesis is summarized as four non-mutually-exclusive strategies: (1) earlier intervention, before extensive fibrosis and loss of regenerative capacity; (2) immune-tailored strategies, including pre-treatment immune profiling, tolerogenic protocols, and de-

immunized vector/transgene designs; (3) combination therapies pairing gene replacement with anti-inflammatory, anti-fibrotic, or pro-regenerative agents to convert partial molecular rescue into stronger functional benefit; and (4) next-generation platforms, including muscle- and cardiac-tropic capsids, redosing-enabled systems, fuller-length dystrophin restoration, and precise gene editing (e.g., CRISPR-based approaches).

Influence of age and disease stage on response

A recurring theme across the reviewed studies is that therapeutic response appears to vary with age and disease stage. Younger ambulant boys with relatively preserved motor function generally show more favorable functional trajectories than older or more advanced patients. This observation aligns with the underlying biology of Duchenne muscular dystrophy, in which progressive loss of muscle mass, expansion of fibro-adipose tissue, and exhaustion of regenerative capacity create an increasingly resistant pathological environment. Evidence from both clinical programs and natural history cohorts suggests that early intervention, before substantial fibrosis and regenerative decline, may yield disproportionately greater and more durable benefit than treatment initiated later in the disease course. Although younger patients also present challenges related to growth, immune development, and endpoint interpretation, the cumulative evidence strongly supports the hypothesis that timing is a determinant of therapeutic effect.

Safety profile and immune-mediated events

The reviewed literature consistently identifies safety as the central constraint on current DMD gene therapy. Systemic high-dose AAV administration has been associated with a recognizable set of adverse events, including transient transaminase elevations, acute serious liver injury, thrombocytopenia, complement activation, infusion-related reactions, cardiac events including myocarditis, and immune-mediated myositis. Although most events have proven manageable with monitoring and immunomodulatory strategies, severe and occasionally fatal outcomes have been reported, underscoring the narrow therapeutic window of whole-body muscle targeting at currently required doses.

Immune responses appear to contribute substantially to these toxicities. Reactions may be directed against the AAV capsid, against newly expressed dystrophin epitopes in patients who have never been immunologically tolerant to the protein, or against host tissues experiencing inflammatory amplification after transduction. Pre-existing capsid immunity further limits eligibility in a proportion of candidates, while adaptive responses following treatment constrain the feasibility of redosing. These observations support the view that durable therapeutic success will depend not only on transgene design but also on immune engineering, including capsid optimization, patient-specific immune profiling, and the development of tolerogenic or immunomodulatory protocols.

FIGURE 2: Integrated Roadmap for Improving DMD Gene Therapy Outcomes

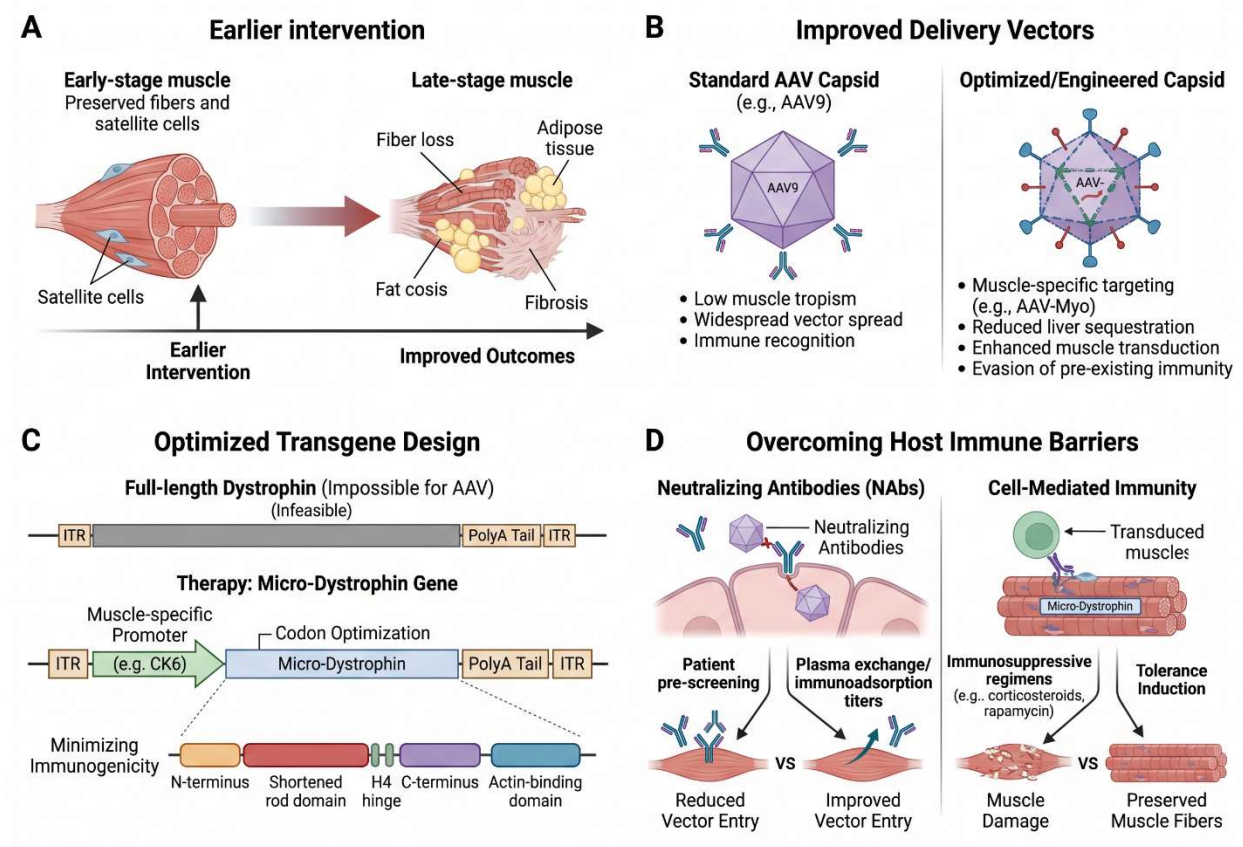


Figure 2. Integrated roadmap for improving gene therapy outcomes in Duchenne muscular dystrophy

This figure summarizes a biologically integrated framework for improving gene therapy outcomes in Duchenne muscular dystrophy. A emphasizes the importance of earlier intervention, when muscle architecture, regenerative capacity, and satellite cell activity are better preserved and fibrotic replacement is still limited. B illustrates delivery-related and immune-related barriers that influence treatment safety, persistence, and biodistribution, highlighting the need for immune-aware administration strategies. C focuses on optimization of the therapeutic construct and broader biologic rescue, showing how improved transgene design and coordinated biologic support can strengthen the translation of molecular correction into functional benefit. D presents future-facing strategies to overcome current platform limitations, including improved vector performance, better tissue targeting, immune barrier reduction, and more durable genetic correction approaches. Together, these panels convey that meaningful progress in DMD will likely depend on earlier, safer, and more biologically integrated therapeutic strategies rather than gene transfer alone.

Biological context: fibrosis, inflammation, and regeneration

Evidence from mechanistic and translational studies indicates that the pathological environment of dystrophin-deficient muscle is a major determinant of therapeutic outcome. Chronic inflammation, macrophage activation, fibro-adipogenic expansion, oxidative stress, impaired satellite cell function, and progressive replacement of contractile tissue by fibrosis and fat collectively shape the substrate into which gene therapy is delivered. Restoring dystrophin into fibers surrounded by established fibrosis and reduced regenerative reserve may stabilize what remains but cannot reverse architectural changes that have already occurred.

These findings support the view that molecular rescue alone may be insufficient in patients with advanced pathology, and that biologically integrated strategies pairing gene replacement with anti-inflammatory, anti-fibrotic, or pro-regenerative therapies may be required to translate partial dystrophin restoration into stronger and more consistent functional benefit. The reviewed evidence is consistent with a model in which successful therapy depends on reprogramming the disease environment, not merely on introducing the transgene.

Cardiac involvement and whole-body considerations

The reviewed literature emphasizes that Duchenne muscular dystrophy is not limited to skeletal muscle. Progressive cardiomyopathy and respiratory muscle involvement contribute significantly to morbidity and mortality, and cardiac disease has become an increasingly prominent cause of death as respiratory care has improved. Adequate cardiac transduction and durable expression of dystrophin in the myocardium are therefore essential components of therapeutic success. Yet cardiac tropism, dose adequacy, and the interaction between gene therapy and pre-existing cardiac vulnerability remain incompletely characterized. Reports of myocarditis following systemic AAV administration further highlight the complex relationship between therapeutic intent and cardiac safety. The evidence indicates that future progress will require vectors and strategies optimized for whole-body benefit, including sustained cardiac protection.

Figure 3 | Integrated determinants of response to AAV micro-dystrophin therapy in Duchenne muscular dystrophy

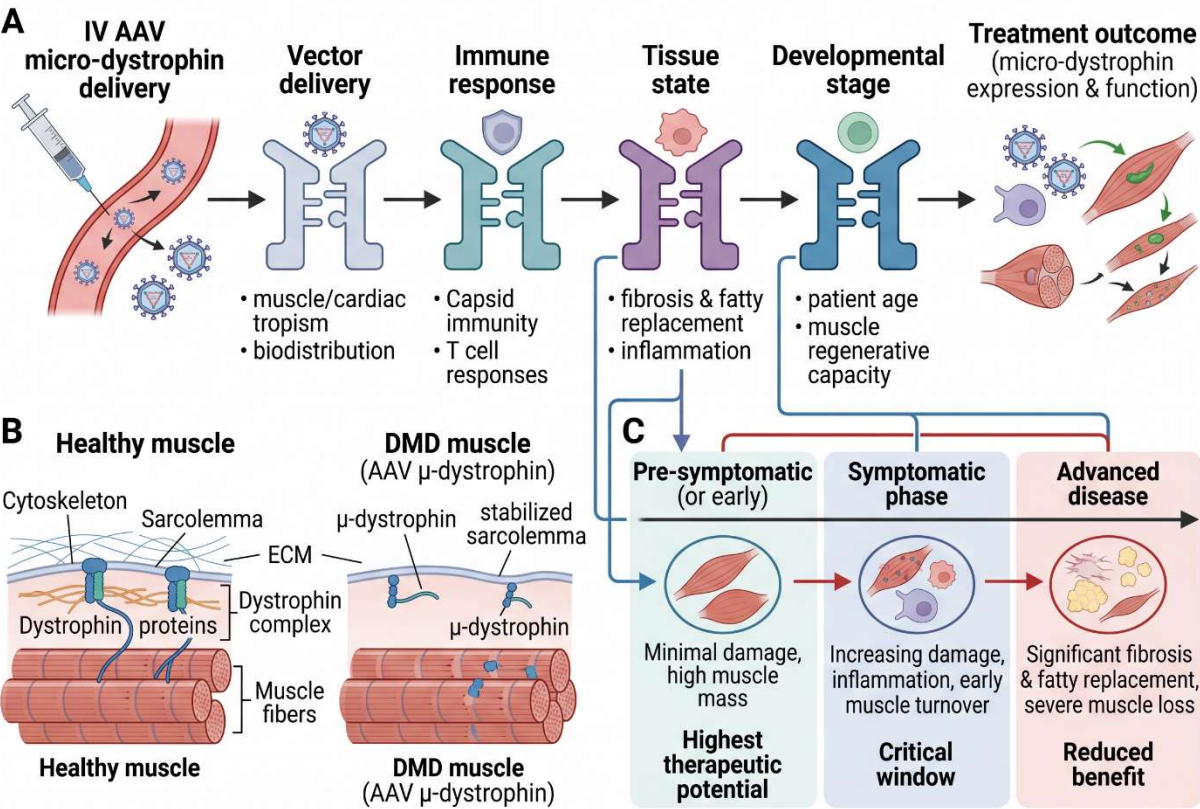


Figure 3 | Integrated determinants of response to AAV micro-dystrophin therapy in Duchenne muscular dystrophy.

A, Clinical benefit after systemic AAV micro-dystrophin delivery is governed by four serial biological gates: vector delivery, immune response, tissue state and developmental stage. Together, these layers determine tissue exposure, persistence of expression and the magnitude of downstream functional rescue. B, Precision stratification framework illustrating patient features associated with more favourable versus more challenging response profiles, including treatment timing, fibrosis

burden, regenerative capacity, pre-existing AAV immunity, inflammatory activity and cardiac risk. C, Conceptual model of trajectory modification, showing that gene therapy may produce durable slowing of functional decline rather than immediate short-term reversal, such that a 52-week snapshot can underestimate longer-term benefit.

Heterogeneity across constructs, patients, and trial designs

The reviewed evidence highlights substantial heterogeneity across the field. Micro-dystrophin constructs differ in domain composition, promoter selection, and expected functional performance, meaning that “micro-dystrophin therapy” is best understood as a class of related but nonidentical interventions. Patient populations also vary across programs with respect to age range, baseline motor function, mutation spectrum, steroid regimen, and standards of care. Trial designs differ in endpoint selection, duration of follow-up, comparator choice, and statistical framework. This heterogeneity complicates direct cross-program comparison and partly explains why biomarker-level and clinical-level results do not always align in a uniform manner. It also reinforces the need for standardized, biologically informed endpoints that better capture therapeutic effect over clinically meaningful time horizons.

Emergence of next-generation platforms

The reviewed literature documents rapid development of next-generation approaches designed to address limitations of first-generation AAV micro-dystrophin therapy. These include engineered capsids with improved muscle and cardiac tropism and reduced off-target uptake, regulatory elements that enhance durability and tissue specificity, constructs that provide fuller dystrophin restoration, and platforms that may eventually enable redosing. Gene editing strategies, including approaches based on CRISPR-associated systems and related technologies, are under investigation as potential means of achieving more precise and potentially mutation-specific correction. Although these platforms remain at varying stages of development, the cumulative evidence indicates that the therapeutic landscape is evolving beyond first-generation gene transfer toward more refined, integrated, and potentially more durable strategies.

Synthesis

Taken together, the reviewed evidence supports a coherent interpretation of the current state of gene therapy in Duchenne muscular dystrophy. Biological activity of systemic AAV micro-dystrophin therapy is well established. Clinical benefit appears real but heterogeneous, shaped strongly by age, disease stage, construct design, immune response, and the pathological context of the treated muscle. Safety constraints remain significant and centrally determine the pace and scale of therapeutic deployment. Progress toward more consistent and durable benefit is likely to depend on earlier intervention, immune-tailored strategies, combination therapies that address the broader disease environment, and next-generation platforms that overcome current limitations in delivery, durability, and payload. These findings provide the empirical foundation for the four working hypotheses developed in the following section.

From Biological Promise to Clinical Complexity

This article highlights a central challenge in current Duchenne muscular dystrophy (DMD) treatment: gene therapy has moved beyond theory and entered real clinical practice, but the field still has not fully clarified how biologic success should translate into clear, measurable clinical benefit. Current AAV-mediated micro-dystrophin programs have shown that systemic gene delivery to muscle is possible, that micro-dystrophin can be detected after treatment, and that some timed motor outcomes may improve or remain stable in treated patients (Zaidman et al., 2023; Sahenk et al., 2024; Mendell et al., 2025). However, randomized trials have not consistently met the primary functional endpoint at 52 weeks, suggesting that the clinical effects are more complex than a simple positive-or-negative result based on one timepoint.

One reasonable interpretation is that first-generation gene transfer solves only part of the problem. It addresses dystrophin deficiency, but it does not immediately reverse years of

inflammation, muscle fiber necrosis, fatty replacement, fibrosis, impaired regeneration, and emerging cardiopulmonary decline that are already present by the time many patients enter trials (Guiraud et al., 2015; Roberts et al., 2023). In this sense, gene transfer may be necessary, but not sufficient. Longer-term studies suggest that treated patients may diverge from expected natural history over time, particularly when compared with external controls, but the size and consistency of this benefit remain variable (Sahenk et al., 2024; Signorovitch et al., 2022). That variability likely reflects real biological differences in disease stage, muscle condition, immune status, steroid exposure, and vector uptake.

This supports the manuscript's central idea that the field is both transformative and transitional. Gene therapy has reached biological credibility, but it has not yet achieved predictable, durable, and universally interpretable clinical benefit. The appropriate response is therefore neither pessimism nor overconfidence. Instead, the field needs a more integrated model that aligns the biology of DMD progression with the timing, safety profile, and measurement strategies of gene therapy. Recent reviews also emphasize that enthusiasm for micro-dystrophin should be balanced with continued attention to efficacy, durability, and immunologic risk (Chwalenia et al., 2025; Oskoui et al., 2025). The next phase of progress will depend less on proving that gene transfer can work and more on understanding in whom, when, and under what biological conditions it works best.

Molecular Success Does Not Guarantee Functional Benefit

One of the most important issues raised by current DMD gene therapy studies is the gap between strong molecular findings and less consistent short-term functional outcomes. Micro-dystrophin expression has become a major marker of biologic activity and played a key role in the rationale for accelerated approval (Robb et al., 2023). Still, expression alone cannot be assumed to prove therapeutic sufficiency. DMD is not simply a condition caused by missing protein; it is a progressive degenerative disease in which muscle structure, extracellular matrix composition, regenerative ability, and motor function change continuously over time. A treated biopsy can confirm vector delivery and transgene production, but it cannot fully show whether the corrected protein is expressed broadly enough, strongly enough, and long enough to produce meaningful clinical change (Chamberlain and Chamberlain, 2017; Roberts et al., 2023).

This distinction matters because the field risks overestimating the link between a surrogate molecular marker and short-term motor benefit. The EMBARK trial demonstrated substantial micro-dystrophin expression but did not achieve statistical significance on the primary endpoint at 52 weeks, although some secondary timed tests numerically favored treatment (Mendell et al., 2025). This suggests not that the surrogate is irrelevant, but that the path from protein expression to motor improvement is longer and more conditional than initially expected. The quality of the micro-dystrophin construct may also be important. Truncated proteins retain key domains, but they do not fully reproduce full-length dystrophin, and different engineered constructs may not be functionally equivalent (Muntoni et al., 2003; Szwec et al., 2024). Differences in nNOS localization, membrane stability, cytoskeletal interaction, and cardiac performance may all affect downstream outcomes.

In addition, muscle biopsy has inherent sampling limitations. DMD pathology is patchy, and one biopsy site may not reflect restoration across the whole body, especially in a disease where walking, stair climbing, rising from the floor, respiratory strength, and cardiac protection depend on many different muscles with different burdens of disease. For this reason, some researchers have cautioned against treating micro-dystrophin as a complete surrogate endpoint rather than as a biologic marker that still requires clinical validation (Robb et al., 2023; Oskoui et al., 2025). Biologic activity should therefore be interpreted as proof of mechanism, but not yet proof of broad clinical sufficiency. Future studies should link tissue expression with imaging, serum biomarkers, wearable data, and long-term functional measures that better capture whole-body benefit.

Rethinking Endpoints in DMD Trials

The mixed efficacy results also force a broader re-evaluation of endpoint strategy in DMD trials. The North Star Ambulatory Assessment (NSAA) is widely used because it is clinically meaningful, familiar, and sensitive to changes in ambulatory function. Yet its behavior is not consistent across ages and disease stages. Younger boys may still gain skills due to normal development, steroid optimization, or physical therapy, while older boys may be entering a plateau or decline. As a result, the same absolute change at 52 weeks may have very different biological meaning depending on the patient's baseline trajectory (Bello et al., 2016; Signorovitch et al., 2022). This makes one-timepoint comparisons vulnerable to developmental confounding, regression to the mean, and baseline imbalance.

The EMBARK findings therefore offer an important methodological lesson: DMD is a slowly progressive disease, and treatments that alter the slope of decline may not be fully captured by a one-year functional snapshot (Mendell et al., 2025). Open-label and longer-term studies suggest stabilization or divergence from external natural history comparators, especially in timed function tests, but those analyses are inherently harder to interpret than placebo-controlled trials (Zaidman et al., 2023; Sahenk et al., 2024). Even so, external control methods are becoming increasingly important in rare neuromuscular disease, and current evidence supports the conditional value of carefully adjusted natural history comparators in NSAA-based analyses (Signorovitch et al., 2022), particularly when placebo exposure is difficult or ethically challenging.

Future trials may benefit from a more sophisticated endpoint framework. Instead of relying on NSAA alone, composite approaches could combine timed rise, 10-meter walk/run, stair measures, stride velocity, patient-reported mobility, and quantitative imaging biomarkers. Such multidimensional designs may better reflect the distributed effects of therapy across muscle groups and disease stages (Willcocks et al., 2020; Todd et al., 2025). Longitudinal modeling may also be more appropriate than simple absolute change scores, especially if treatment is expected to slow decline rather than produce dramatic short-term improvement. Additional prognostic enrichment using age, baseline NSAA, MRI fat fraction, steroid regimen, and genotype may further reduce heterogeneity.

The manuscript is therefore right to question whether current trial design fully matches the biology of the intervention. A therapy that modifies disease tempo may appear only modestly beneficial at 52 weeks but become clearly meaningful over several years. The challenge is not merely to find more favorable endpoints, but to identify endpoints that are mechanistically aligned, developmentally appropriate, and convincing to clinicians, regulators, and families. A shift from cross-sectional assessment to trajectory-based interpretation may become one of the most important accelerators of progress in the field.

The Importance of Earlier Intervention

The idea that earlier intervention could materially improve outcomes is one of the most compelling conclusions of this article. DMD pathology begins long before obvious clinical decline appears. Even in early childhood, repeated cycles of membrane fragility, necrosis, inflammation, and incomplete regeneration progressively remodel skeletal muscle and contribute to later cardiopulmonary complications (Wein et al., 2015; Guiraud et al., 2015). By the time many boys qualify for current gene therapy trials, pathology is already established, and fibrofatty changes may limit the ability of restored dystrophin to rescue tissue architecture. Earlier treatment is therefore not just a matter of convenience or developmental plasticity; it may determine whether the therapy is acting on viable muscle or on tissue that has already passed a threshold of irreversible damage.

This view is indirectly supported by both natural history data and trial observations. Younger ambulatory boys often show the most favorable treatment signals, though interpretation is complicated by ongoing developmental gains and steroid effects (Zaidman et al., 2023; Mendell et

al., 2025). Still, from a biologic perspective, it is reasonable to expect that treatment before major fibrosis, before satellite cell exhaustion, and before advanced myocardial involvement would offer the greatest chance of benefit. DMD care guidelines already emphasize early diagnosis and anticipatory management because timing affects outcomes even outside gene therapy (Birnkrant et al., 2018). The same principle should apply to molecular therapies.

At the same time, early treatment raises practical and ethical questions. If the optimal treatment window is very early in life, then broader genetic diagnosis, faster referral, and perhaps newborn screening become increasingly important. However, earlier dosing must be balanced against uncertainties about long-term durability, the inability to redose many AAV platforms, and the possibility that vector genomes may dilute as muscles grow (Chwalenia et al., 2025; Roberts et al., 2023). These concerns do not argue against early intervention, but they do show that the idea cannot be implemented effectively without parallel advances in vector persistence and re-administration.

Importantly, early intervention should not be defined only by chronological age. Biological age may be more informative. MRI findings, serum biomarkers, baseline motor phenotype, and perhaps immune profiling may better identify boys whose muscles remain most salvageable (Willcocks et al., 2020; Magrath et al., 2018). A child with relatively preserved muscle structure may benefit more than another child of the same age with greater fibrosis or inflammatory burden. The field should therefore move from age-based eligibility toward pathology-informed patient selection. If that happens, some of the current variability in treatment response may prove to be a consequence not of therapeutic failure, but of treatment being delivered too late in the biological course of disease.

Muscle Environment as a Determinant of Response

A related concept is that the muscle environment itself shapes therapeutic responsiveness. Restoring dystrophin in a myofiber is only one part of recovery; the surrounding tissue environment must also support force generation, regeneration, and coordinated movement. In DMD, chronic inflammation and extracellular matrix expansion profoundly alter that environment. Fibrosis reduces contractile reserve, stiffens muscle, and likely limits the translation of molecular correction into functional improvement. This is especially important because AAV-based therapies do not directly remove scar tissue or reverse established fatty infiltration. As a result, patients with more advanced pathology may show evidence of transgene expression but still gain only modest functional benefit.

This strengthens the manuscript's argument for combining gene transfer with biologically complementary approaches. Quantitative MRI studies have shown that fat fraction and T2-based measures track disease progression and predict future functional decline, including loss of ambulation (Willcocks et al., 2020). These biomarkers may help identify when muscle remains biologically salvageable and may also serve as intermediate indicators of whether gene therapy is altering tissue trajectory before obvious functional milestones change. Similar logic applies to cardiac MRI, which can detect fibrosis and early involvement before major reductions in ejection fraction occur (Magrath et al., 2018; McNally et al., 2015). If treatment is being evaluated in tissue that is already heavily remodeled, the expected response will differ from treatment given earlier in relatively preserved muscle.

The consequences of muscle pathology also extend to satellite cells and regeneration. AAV-delivered micro-dystrophin primarily targets existing myofibers rather than stem cell compartments, raising the possibility that newly regenerated fibers may remain uncorrected over time (Aartsma-Rus, 2023; Fatehi et al., 2023). This issue becomes especially important in a disease marked by chronic degeneration and regeneration. It may help explain why long-term durability remains uncertain and why strategies targeting stem cells or regenerative biology continue to hold strong appeal.

For these reasons, the future of DMD gene therapy may depend on a dual strategy: correcting dystrophin deficiency while also improving the condition of the host tissue. Anti-inflammatory, anti-fibrotic, membrane-stabilizing, or myogenic adjuncts could make corrected muscle more able to translate molecular rescue into functional benefit. Reviews of emerging DMD therapeutics increasingly describe the disease as one that requires layered biological intervention rather than monotherapy (Roberts et al., 2023; Kim et al., 2023). The manuscript is therefore well positioned in arguing that accelerated progress will come not only from better expression, but from pairing gene transfer with therapies that improve the diseased muscle environment. In other words, the target is not just the dystrophin gene, but the dystrophic tissue state in which that gene must function.

Safety as a Limiting Factor

Safety remains the most immediate barrier to wider use of systemic AAV gene therapy in DMD. Although many treatment-emergent adverse events are manageable, the pattern of immune-mediated toxicities has shown that high-dose whole-body delivery carries real biological risk. Across current programs, liver injury, thrombocytopenia, myocarditis, peri-infusion reactions, and inflammatory myositis have all been reported, and expert reviews stress the need for specialized monitoring before and after infusion (Mendell et al., 2024; Oskoui et al., 2025). These issues are not secondary concerns. They influence which patients can be treated, where treatment can be delivered, and how broadly the platform can be implemented in clinical practice.

The liver has emerged as a particularly important site of concern because it receives a substantial vector burden after systemic administration. Hepatotoxicity associated with gene therapy appears heterogeneous, ranging from asymptomatic laboratory abnormalities to clinically significant injury requiring prolonged immunosuppression (Larrey et al., 2024). More broadly, high-dose AAV toxicology has prompted renewed concern across multiple diseases, especially regarding innate immune activation, complement involvement, and T-cell responses to capsid or transgene products (Duan, 2023). In DMD, this safety calculus is further complicated by chronic steroid exposure, baseline disease burden, and the possibility that dystrophin-deficient heart and skeletal muscle may be especially sensitive to inflammatory stress.

These realities explain why practical treatment guidance has become just as important as efficacy reporting. Pre-infusion antibody screening, vaccination planning, laboratory surveillance, troponin monitoring, platelet assessment, and structured corticosteroid augmentation are now essential parts of treatment delivery rather than optional precautions (Mendell et al., 2024). Yet even ideal monitoring does not solve the central problem that current AAV dosing strategies may already be approaching a narrow therapeutic window. If broad muscle transduction requires very high exposure, but that same exposure increases immunotoxicity, then dose escalation alone may no longer offer a viable path to better outcomes.

For that reason, the manuscript's emphasis on immune-tailored strategies is highly convincing. The next generation of progress will likely depend on reducing vector burden, improving capsid efficiency, identifying patients at greatest immunologic risk, and developing safer immunomodulatory regimens. This may include better handling of pre-existing anti-capsid antibodies, more refined steroid-sparing protocols, or vector engineering that preserves potency at lower doses (Chwalenia et al., 2025; Piccolo and Brunetti-Pierri, 2025). Ultimately, a treatment that cannot be delivered safely, repeated if needed, or extended to a broader patient population will remain limited no matter how promising its early biological signal may seem. Safety is therefore not just a tolerability issue; it is a major determinant of long-term clinical and commercial viability.

Cardiac and Respiratory Outcomes Need Greater Weight

The heart and respiratory system deserve much stronger emphasis in the interpretation of DMD gene therapy outcomes because they remain the major drivers of long-term morbidity and mortality. Improvements in supportive care, corticosteroid use, ventilation strategies, and

cardioprotective management have extended survival, but cardiomyopathy and respiratory failure still account for much of the disease burden in adolescence and adulthood (Birnkrant et al., 2018; Birnkrant et al., 2022; Szabo et al., 2021). A therapy that mainly improves ambulatory motor scores without clearly protecting cardiac and respiratory function may therefore deliver only partial long-term value.

This issue is especially important because some micro-dystrophin programs were designed primarily around skeletal muscle rationale, while cardiac translation remains less clearly characterized in humans. Preclinical studies suggest that micro-dystrophin gene therapy can reduce inflammation, fibrosis, and functional decline in dystrophic hearts, supporting a plausible cardioprotective effect (Piepho et al., 2023; Meyers and Townsend, 2019). However, it remains uncertain whether a similar magnitude of benefit occurs in patients and whether it lasts long enough to reduce clinically meaningful cardiomyopathy. Cardiac MRI studies show that myocardial disease in DMD begins before overt symptoms and can be tracked using late gadolinium enhancement, strain, and tissue characterization measures (Magrath et al., 2018; McNally et al., 2015). These tools should become routine secondary or exploratory endpoints in gene therapy trials rather than being treated as peripheral assessments.

Respiratory outcomes are equally important, even if they progress more slowly in the young ambulatory populations usually enrolled in trials. Standardized respiratory monitoring is essential not only for clinical care but also for determining whether treatment meaningfully alters the disease course over time (Birnkrant et al., 2022; Sheehan et al., 2018). If gene therapy truly changes DMD progression, that effect should eventually be reflected in preserved pulmonary reserve, delayed need for assisted ventilation, or slower deterioration of respiratory muscle performance. These are outcomes that will require longer follow-up than most present studies provide.

The field should therefore avoid defining success solely through short-term ambulatory metrics. DMD is a multisystem dystrophinopathy, and the promise of systemic gene transfer is precisely that it should benefit skeletal, cardiac, and respiratory tissues together. A full therapeutic evaluation must reflect that broader goal. The manuscript's argument for deeper biological integration aligns with this principle: if future vector design, patient selection, and adjunctive therapies can improve not only walking-related outcomes but also myocardial and respiratory preservation, the clinical significance of gene therapy will become much more convincing. Over the long term, delaying heart failure and respiratory decline may matter even more to survival and quality of life than modest gains on early motor scales.

Why Combination Therapy May Be Necessary

Another major implication of the current evidence is that DMD should increasingly be approached as a disease requiring combination therapy. Corticosteroids remain the foundation of standard care because they delay functional decline, prolong ambulation, and influence cardiopulmonary progression, even though their long-term toxicities are substantial (Gloss et al., 2016; Kourakis et al., 2021). Most gene therapy studies have therefore been conducted on a background of steroid treatment, meaning that observed outcomes reflect interaction with established care rather than replacement of it. This complicates interpretation, but it also reveals an opportunity: gene therapy may work best when it is deliberately integrated with other disease-modifying strategies instead of being viewed as a stand-alone treatment.

The logic for combination therapy exists at several levels. Anti-inflammatory support may help manage vector-related immune activation and reduce early post-infusion risk. Anti-fibrotic or membrane-stabilizing treatments may improve the mechanical consequences of partial dystrophin restoration. Mutation-specific approaches such as exon skipping may still be valuable in selected patients or may help shape broader hybrid strategies for correction (Echevarría et al., 2018; Aartsma-Rus, 2023). In addition, emerging cell-based or paracrine therapies aimed at cardiac

protection may complement the strengths and limitations of micro-dystrophin transfer, especially if the latter ultimately proves more effective in skeletal muscle than in the myocardium (Kim et al., 2023).

The broader therapeutic literature supports this move away from monotherapy thinking. Reviews comparing dystrophin-based, utrophin-based, exon-skipping, and gene-editing approaches consistently conclude that each modality addresses some parts of the DMD problem while leaving others unresolved (Roberts et al., 2023; Szewc et al., 2024). For instance, exon skipping is mutation-specific and generally yields lower dystrophin levels, but it avoids some of the systemic dose-related toxicities of AAV. Gene editing offers the theoretical benefit of more durable genomic correction, potentially including stem cell compartments, but it still faces major delivery and safety obstacles (Fatehi et al., 2023). Utrophin-based strategies may reduce immunogenicity concerns, but they still require convincing clinical proof of efficacy (Szewc et al., 2024). These approaches should not be seen only as competitors. Rather, they point toward a future therapeutic ecosystem in which layered or sequential treatment becomes standard.

Accordingly, the manuscript's proposal for biologically integrated progress is highly credible. The next major clinical breakthrough may not come from a stronger version of the current product alone, but from a rational therapeutic regimen in which gene transfer provides partial structural rescue while other agents preserve muscle environment, cardiac function, regeneration, or immune tolerance. In a disease as complex as DMD, durable benefit will most likely come from therapeutic coordination rather than from a single technological success.

Limitations of Current Platforms and the Need for Next-Generation Strategies

Future platforms will be judged not only by whether they increase expression, but by whether they solve the unresolved structural limitations of current AAV micro-dystrophin therapy. One important limitation is the transgene itself. Because full-length dystrophin is too large to fit into a single AAV vector, current constructs must omit major domains, creating synthetic proteins whose long-term functional equivalence remains uncertain (Duan, 2018; Roberts et al., 2023). Although these constructs preserve key binding regions, they do not fully reproduce native dystrophin organization, and some deleted domains may be especially important in the heart, in certain muscle groups, or under chronic mechanical stress (Muntoni et al., 2003; Szewc et al., 2024). Future design efforts may therefore need to focus not just on higher expression, but on better functional architecture.

A second limitation is persistence. AAV genomes are largely episomal, and because skeletal muscle in DMD undergoes continuous damage and regeneration, corrected fibers may be lost over time while newly formed fibers remain untreated. This is particularly problematic if satellite cells are not efficiently targeted, since the regenerative compartment then remains genetically uncorrected (Aartsma-Rus, 2023; Fatehi et al., 2023). Redosing would seem like an obvious solution, but pre-existing anti-capsid immunity makes repeat administration difficult for many AAV platforms. This is not a minor issue; it may ultimately determine whether gene therapy can provide meaningful benefit across the full life course of a pediatric disease that evolves over decades.

A third limitation is patient breadth. Current indications and trial populations are concentrated in young ambulatory boys, leaving major uncertainty about older patients, nonambulatory individuals, those with advanced cardiomyopathy, and patients with pre-existing antibodies. If the platform remains restricted to a narrow early-life subgroup, its overall impact on the DMD population will be important but still incomplete (Oskoui et al., 2025; Chwalenia et al., 2025). Progress will therefore require vector engineering that improves muscle tropism, lowers overall dose requirements, expands eligibility, and potentially allows redosing or serotype switching.

Alternative therapeutic strategies remain highly relevant in this setting. Exon skipping continues to evolve, CRISPR-based approaches aim for more durable correction, and utrophin-directed therapies offer a conceptually attractive way to bypass both dystrophin immunogenicity and

mutation specificity (Echevarría et al., 2018; Fatehi et al., 2023; Szwec et al., 2024). The key lesson is that first-generation AAV micro-dystrophin should be viewed as an opening chapter, not as the final form of therapy. The manuscript correctly presents today's success as provisional: the field has demonstrated feasibility, but faster progress will depend on solving durability, immune exclusion, transgene design, and lifespan-wide applicability. That is the point at which historical innovation becomes mature therapeutic control of DMD.

Conclusion and Future Direction

Overall, the current evidence supports a balanced conclusion: DMD gene therapy has achieved real biologic and clinical significance, but its role is still being shaped by the interaction of treatment timing, tissue context, endpoint selection, and safety. The most convincing interpretation of existing data is not that the approach has failed because one randomized primary endpoint was missed, nor that it has been fully validated simply because micro-dystrophin expression is measurable and some secondary outcomes are favorable. Rather, the therapy appears to produce a genuine but heterogeneous effect that may be incompletely captured by conventional trial design and constrained by the biology of established disease (Mendell et al., 2025; Sahenk et al., 2024; Oskoui et al., 2025).

This leads to several practical implications. Patient selection should become more biologically informed, incorporating imaging, baseline disease trajectory, and possibly immune characteristics rather than relying mainly on age and ambulatory status. Efficacy assessment should shift toward longitudinal trajectory analysis and multidimensional outcome sets that include motor, imaging, cardiac, and respiratory measures. Safety management must evolve from reactive monitoring to predictive immunologic strategy, with the explicit aim of widening the therapeutic window. The field should also embrace combination therapy models in which gene transfer is integrated with optimized steroid use, cardiopulmonary care, and emerging molecular or cellular adjuncts. Finally, next-generation platforms must address redosing, stem cell correction, long-term durability, and construct design if they are to realize the full promise of disease modification.

The broader message of this manuscript is therefore both important and timely. DMD can no longer be understood as a disease in which therapy is judged only by whether it replaces a missing protein. It is a systems disease in which molecular correction must interact productively with developmental timing, chronic inflammation, fibrosis, regeneration, and multisystem organ decline. Modern care has already shown that survival and quality of life improve when treatment is anticipatory, coordinated, and multidisciplinary (Birnkrant et al., 2018; Birnkrant et al., 2022). Gene therapy should now be incorporated into that same philosophy rather than imagined as a stand-alone cure.

If the next decade succeeds in moving treatment earlier, making vectors safer, broadening access, and embedding gene transfer within a biologically integrated framework, then current uncertainties may eventually be seen not as signs of failure, but as the expected growing pains of a field moving from proof of concept to durable clinical impact. Under that interpretation, the present transitional period is not a reason to retreat. It is a reason for better trial design, deeper biological stratification, and more disciplined therapeutic ambition. That is where accelerated progress in DMD is most likely to emerge.

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Economic Sciences

XARİCİ VƏ YERLİ TƏCRÜBƏDƏ İNFORMASIYA BAZALARININ TƏŞKİLİ XÜSUSİYYƏTLƏRİ

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XÜLASƏ

Müasir rəqəmsal iqtisadiyyat şəraitində informasiya bazalarının təşkili müəssisələrin və bütövlükdə iqtisadi sistemlərin səmərəli fəaliyyətinin əsas determinantlarından birinə çevrilmişdir. İnformasiya resurslarının düzgün strukturlaşdırılması, operativ emalı və təhlükəsiz saxlanması idarəetmə qərarlarının keyfiyyətinə birbaşa təsir göstərir.

Xarici təcrübə göstərir ki, inkişaf etmiş ölkələrdə informasiya bazalarının təşkili yüksək səviyyədə inteqrasiya olunmuş, standartlaşdırılmış və texnoloji cəhətdən inkişaf etmiş platformalar əsasında həyata keçirilir. Bu sistemlərdə bir çox korporativ həllər, həmçinin bulud texnologiyaları və Big Data analitikası geniş tətbiq olunur. İnformasiya axınlarının vahid mərkəzdə idarə olunması, real vaxt rejimində məlumatların emalı və müxtəlif sistemlər arasında qarşılıqlı uyğunluğun təmin edilməsi əsas xüsusiyyətlər kimi çıxış edir. Bununla yanaşı, məlumat təhlükəsizliyi beynəlxalq standartlara uyğun şəkildə təmin edilir və fərdi məlumatların qorunması prioritet istiqamət hesab olunur.

Yerli təcrübədə isə informasiya bazalarının təşkili prosesi son illərdə əhəmiyyətli inkişaf mərhələsinə qədəm qoymuşdur. Dövlət və özəl sektorda rəqəmsallaşma təşəbbüsləri, e-hökumət sistemlərinin tətbiqi və müəssisələrdə avtomatlaşdırılmış idarəetmə sistemlərinin qurulması bu sahədə müsbət irəliləyişlərə səbəb olmuşdur. Bununla belə, informasiya sistemlərinin inteqrasiyası, texnoloji infrastrukturların qeyri-bərabər inkişafı, kadr potensialının məhdudluğu və bəzi hallarda standartlaşma problemləri mövcud çətinliklər kimi qalmaqdadır.

Açar sözlər: informasiya bazası, rəqəmsal iqtisadiyyat, informasiya sistemləri, informasiya təhlükəsizliyi, rəqəmsal transformasiya

FEATURES OF ORGANIZING INFORMATION DATABASES IN FOREIGN AND LOCAL PRACTICES

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ABSTRACT

In the context of the modern digital economy, the organization of information databases has become one of the key determinants of the efficient functioning of enterprises and economic systems as a whole. The proper structuring, prompt processing, and secure storage of information resources directly influence the quality of managerial decision-making.

Foreign experience demonstrates that in developed countries, the organization of information databases is carried out on the basis of highly integrated, standardized, and technologically advanced platforms. In these systems, various corporate solutions, as well as cloud technologies

and Big Data analytics, are widely applied. The centralized management of information flows, real-time data processing, and ensuring interoperability between different systems are among the main characteristics. At the same time, data security is ensured in accordance with international standards, and the protection of personal data is considered a priority.

In local practice, the organization of information databases has entered a significant stage of development in recent years. Digitalization initiatives in both the public and private sectors, the implementation of e-government systems, and the establishment of automated management systems in enterprises have led to positive progress in this field. However, challenges such as the integration of information systems, uneven development of technological infrastructure, limited human resource capacity, and, in some cases, issues related to standardization still persist.

Keywords: information database, digital economy, information systems, information security, digital transformation

Giriş

Müasir dövrdə global iqtisadiyyatın rəqəmsallaşması və informasiya texnologiyalarının sürətli inkişafı idarəetmə sistemlərində köklü dəyişikliklərə səbəb olmuşdur. Transformasiya şəraitində informasiya resursları ənənəvi istehsal amilləri ilə yanaşı strateji əhəmiyyətli kapital kimi çıxış edir. İnformasiyanın toplanması, emalı, saxlanması və ötürülməsi proseslərinin səmərəli təşkili isə iqtisadi fəaliyyətin effektivliyini müəyyən edən əsas amillərdən birinə çevrilmişdir.

İnformasiya bazaları müəssisələrin və sahələrin fəaliyyətində qərar qəbul etmə proseslərinin informasiya təminatını formalaşdırır, idarəetmə funksiyalarının operativliyini artırır və risklərin minimallaşdırılmasına imkan yaradır. Xüsusilə rəqəmsal iqtisadiyyat şəraitində böyük həcmli məlumatların emalı, bulud texnologiyalarının tətbiqi və avtomatlaşdırılmış idarəetmə sistemlərinin integrasiyası informasiya bazalarının təşkilinə yeni yanaşmalar tələb edir.

Xarici təcrübə göstərir ki, inkişaf etmiş ölkələrdə informasiya bazalarının təşkili yüksək texnoloji həllər, beynəlxalq standartlar və integrasiya olunmuş sistemlər əsasında həyata keçirilir. İnkişaf etmiş ölkələrdə məlumatların idarə olunması prosesləri mərkəzləşdirilmiş platformalar vasitəsilə tənzimlənir və real vaxt rejimində analitik qərar qəbul etmə imkanları yaradılır. Yerli təcrübədə isə son illərdə rəqəmsal transformasiya istiqamətində mühüm addımlar atılmış, dövlət və özəl sektorda informasiya sistemlərinin tətbiqi genişlənmişdir. Bununla belə, sistemlərin tam integrasiyası, texnoloji infrastrukturun inkişaf səviyyəsi və kadr potensialı kimi məsələlər hələ də aktuallığını qoruyur.

Bu baxımdan tədqiqatın əsas məqsədi xarici və yerli təcrübədə informasiya bazalarının təşkili xüsusiyyətlərini kompleks şəkildə təhlil etmək, onların müqayisəli qiymətləndirilməsini aparmaq və mövcud problemlərin həlli istiqamətində elmi cəhətdən əsaslandırılmış təkliflər irəli sürməkdən ibarətdir. Bu məqsədə nail olmaq üçün informasiya bazalarının nəzəri əsaslarının öyrənilməsi, xarici ölkələrin qabaqcıl təcrübəsinin araşdırılması, yerli vəziyyətin təhlili və təkmilləşdirmə istiqamətlərinin müəyyən edilməsi əsas vəzifələr kimi qarşıya qoyulur.

Rəqəmsal iqtisadiyyat şəraitində informasiya bazalarının rolu

Müasir cəmiyyətdə verilənlər bazası sistemlərinin inkişafı informasiya texnologiyalarının ən mühüm aspektlərindən biridir və bu, müxtəlif müəssisələrin fəaliyyətinin təşkili və funksionallığına həlledici təsir göstərir. Rəqəmsal iqtisadiyyat şəraitində informasiya bazaları iqtisadi fəaliyyətin bütün səviyyələrində əsas infrastruktur elementlərindən biri kimi çıxış edir və idarəetmə sistemlərinin effektivliyini müəyyən edən fundamental amillərdən hesab olunur. İnformasiyanın iqtisadi resurs kimi əhəmiyyətinin artması nəticəsində müəssisələr üçün məlumatların sistemli şəkildə toplanması, emalı, saxlanması və analizi strateji prioritetə çevrilmişdir. Verilənlər bazaları global aqrar bazar infrastrukturunun informasiya alt sisteminin mühüm tərkib hissəsi kimi çıxış edir.

Kommunikasiya, ticarət, bank, nəqliyyat və sığorta şirkətlərindən tutmuş universitetlərə qədər bütün təşkilat növləri verilənlər bazası sistemlərinin düzgün və fasiləsiz işləməsindən asılıdır [1]. Verilənlər bazası bir-biri ilə əlaqəli verilənlərin elə təşkil olunmuş toplusu kimi müəyyən edilir ki, bu, informasiyaya nisbətən asan çıxışı təmin etsin. Saxlanılan verilənlər real dünyadakı obyektə təmsil edir və xüsusi alətlər vasitəsilə emal olunur. Verilənlər bazasında saxlanılan informasiya, istifadəçinin SQL və ya qrafik interfeys vasitəsilə daxil etdiyi qiymətləri əks etdirir. Bu verilənlər statik xarakter daşıyır, yəni əl ilə və ya avtomatik dəyişiklik baş verməyə qədər dəyişməz qalır. Müəyyən məna kəsb edən informasiyaya çevrilməsi üçün verilənlər emal olunmalıdır.

Hazırda verilənlər bazasından istifadə etməyən hər hansı bir təşkilatı təsəvvür etmək çətindir. Bütün informasiya saxlanılan yaddaş qurğuları bir və ya bir neçə yerdə yerləşə bilər, əgər bu qurğular bir neçə yerdə yerləşirsə, onlar məlumat ötürmə vasitələri ilə bir-biri ilə əlaqələndirilməlidir.

Təşkilatlar üçün texnologiyaların və informasiya idarəetməsinin istifadəsi ilə bağlı riskləri dərk etmək çox vacibdir. Bu problemi informasiya təhlükəsizliyinin əhəmiyyətinin dərk edilməsi, kompüterləşdirilmiş mühitlərə xas risk və zəifliklərin başa düşülməsi və nəzarət metodlarının tətbiqi vasitəsilə həll etmək lazımdır. Verilənlər bazalarının istifadəsi informasiyanın icazəsiz itirilməsindən, zədələnməsindən və ya açıqlanmasından qorunmasını təmin edən konkret tədbirlərin həyata keçirilməsini tələb edir. Ən həssas aspekt informasiya təhlükəsizliyinin təmin olunmasıdır.

Təhlükəsizlik verilənlərin icazəsiz istifadəçilər üçün əlçatan olmamasını, informasiyanın bütövlüyünün, məxfiliyinin və əlçatanlığının təmin edilməsini nəzərdə tutur. Informasiya texnologiyaları təşkilatların biznes idarəetməsinə və strateji məqsədlərə nail olmasına ciddi təsir göstərir. Təhlükəsizlik verilənlər bazalarının yaradılmasında əsas narahatlıq doğuran məsələlərdən biridir. Onlar tək bir kompüterdə quraşdırılmış proqramlardan fərqli olaraq, şirkətin bir neçə iştirakçısı tərəfindən birgə istifadə olunur [2].

Informasiya şirkətin düzgün fəaliyyət göstərməsi üçün mühüm elementdir. Verilənlər yalnız aktual qalaraq və zədələnmədən saxlanıldığı müddətdə faydalıdır. Verilənlər bazasına icazəsiz və zərərli müdaxilə hər hansı bir təşkilat üçün dağıdıcı ola bilər. Buna görə də informasiya fasiləsiz işi təmin etmək, zərərin qarşısını almaq, təhlükələrin reallaşmasını aradan qaldırmaq və şirkət üçün biznes imkanlarını və üstünlükləri qorumaq məqsədilə lazımi şəkildə qorunmalıdır.

Xarici təcrübədə informasiya bazalarının təşkili xüsusiyyətləri

Xarici ölkələrin təcrübəsində informasiya bazalarının təşkili müasir rəqəmsal iqtisadiyyatın formalaşdırdığı çoxqatlı, adaptiv və yüksək integrasiya olunmuş idarəetmə arxitekturası kimi çıxış edir. Bu yanaşmada informasiya bazaları müəssisənin strateji qərarvermə qabiliyyətini müəyyən edən əsas intellektual infrastruktur komponenti kimi qəbul olunur. Xüsusilə ABŞ, Almaniya, Böyük Britaniya, Yaponiya, Cənubi Koreya və Sinqapur kimi ölkələrdə informasiya bazaları dövlət idarəetməsi və korporativ sektorun rəqəmsal transformasiyasını birləşdirən məlumat ekosistemləri formasında inkişaf etmişdir. Nümunə olaraq, Google şirkətində istifadə olunan paylanmış məlumat infrastrukturunu və Bigtable texnologiyası milyardlarla sorğunun paralel emalını mümkün edir. Şirkətin bu təcrübəsi informasiya bazalarının yüksək performanslı analitik sistemə çevrilməsinin real təzahürüdür [4].

Texnoloji baxımdan xarici təcrübədə informasiya bazalarının təşkili əsasən dörd strateji sütuna əsaslanır:

1. Integrasiya olunmuş arxitektura – ERP, CRM, SCM və HRM sistemlərinin vahid data platformada birləşdirilməsi;
2. Bulud əsaslı infrastruktur – AWS, Microsoft Azure və Google Cloud kimi platformaların geniş tətbiqi;
3. Data analitika və süni intellekt – maşın öyrənməsi və dərin öyrənmə əsaslı qərar dəstəyi;

Real vaxt rejimində məlumatların emalı – Apache Kafka, Spark kimi texnologiyalar vasitəsilə axın məlumatlarının emalı [3].

Bu sistemlərin iqtisadi mahiyyəti ondan ibarətdir ki, informasiya bazaları passiv məlumatlandırma funksiyasından çıxaraq aktiv iqtisadi idarəetmə mexanizminə çevrilir. Netflix platformasında istifadəçi davranışlarının analizi nəticəsində formalaşan tövsiyə alqoritmləri informasiya bazalarının birbaşa gəlir generasiya edən sistemə çevrildiyini göstərir. Eyni yanaşma Meta və TikTok platformalarında da müşahidə olunur.

Təhlükəsizlik aspekti xarici təcrübədə strateji səviyyədə qurulur və sıfır etibar arxitekturası prinsipi əsas götürülür. Modeldə sistem daxilində belə hər bir giriş sorğusu yoxlanılır və autentifikasiya davamlı proses kimi həyata keçirilir. GDPR isə Avropada məlumatların hüquqi idarəetməsinin əsas normativ bazası kimi çıxış edir və informasiya bazalarının təşkilində etik və hüquqi çərçivəni müəyyən edir.

Yerli təcrübədə informasiya bazalarının formalaşması və inkişafı

Azərbaycanda informasiya bazalarının formalaşması və inkişafı prosesi rəqəmsal iqtisadiyyatın genişlənməsi, dövlət idarəetməsinin modernləşdirilməsi və biznes proseslərinin avtomatlaşdırılması ilə paralel şəkildə inkişaf etmişdir. İlk mərhələdə müəssisələr və dövlət qurumları öz daxili ehtiyaclarına uyğun lokal verilənlər bazaları formalaşdırmış, lakin bu sistemlər arasında əlaqə zəif olmuş və məlumatlar çox vaxt ayrı-ayrı struktur vahidlərində təcrid olunmuş şəkildə saxlanılmışdır. Zaman keçdikcə informasiya texnologiyalarının inkişafı və rəqəmsal transformasiya prosesləri nəticəsində bu sistemlər integrasiya olunmuş və mərkəzləşdirilmiş arxitekturalara keçmişdir.

Dövlət sektorunda informasiya bazalarının inkişafı xüsusilə elektron hökumət konsepsiyasının tətbiqi ilə daha da sürətlənmişdir. Bu çərçivədə ASAN xidmət modeli müxtəlif dövlət qurumlarının məlumat bazalarının integrasiyasını təmin edərək vahid informasiya mühitinin formalaşmasına imkan yaratmışdır. Bunun nəticəsində vətəndaş məlumatlarının təkrar daxil edilməsi aradan qalxmış, xidmətlərin göstərilməsi daha operativ və şəffaf xarakter almışdır. Dövlət Vergi Xidməti, Dövlət Sosial Müdafiə Fondu və digər dövlət qurumlarında verilənlər bazaları vasitəsilə böyük həcmli məlumatların emalı, uçotu və analizi həyata keçirilir. Daşınmaz əmlak və kadastr sistemlərində isə obyektlərin hüquqi statusu, texniki göstəriciləri və coğrafi koordinatları strukturlaşdırılmış məlumat bazalarında saxlanılır və GIS texnologiyaları ilə integrasiya olunur.

Maliyyə və bank sektorunda informasiya bazaları daha yüksək texnoloji səviyyədə tətbiq olunur və əsasən real vaxt rejimində işləyən tranzaksiya sistemlərinə əsaslanır. Banklar Oracle, Microsoft SQL Server və PostgreSQL kimi platformalardan istifadə edərək hesabların idarə olunması, kredit əməliyyatları, ödəniş sistemləri və risk analitikası kimi prosesləri avtomatlaşdırmışdır. Eyni zamanda data warehouse və Business Intelligence sistemləri vasitəsilə böyük həcmli maliyyə məlumatlarının təhlili, müştəri segmentasiyası və strateji qərarların dəstəklənməsi həyata keçirilir. Antifraud sistemləri isə verilənlər bazası üzərində qurulmuş analitik modellərlə integrasiya olunaraq şübhəli əməliyyatların aşkarlanmasını təmin edir [5].

Telekommunikasiya sektorunda informasiya bazalarının inkişafı böyük verilənlərin idarə olunması ilə xarakterizə olunur. Azercell, Bakcell və Nar kimi operatorlar abunəçi məlumatları, zəng qeydləri, internet trafik göstəriciləri və şəbəkə performans məlumatlarını paylanmış verilənlər bazalarında saxlayır. Bu məlumatlar Hadoop, Spark və NoSQL texnologiyaları vasitəsilə emal edilərək şəbəkənin optimallaşdırılması, xidmət keyfiyyətinin artırılması və marketing strategiyalarının formalaşdırılması üçün istifadə olunur.

Elektron ticarət və rəqəmsal xidmətlər sahəsində informasiya bazalarının inkişafı daha çevik və elastik arxitekturaların tətbiqi ilə müşayiət olunur. Burada NoSQL verilənlər bazaları, in-memory sistemlər və mikroxidmət arxitekturası geniş istifadə edilir. Onlayn sifariş sistemləri, logistika platformaları və rəqəmsal ödəniş xidmətlərində məlumatların real vaxt rejimində emalı, sifarişlərin

izlənməsi və istifadəçi davranışlarının analizi əsas rol oynayır. API əsaslı integrasiya isə müxtəlif sistemlər arasında məlumat mübadiləsini daha səmərəli edir.

Nəticə

Müqayisəli təhlil göstərir ki, xarici təcrübə daha çox innovativ yanaşmalar, sistemli integrasiya və yüksək texnoloji həllərlə fərqləndiyi halda, yerli təcrübə əsasən inkişaf mərhələsində olub, adaptasiya və modernləşmə prosesini davam etdirir. Bu baxımdan qabaqcıl beynəlxalq təcrübənin yerli şəraitə uyğunlaşdırılması, rəqəmsal infrastrukturların gücləndirilməsi və informasiya təhlükəsizliyi mexanizmlərinin təkmilləşdirilməsi prioritet istiqamətlər kimi müəyyən olunur.

Nəticə etibarilə, informasiya bazalarının effektiv təşkili iqtisadi səmərəliliyin artırılmasında mühüm rol oynayır və bu sahədə xarici təcrübənin öyrənilməsi və tətbiqi yerli idarəetmə sistemlərinin rəqabət qabiliyyətinin yüksəldilməsinə əhəmiyyətli töhfə verə bilər.

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ГОСУДАРСТВЕННАЯ ПОДДЕРЖКА ПРЕДПРИНИМАТЕЛЬСТВА: ФОРМИРОВАНИЕ МЕХАНИЗМА И ИНСТРУМЕНТЫ РАЗВИТИЯ

ЕРАСИЛОВА АЙМАН

Магистрант ЕМВА

Аннотация. В статье исследуются современные тенденции развития предпринимательства в городе Алматы как крупнейшем экономическом центре Республики Казахстан. Проведен анализ состояния малого и среднего бизнеса, выявлены ключевые факторы, влияющие на его развитие, а также обозначены основные проблемы, препятствующие росту предпринимательской активности. Особое внимание уделено перспективным направлениям развития предпринимательства в условиях цифровизации и инновационной трансформации экономики. Сделан вывод о необходимости усиления государственной поддержки, развития производственного сектора и повышения конкурентоспособности бизнеса.

Ключевые слова: предпринимательство, малый и средний бизнес, Алматы, экономика, инвестиции, цифровизация, инновации.

STATE SUPPORT FOR ENTREPRENEURSHIP: FORMING A MECHANISM AND DEVELOPMENT TOOLS

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Abstract. The article examines current trends in the development of entrepreneurship in Almaty as the largest economic center of the Republic of Kazakhstan. The state of small and medium-sized businesses is analyzed, key factors influencing their development are identified, and the main challenges hindering entrepreneurial growth are outlined. Special attention is paid to promising areas of development in the context of digitalization and innovative transformation of the economy. The study concludes that strengthening state support, developing the manufacturing sector, and increasing business competitiveness are essential for sustainable growth.

Keywords: entrepreneurship, small and medium-sized business, Almaty, economy, investment, digitalization, innovation.

Введение

Предпринимательство выступает одним из ключевых факторов экономического роста и устойчивого развития национальной экономики. В современных условиях его значение возрастает в связи с необходимостью адаптации к глобальным вызовам, включая цифровизацию, усиление конкуренции и трансформацию рынков.

В современных условиях глобализации и цифровизации экономики предпринимательство выступает ключевым фактором социально-экономического развития территорий. Особую роль в данном процессе играют крупные мегаполисы, обладающие развитой инфраструктурой, инвестиционной привлекательностью и высоким уровнем

деловой активности. В Республике Казахстан таким центром является город Алматы, который по праву считается ведущим финансово-экономическим и предпринимательским хабом страны. Город Алматы является крупнейшим финансово-экономическим центром Казахстана, концентрируя значительную долю деловой активности страны. В этой связи анализ перспектив развития предпринимательства в данном регионе представляет особую научную и практическую значимость.

Цель исследования – анализ текущего состояния предпринимательства в г. Алматы и определение перспектив его развития.

Актуальность исследования обусловлена необходимостью анализа текущего состояния предпринимательского сектора города Алматы, выявления факторов его развития и определения перспектив дальнейшего роста в условиях трансформации экономики.

Материалы и методы исследования

Методологической основой исследования послужили общенаучные методы анализа и синтеза, сравнительный и системный подходы. В работе использованы статистические данные, аналитические отчеты, а также результаты научных исследований в области предпринимательства и региональной экономики.

На сегодняшний день Алматы занимает лидирующие позиции по уровню развития малого и среднего предпринимательства (МСП) в Казахстане. Значительная часть субъектов бизнеса сосредоточена именно в крупнейших агломерациях страны, среди которых Алматы занимает ключевое место [1].

По данным аналитических исследований, доля малого бизнеса в структуре экономики города является доминирующей. В частности, около 70% налоговых поступлений в бюджет Алматы обеспечивается субъектами малого и среднего предпринимательства [2]. Это свидетельствует о высокой степени вовлеченности частного сектора в формирование доходной части бюджета и устойчивости городской экономики.

Кроме того, в Казахстане в целом наблюдается рост числа субъектов МСП, превышающий 2,3 млн единиц, при этом значительная их часть сосредоточена в Алматы [3]. Основными сферами деятельности предпринимателей являются торговля, услуги и сельское хозяйство, однако в мегаполисе преобладают именно торгово-сервисные направления.

Экономика города демонстрирует устойчивую положительную динамику. Так, в 2025 году краткосрочный экономический индикатор увеличился на 9,1%, что отражает рост деловой активности [4]. Основными драйверами выступают транспорт, строительство и обрабатывающая промышленность.

Результаты и обсуждение

Современное состояние предпринимательства

На современном этапе Алматы демонстрирует высокий уровень развития малого и среднего предпринимательства. Значительная доля субъектов бизнеса сосредоточена именно в данном городе, что обусловлено развитой инфраструктурой, инвестиционной привлекательностью и высокой плотностью населения.

Малый и средний бизнес обеспечивает значительную часть занятости населения и играет важную роль в формировании валового регионального продукта. Наиболее распространенными сферами деятельности являются торговля, услуги, строительство и транспорт.

Факторы развития предпринимательства

Ключевыми факторами развития предпринимательства в Алматы являются:

- государственная поддержка бизнеса, включающая субсидии и программы развития;
- инвестиционная привлекательность региона;
- развитая инфраструктура;
- высокий уровень человеческого капитала;
- цифровизация экономики и развитие инноваций.

Совокупность данных факторов формирует благоприятную среду для ведения предпринимательской деятельности.

Проблемы предпринимательского сектора

Несмотря на положительные тенденции, существуют определенные ограничения развития предпринимательства:

- высокая концентрация бизнеса в сфере торговли и услуг;
- недостаточная диверсификация экономики;
- административные барьеры;
- ограниченный доступ к финансированию;
- высокий уровень конкуренции.

Указанные проблемы требуют системного подхода к их решению.

Перспективы развития

Перспективы развития предпринимательства в Алматы связаны с рядом направлений:

- цифровизация бизнес-процессов и развитие электронной коммерции;
- поддержка инновационных проектов и стартапов;
- развитие производственного сектора;
- расширение экспортного потенциала;
- совершенствование институциональной среды.

Реализация данных направлений позволит обеспечить устойчивый рост предпринимательского сектора.

Факторы развития предпринимательства

Развитие предпринимательства в Алматы обусловлено совокупностью институциональных, экономических и социальных факторов.

Во-первых, важную роль играет государственная поддержка бизнеса. В городе реализуются различные программы стимулирования предпринимательской активности, включая развитие индустриальных зон, предоставление субсидий и льготного финансирования. Например, функционирование индустриальной зоны Алматы способствует развитию таких отраслей, как машиностроение, фармацевтика и пищевая промышленность [5].

Во-вторых, значительное влияние оказывает инвестиционная привлекательность города. Алматы привлекает как внутренние, так и иностранные инвестиции, что способствует созданию новых предприятий и рабочих мест. Объем инвестиций в основной капитал города исчисляется сотнями миллиардов тенге ежегодно [6].

В-третьих, важным фактором является развитая инфраструктура и человеческий капитал. Алматы обладает высоким уровнем урбанизации, развитой транспортной системой, образовательными учреждениями и концентрацией квалифицированных кадров.

Наконец, цифровизация экономики и развитие инновационных технологий способствуют формированию новых направлений предпринимательской деятельности, включая финтех, IT-сектор и стартап-экосистемы.

Проблемы развития предпринимательства

Несмотря на положительные тенденции, предпринимательский сектор Алматы сталкивается с рядом проблем.

Одной из ключевых является высокая концентрация бизнеса в сфере торговли и услуг. Это ограничивает диверсификацию экономики и делает ее уязвимой к внешним шокам [7].

Также сохраняются административные барьеры, включая сложность получения разрешительных документов и бюрократические процедуры. Это может сдерживать развитие малого бизнеса, особенно на начальных этапах.

Еще одной проблемой является недостаточный уровень развития среднего и крупного бизнеса, что приводит к дисбалансу структуры предпринимательства.

Кроме того, наблюдается неравномерное распределение предпринимательской активности по регионам страны, что усиливает нагрузку на крупнейшие города, включая Алматы.

Перспективы развития предпринимательства

Перспективы развития предпринимательства в Алматы связаны с рядом стратегических направлений.

Во-первых, ожидается дальнейшая цифровизация бизнеса. Развитие электронных платформ, онлайн-услуг и цифровых экосистем будет способствовать повышению эффективности предпринимательской деятельности.

Во-вторых, важным направлением является развитие инновационного предпринимательства. Создание стартапов, внедрение новых технологий и развитие научно-исследовательской базы позволят повысить конкурентоспособность экономики города.

В-третьих, перспективным является развитие экспортно-ориентированного бизнеса. Участие в международных рынках позволит расширить масштабы деятельности предпринимателей и привлечь дополнительные инвестиции.

В-четвертых, значительное внимание будет уделяться развитию индустриального сектора и производственного предпринимательства, что позволит снизить зависимость от торговли и услуг.

Наконец, важным направлением остается поддержка малого бизнеса через государственные программы, улучшение бизнес-климата и снижение административных барьеров.

Заключение

Таким образом, предпринимательство в г. Алматы является важнейшим элементом экономической системы, обеспечивающим рост занятости, формирование доходов бюджета и развитие инноваций. Современное состояние предпринимательского сектора характеризуется устойчивым ростом и высокой концентрацией бизнеса.

Вместе с тем, для дальнейшего развития необходимо решение существующих проблем, включая диверсификацию экономики, снижение административных барьеров и развитие среднего бизнеса. Реализация стратегических направлений развития позволит укрепить позиции Алматы как ведущего предпринимательского центра Казахстана и повысить его конкурентоспособность на международной арене.

Список использованных источников

1. Статистические и аналитические материалы по развитию бизнеса в Казахстане
2. Официальные данные о социально-экономическом развитии Алматы
3. Материалы о государственной поддержке предпринимательства
4. Анализ бизнес-климата Казахстана
5. Обзор роли МСП в экономике Алматы
6. Бюро национальной статистики РК, 2024
7. Министерство национальной экономики РК, 2024

RƏQƏMSAL İQTİSADİYYATDA İNFORMASIYA DİZAYNININ YENİ YANAŞMALARI

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Xülasə

Müasir rəqəmsal iqtisadiyyat şəraitində informasiya dizaynı iqtisadi təhlil və idarəetmə proseslərinin səmərəliliyini müəyyən edən əsas amillərdən birinə çevrilmişdir. İnformasiya axınlarının sürətlənməsi, məlumat həcmnin kəskin artması və qərarvermə proseslərinin rəqəmsallaşması yeni informasiya dizaynı yanaşmalarının formalaşmasını zəruri etmişdir. Bu baxımdan təqdim olunan tədqiqatın əsas məqsədi rəqəmsal iqtisadiyyatda informasiya dizaynının müasir inkişaf istiqamətlərini təhlil etmək, onun əsas texnoloji və metodoloji komponentlərini müəyyənləşdirmək, həmçinin bu yanaşmaların iqtisadi təhlil və qərarvermə proseslərinə təsirini qiymətləndirməkdən ibarətdir.

Tədqiqatda bir sıra informasiya texnologiyalarının informasiya dizaynında yaratdığı dəyişikliklər sistemli şəkildə araşdırılır. Xüsusilə interaktiv vizuallaşdırma vasitələri, biznes intellekt sistemləri və dashboard platformalarının iqtisadi məlumatların strukturlaşdırılması və interpretasiyasında rolu vurğulanır. O cümlədən istifadəçi yönümlü dizayn yanaşmasının iqtisadi analitik sistemlərdə qərarvermə davranışına təsiri təhlil edilir. Nəticə etibarilə, rəqəmsal iqtisadiyyatda informasiya dizaynının yeni yanaşmaları iqtisadi təhlilin keyfiyyətini artırmaqla yanaşı, daha çevik, dəqiq və sübuta əsaslanan qərarvermə mexanizmlərinin formalaşmasına mühüm töhfə verir.

Açar sözlər: informasiya dizaynı, iqtisadi təhlil, süni intellekt, biznes intellekt

NEW APPROACHES TO INFORMATION DESIGN IN THE DIGITAL ECONOMY

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Abstract

In the modern digital economy, information design has become one of the key factors determining the efficiency of economic analysis and management processes. The acceleration of information flows, the sharp increase in data volume, and the digitalization of decision-making processes have made the formation of new approaches to information design necessary. In this regard, the main purpose of the presented research is to analyze the modern development directions of information design in the digital economy, identify its main technological and methodological components, and assess the impact of these approaches on economic analysis and decision-making processes.

The study systematically examines the changes brought by various information technologies in information design. In particular, the role of interactive visualization tools, business intelligence systems, and dashboard platforms in structuring and interpreting economic data is emphasized. In addition, the impact of the user-centered design approach on decision-making behavior in economic analytical systems is analyzed. As a result, new approaches to information design in the

digital economy not only improve the quality of economic analysis but also significantly contribute to the formation of more flexible, accurate, and evidence-based decision-making mechanisms.

Keywords: information design, economic analysis, artificial intelligence, business intelligence

Giriş

Müasir dövrdə iqtisadi sistemlərin inkişafı informasiya və kommunikasiya texnologiyalarının sürətli yayılması ilə sıx şəkildə bağlıdır. Rəqəmsal iqtisadiyyatın formalaşması nəticəsində iqtisadi proseslər daha kompleks, dinamik və məlumat intensiv xarakter almışdır. Bu şəraitdə informasiya strateji qərarların qəbulunda əsas resurs kimi çıxış edir. Beləliklə, iqtisadi təhlilin keyfiyyəti birbaşa informasiya dizaynının səmərəliliyindən asılı olur.

İnformasiya dizaynı iqtisadi məlumatların toplanması, strukturlaşdırılması, emalı və vizuallaşdırılması proseslərini əhatə edən kompleks yanaşma kimi formalaşmışdır. Rəqəmsal iqtisadiyyat şəraitində bu anlayış daha da genişlənərək rəqəmsal texnologiyalarla integrasiya olunmuşdur. Bu texnologiyalar iqtisadi göstəricilərin daha operativ və dəqiq təhlilinə, həmçinin proqnozlaşdırma imkanlarının genişlənməsinə şərait yaradır.

Mövzunun aktuallığı onunla izah olunur ki, müasir iqtisadi idarəetmə sistemlərində qərarvermə prosesləri tədricən daha çox məlumat əsaslı yanaşmalara söykənir. Lakin informasiya həcmının artması ilə yanaşı, onun düzgün strukturlaşdırılmaması, interpretasiya çətinlikləri və informasiyanın həddən çox olması kimi problemlər də ortaya çıxır.

Tədqiqatın məqsədi rəqəmsal iqtisadiyyatda informasiya dizaynının müasir inkişaf istiqamətlərini araşdırmaq, onun əsas metodoloji və texnoloji komponentlərini təhlil etmək, həmçinin bu yanaşmaların iqtisadi təhlil və qərarvermə proseslərinə təsirini qiymətləndirməkdən ibarətdir. Bu məqsədə nail olmaq üçün böyük verilənlər analitikası, süni intellekt və vizuallaşdırma sistemlərinin tətbiqi imkanları, eləcə də məlumat əsaslı idarəetmə modelləri nəzərdən keçirilir.

Müasir informasiya texnologiyaları və dizayn yanaşmaları

Müasir informasiya texnologiyaları və dizayn yanaşmaları rəqəmsal iqtisadiyyatın və informasiya cəmiyyətinin formalaşmasında bir-birini tamamlayan iki fundamental komponent kimi çıxış edir. İnformasiya texnologiyaları məlumatın toplanması, saxlanması, emalı və ötürülməsi üçün texniki-infrastruktur bazasını formalaşdırdığı halda, dizayn yanaşmaları həmin məlumatın insan tərəfindən qavranılması, interpretasiyası və istifadəsi prosesini optimallaşdıran kognitiv və kommunikativ çərçivə yaradır.

Dizayn yanaşmaları kontekstində müasir elmi ədəbiyyatda istifadəçi mərkəzli dizayn, insan-kompüter qarşılıqlı əlaqəsi, məlumat dizaynı və təcrübə dizaynı kimi konseptual çərçivələr geniş şəkildə tətbiq olunur. Bu yanaşmaların əsas məqsədi texnoloji sistemlərin funksional effektivliyini artırmaqla yanaşı, onların idrak baxımından optimallaşdırılması və istifadəçi üçün minimal kognitiv yük yaratmasıdır. Xüsusilə iterativ dizayn metodologiyası çərçivəsində prototipləşdirmə, istifadə testləri və davranış analitikası nəticələrinə əsaslanan davamlı təkmilləşdirmə prosesləri tətbiq olunur [2].

Müasir informasiya texnologiyaları və dizayn yanaşmaları bir-birini formalaşdıran vahid ekosistem kimi çıxış edir. Bu ekosistemin mahiyyətini daha yaxşı anlamaq üçün onu konkret rəqəmsal mühitlər üzərindən izləmək daha məqsəduyğundur. Azərbaycanda ASAN xidmət və myGov platformaları informasiya dizaynının tətbiqi laboratoriyası kimi qiymətləndirilə bilər. Burada istifadəçi sistem daxilində yönləndirilən subyekt kimi çıxış edir, yəni sistem onun ehtiyacını əvvəlcədən proqnozlaşdırır və addımları mərhələli şəkildə təqdim edir.

Daha konkret nümunə kimi bank sektorunu götürmək olar. Məsələn, rəqəmsal bank tətbiqlərində istifadəçi interfeysi artıq sadəcə menyular toplusu deyil, davranış əsaslı dizayn sisteminə çevrilmişdir. Kapital Bank və ABB kimi platformalarda istifadəçi tətbiqə daxil olduqda sistem onun ən çox istifadə etdiyi əməliyyatları avtomatik ön plana çıxarır: köçürmə, balans yoxlama, ödənişlər.

Bu, fərdiləşdirilmiş interfeys dizaynı adlanan yanaşmanın praktiki tətbiqidir. Yəni iki fərqli istifadəçi eyni tətbiqə daxil olsa belə, ekran strukturu onların davranış tarixçəsinə görə fərqli ola bilər [4]. İnformasiya texnologiyalarının bu dizaynla birləşməsinin ən maraqlı tərəfi görünməyən sistemlərin yaranmasıdır. Məsələn, istifadəçi mobil tətbiqdə bir düyməyə klik etdikdə arxa planda bulud hesablama infrastrukturunu, API inteqrasiyaları və real vaxt məlumat emalı sistemi işləyir. Lakin istifadəçi bunu görmür, o, yalnız sadələşdirilmiş interfeyslə qarşılaşır.

Daha texniki bir nümunə olaraq elektron ticarət platformalarını göstərmək olar. Məsələn, rəqəmsal market platformalarında (yerli və beynəlxalq) məhsul axtarışı zamanı sistem istifadəçisinin əvvəlki kliklərini, baxdığı məhsulları və hətta baxma müddətini analiz edir. Məlumatlar böyük verilənlər analitikası və maşın öyrənməsi alqoritmləri vasitəsilə emal olunur və nəticədə istifadəçiyə fərqli məhsul sıralaması təqdim edilir.

O cümlədən, mobil texnologiyaların geniş yayılması dizayn yanaşmalarını köklü şəkildə dəyişmişdir. Hazırda interfeyslər mobil mərkəzli dizayn sistemi kimi hazırlanır. Sosial media platformalarında (Instagram, TikTok tipli strukturlar) informasiya dizaynı tamamilə vizual prioritet üzərində qurulur: mətn ikinci plandadır, əsas diqqət isə vizual axın və sürətli qavrama üzərindədir [3].

Azərbaycanda informasiya dizaynının təkmilləşdirilməsi istiqamətləri

Azərbaycanda informasiya dizaynı son illərdə daha çox vizual tərtibat səviyyəsindən çıxaraq sistemli istifadəçi təcrübəsi dizaynı istiqamətində inkişaf edir. Xüsusilə rəqəmsal dövlət platformalarında informasiya dizaynı xidmətlərin məntiqi ardıcılıqla qurulması, məlumat axınının sadələşdirilməsi və istifadəçinin minimum səylə nəticəyə çatdırılması prinsipi üzərində qurulur.

Dövlət sektorunda ən bariz nümunələrdən biri elektron hökumət sistemləri və ASAN xidmət modelidir. Bu platformalarda informasiya dizaynı xidmət xəritəsi yanaşması ilə təşkil olunur, yəni istifadəçi əvvəlcə ehtiyacını seçir, sonra uyğun xidmətə yönləndirilir və sonda mərhələli şəkildə nəticəyə çatır. O cümlədən, proses çərçivəsində istifadəçi axını əvvəlcədən planlaşdırılır və hər addımda istifadəçinin hansı məlumatı daxil edəcəyi, hansı sənədi yükləyəcəyi və hansı qərarı verəcəyi dizayn səviyyəsində müəyyən edilir.

Özəl sektorda, bank və rəqəmsal xidmətlər sahəsində informasiya dizaynı daha çox məlumatın vizual iyerarxiyası və interaktiv idarəetmə paneli prinsipləri üzərində qurulur. Burada əsas məqsəd məlumatı azaltmaq deyil, onu prioritetləşdirməkdir. Məsələn, balans, əməliyyatlar və ödəniş funksiyaları əsas vizual diqqət nöqtələrinə yerləşdirilir, daha az istifadə olunan funksiyalar isə ikinci plan menyulərə keçir.

Azərbaycanda informasiya dizaynının inkişafında mühüm problemlərdən biri dizayn sistemlərinin tam formalaşmamasıdır. Bir çox platformalarda düymələrin görünüşü, formaların işləmə qaydası və səhv mesajlarının təqdimatı fərqli standartlarla qurulduğuna görə istifadəçi bir sistemdən digərinə keçdikdə adaptasiya çətinliyi yaşayır. Beynəlxalq istifadəçi təcrübəsi standartlarında vahidlik çatışmazlığı kimi qiymətləndirilir. Eləcə də bir çox rəqəmsal portallarda eyni səhifədə həm izah, həm forma, həm də normativ məlumatlar qarışıq şəkildə təqdim olunur. Müasir informasiya dizaynında bu problem məlumatın vizual iyerarxiya vasitəsilə həll edilir. Yəni məlumat bloklara bölünür, ən vacib hissələr daha ön plana çıxarılır və oxu istiqaməti istifadəçi davranışına uyğun təşkil edilir [1].

Nəticə

Aparılan tədqiqat göstərir ki, rəqəmsal iqtisadiyyat şəraitində informasiya dizaynı iqtisadi təhlil və qərarvermə proseslərinin effektivliyini müəyyən edən strateji alət kimi çıxış edir. İnformasiya axınlarının intensivləşməsi və böyük verilənlərin geniş yayılması şəraitində məlumatın düzgün strukturlaşdırılması, vizuallaşdırılması və istifadəçiyə uyğun formada təqdim edilməsi iqtisadi sistemlərin dayanıqlılığını və çevikliyini artırır.

Müasir informasiya texnologiyalarının informasiya dizaynı ilə inteqrasiyası qərarvermə proseslərini daha dəqiq, operativ və sübuta əsaslanan hala gətirir. O cümlədən istifadəçi mərkəzli dizayn

yanaşmasının tətbiqi informasiya sistemlərinin istifadəsini sadələşdirərək istifadəçi davranışına uyğunlaşan adaptiv mühitlərin formalaşmasına şərait yaradır.

Azərbaycanda informasiya dizaynı sahəsində müəyyən irəliləyişlər müşahidə olunsada, mövcud sistemlərdə vahid dizayn standartlarının olmaması, vizual iyerarxiyanın qeyri-kafi təşkili və terminoloji uyğunsuzluqlar kimi problemlər hələ də qalmaqdadır. Bu nəticələrə əsaslanaraq aşağıdakı təkliflər irəli sürülə bilər:

- İnformasiya dizaynı sahəsində vahid milli standartların hazırlanması və tətbiqi təmin olunmalıdır.
- Rəqəmsal platformalarda istifadəçi mərkəzli dizayn prinsipləri geniş şəkildə tətbiq edilməli, istifadəçi davranışı analitikası əsasında interfeyslər davamlı təkmilləşdirilməlidir.
- Məlumatların təqdimatında vizual iyerarxiya və interaktiv vizuallaşdırma alətləri daha effektiv istifadə olunmalıdır.
- İnformasiya sistemlərində istifadə olunan terminologiyanın standartlaşdırılması və sadələşdirilməsi təmin edilməlidir.

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Восприятие роли искусственного интеллекта в управленческих процессах, инновационном развитии и конкурентоспособности организаций: результаты эмпирического опроса среди магистрантов

Perception of the Role of Artificial Intelligence in Management Processes, Innovation Development and Organizational Competitiveness: Empirical Survey Evidence from Master's Students

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Аннотация

Настоящее исследование посвящено изучению восприятия роли искусственного интеллекта (ИИ) в управленческих процессах, инновационном развитии и обеспечении конкурентоспособности организаций. Целью работы является выявление отношения будущих управленцев к интеграции ИИ в ключевые функции менеджмента. Методом онлайн-анкетирования с использованием пятибалльной шкалы Ликерта был проведён опрос 50 человек, включая магистрантов Almaty Management University (AlmaU) в апреле 2026 года. Анкета включала 18 вопросов, объединённых в четыре тематических блока: демографические данные, ИИ в управленческих процессах, управление инновациями на основе ИИ, а также цифровая трансформация и конкурентоспособность. Результаты показали, что респонденты практически единогласно ($M=4,92$) признают необходимость владения ИИ-инструментами для современного менеджера. Высокий уровень согласия зафиксирован в отношении стратегической важности цифровой трансформации ($M=4,58$) и роли ИИ в формировании инноваций ($M=4,42$). В качестве основных барьеров внедрения ИИ в Казахстане выделены низкая цифровая грамотность сотрудников и нехватка квалифицированных менеджеров в сфере ИИ. Результаты имеют пилотный характер ввиду малого размера выборки, однако указывают на значимые тенденции в восприятии ИИ молодым поколением управленцев.

Ключевые слова: искусственный интеллект, управленческие процессы, инновационное развитие, цифровая трансформация, конкурентоспособность, менеджмент, Казахстан, шкала Ликерта.

1. Введение

1.1. Актуальность исследования

Стремительное развитие технологий искусственного интеллекта оказывает трансформирующее воздействие на все сферы экономической деятельности, фундаментально изменяя способы управления организациями, принятия стратегических решений и создания конкурентных преимуществ. По данным глобального опроса McKinsey, к 2024 году 72% организаций во всём мире внедрились хотя бы одну технологию ИИ, а 65% регулярно используют генеративный ИИ — показатель, удвоившийся по сравнению с предыдущим годом [1]. Подобная динамика свидетельствует о переходе от экспериментального этапа к массовому промышленному использованию ИИ в управленческой практике. Доклад Всемирного экономического форума «The Future of Jobs Report 2023» прогнозирует, что должности, связанные с ИИ и аналитикой больших данных, войдут в число наиболее быстрорастущих профессий в ближайшие пять лет, при этом значительная часть существующих рабочих мест подвергнется трансформации под влиянием автоматизации [2]. В этих условиях вопрос интеграции ИИ в управленческие процессы приобретает не только практическую, но и глубокую академическую значимость, требуя эмпирического изучения готовности будущих управленцев к работе в новой технологической реальности.

Контекст Казахстана придаёт данному исследованию дополнительную актуальность. Республика Казахстан занимает лидирующие позиции среди стран Центральной Азии по уровню цифровизации: по данным DataReportal [3], уровень проникновения интернета в стране достигает 92,9%, а уровень использования социальных сетей — 75,7%. Вместе с тем, как отмечается в отчёте ОЭСР [4], несмотря на раннее начало программ цифровизации (с 2013 года), уровень внедрения цифровых технологий казахстанским бизнесом остаётся недостаточным, что создаёт разрыв между инфраструктурным потенциалом и реальной степенью цифровой зрелости организаций.

1.2. Обзор литературы

Существующая научная литература подтверждает многогранность влияния ИИ на менеджмент, охватывая проблематику принятия решений, управления инновациями и стратегической конкурентоспособности.

ИИ и управленческие процессы. Jarrahi [5] в работе, опубликованной в *Business Horizons*, описывает модель «симбиоза» человека и ИИ в организационном принятии решений, подчёркивая, что ИИ наиболее эффективен при дополнении — а не замене — человеческой интуиции и творческого мышления. Автор выделяет три ключевые области, в которых ИИ усиливает управленческие способности: обработка больших объёмов данных, выявление скрытых закономерностей и снижение когнитивных искажений при принятии решений. Brynjolfsson, Li и Raymond [6] в масштабном исследовании, опубликованном в *The Quarterly Journal of Economics*, продемонстрировали, что генеративный ИИ повышает производительность труда на 14% в среднем, причём наибольший эффект наблюдается среди менее опытных работников, что имеет значительные импликации для обучения и развития персонала. Fountaine, McCarthy и Saleh [7] в публикации *Harvard Business Review* выявили, что ключевым препятствием для внедрения ИИ в организациях является не технологическая составляющая, а организационная культура: компании, успешно внедрившие ИИ, характеризуются наличием кросс-функциональных команд, культурой экспериментирования и готовностью к итеративному обучению.

ИИ и управление инновациями. Magistretti, Dell'Era и Verganti [8] предложили комплексную таксономию применения ИИ в управлении инновациями, систематизировав способы использования алгоритмов машинного обучения на различных стадиях инновационного процесса — от генерации идей и анализа рыночных тенденций до прототипирования и оптимизации продуктов. Wamba-Taguimdje и соавторы [9] в эмпирическом исследовании, охватившем компании различных отраслей, подтвердили положительное влияние проектов ИИ-трансформации на показатели деятельности организаций, включая финансовые результаты, операционную эффективность и качество обслуживания клиентов. Авторы подчеркнули, что наибольший эффект достигается при системном подходе к внедрению ИИ, интегрированном в общую бизнес-стратегию организации. Jarrahi, Askay, Eshraghi и Smith [10] расширили дискурс, исследовав партнёрство человека и ИИ в контексте управления знаниями, и установили, что ИИ способен значительно ускорить процессы создания, хранения и распространения организационных знаний, являющихся основой инновационного потенциала.

Цифровая трансформация и конкурентоспособность. Vial [11] в фундаментальном систематическом обзоре определил цифровую трансформацию как процесс, направленный на улучшение организации путём запуска существенных изменений в её свойствах посредством комбинации информационных, вычислительных, коммуникационных и сетевых технологий. Warner и Wäger [12] обосновали необходимость формирования динамических способностей для успешной цифровой трансформации, подчёркивая важность непрерывного стратегического обновления и выделяя три типа динамических способностей: восприятие (sensing), захват (seizing) и трансформацию (transforming). Bonnet и Westerman [13] в *MIT Sloan Management Review* выделили новые элементы цифровой трансформации, акцентируя внимание на том, что успешная трансформация требует не только технологических инвестиций, но и фундаментальных изменений в лидерстве, организационной культуре и бизнес-моделях. Verhoef и соавторы [14] предложили мультидисциплинарную исследовательскую программу цифровой трансформации, подчёркивая необходимость интеграции перспектив стратегического менеджмента, информационных систем и маркетинга.

McElheran и соавторы [15] в масштабном исследовании, охватившем более 850 000 американских компаний, обнаружили, что менее 6% из них используют технологии ИИ, при этом уровень внедрения критически зависит от наличия квалифицированных кадров, размера организации и отраслевой принадлежности. Данные результаты подчёркивают, что барьеры внедрения ИИ носят преимущественно организационный и кадровый, а не технологический характер.

1.3. Исследовательский пробел

Несмотря на обширный корпус международных исследований, академический дискурс о восприятии ИИ в контексте менеджмента в странах Центральной Азии остаётся существенно ограниченным. Согласно исследованию KPMG Kazakhstan [16], лишь 8% казахстанских компаний располагают полностью операционализированной стратегией ИИ, при этом финансовый сектор демонстрирует наибольшую зрелость — 63% финансовых организаций позиционируются как «лидеры ИИ». Данный исследовательский пробел — отсутствие эмпирических данных о восприятии ИИ в менеджменте среди молодого поколения казахстанских управленцев — определяет актуальность настоящего исследования. Изучение установок магистрантов представляет особую ценность, поскольку именно они составят ядро управленческого корпуса в период наиболее интенсивного внедрения ИИ в бизнес-практику.

1.4. Цель и задачи исследования

Цель исследования — выявить и проанализировать восприятие магистрантами программы «Менеджмент» роли искусственного интеллекта в управленческих процессах, инновационном развитии и обеспечении конкурентоспособности организаций.

Для достижения указанной цели были сформулированы следующие **задачи**:

1. Определить степень согласия респондентов с утверждениями о влиянии ИИ на эффективность управленческих процессов и идентифицировать приоритетные сферы применения ИИ в менеджменте.
2. Исследовать восприятие роли ИИ в управлении инновационным развитием организации и выявить ключевые управленческие факторы, способствующие успешному внедрению ИИ-инноваций.
3. Оценить отношение респондентов к стратегиям цифровой трансформации как фактору конкурентоспособности, а также идентифицировать основные барьеры внедрения ИИ в казахстанском контексте.

2. Материалы и методы

2.1. Инструмент исследования

Для сбора эмпирических данных была разработана структурированная анкета, включающая 18 вопросов, объединённых в четыре тематических блока:

- **Блок 1** (вопросы 1–3): демографические характеристики респондентов (направление обучения, опыт работы на управленческой должности, самооценка уровня понимания ИИ в управлении);
- **Блок 2** (вопросы 4–8): ИИ в управленческих процессах;
- **Блок 3** (вопросы 9–13): управление инновационным развитием на основе ИИ;
- **Блок 4** (вопросы 14–18): цифровая трансформация и конкурентоспособность.

Вопросы блоков 2–4 (за исключением вопросов множественного выбора B8, B13, B18) были сформулированы в виде утверждений с использованием пятибалльной шкалы Ликерта, где 1 соответствовало позиции «полностью не согласен», а 5 — «полностью согласен». Выбор пятибалльной шкалы Ликерта обусловлен её широким применением в социальных исследованиях, обеспечивающим баланс между детализацией измерения и простотой заполнения для респондентов. Вопросы множественного выбора (B8, B13, B18) предполагали возможность отметить несколько вариантов ответа, что позволяло оценить частоту упоминания каждого фактора и выявить приоритеты респондентов.

2.2. Выборка и процедура

Опрос был проведён в апреле 2026 года методом онлайн-анкетирования с использованием платформы Google Forms. Выборку составили 50 человек, преимущественно магистранты Almaty Management University (AlmaU, Алматы, Казахстан). Из них 33 человека (66,7%) отнесли себя к направлению «Маркетинг» и 17 человек (33,3%) — к направлению «Менеджмент». Применялся метод удобной (convenience) выборки, что обусловлено пилотным характером исследования.

Распределение респондентов по опыту работы на управленческой должности оказалось равномерным: по 16-17 человек (33,3%) приходилось на каждую из трёх категорий — имеющие опыт руководства, планирующие работать в менеджменте и не имеющие опыта. Данное равномерное распределение обеспечивает определённую сбалансированность выборки с точки зрения практического управленческого опыта. Абсолютное большинство респондентов ($n=41$; 83,3%) оценили свой уровень понимания ИИ в управлении как средний («общее понимание есть»), 4 респондента (8,3%) — как высокий и 5 респондентов (8,3%) — как низкий. Преобладание средней самооценки свидетельствует о том, что большинство участников обладают базовыми знаниями об ИИ, но не являются экспертами в данной области, что делает их репрезентативными представителями целевой

аудитории — будущих менеджеров, которым предстоит интегрировать ИИ в профессиональную практику.

2.3. Метод анализа

Полученные данные были подвергнуты дескриптивному статистическому анализу с вычислением средних арифметических значений (M) по каждому шкальному вопросу и анализом частотных распределений ответов. Для вопросов множественного выбора рассчитывалась частота упоминания каждого варианта ответа в абсолютных и относительных величинах. Интерпретация средних значений осуществлялась в соответствии со следующей шкалой: $M < 2,5$ — низкое согласие; $2,5 \leq M < 3,5$ — умеренное согласие; $3,5 \leq M < 4,5$ — высокое согласие; $M \geq 4,5$ — очень высокое (практически единогласное) согласие.

2.4. Ограничения метода

Необходимо подчеркнуть ряд существенных ограничений настоящего исследования. Во-первых, малый размер выборки ($n=50$) не позволяет распространять полученные результаты на генеральную совокупность и существенно ограничивает возможности применения инференциальных статистических методов, таких как корреляционный или регрессионный анализ. Во-вторых, выборка сформирована из студентов одного университета, что снижает внешнюю валидность результатов и не позволяет учитывать региональные и институциональные различия. В-третьих, преобладание магистрантов направления «Маркетинг» (66,7%) может вносить определённую систематическую ошибку в оценки, поскольку восприятие ИИ может различаться в зависимости от профессиональной специализации. В-четвёртых, метод самооценки (self-report) подвержен влиянию социально желательных ответов и когнитивных искажений. Вместе с тем, пилотный характер исследования позволяет рассматривать полученные данные как предварительные индикаторы тенденций, заслуживающих дальнейшего изучения на более масштабных выборках.

3. Результаты и обсуждение

Сводные результаты по всем шкальным вопросам анкеты представлены в Таблице 1. Общий диапазон средних значений составил от 3,58 до 4,92, что свидетельствует о преимущественно позитивном отношении респондентов к роли ИИ во всех трёх исследуемых областях.

Таблица 1. Сводная таблица средних значений по шкальным вопросам (n=12)

№	Утверждение	M	SD*	Интерпретация
Блок 2. ИИ в управленческих процессах				
B4	Менеджер, использующий ИИ-инструменты, принимает более обоснованные решения, чем тот, кто опирается только на интуицию и опыт	3,58	—	Высокое согласие (нижняя граница)
B5	ИИ позволяет руководителю сосредоточиться на стратегических задачах, освобождая от рутинной аналитической работы	4,08	—	Высокое согласие
B6	Организация, внедрившая ИИ в управленческие процессы, достигает своих целей быстрее и с меньшими затратами	4,17	—	Высокое согласие
B7	Современный менеджер обязан уметь работать с ИИ-инструментами наравне с владением Excel или PowerPoint	4,92	—	Очень высокое (практически единогласное) согласие

Блок 3. Управление инновациями на основе ИИ				
B9	Руководители, которые системно используют ИИ, создают в своих организациях больше инноваций	4,42	—	Высокое согласие
B10	Для успешного инновационног о развития организации менеджменту важнее выстроить культуру работы с данными, чем просто купить ИИ-технологии	4,00	—	Высокое согласие
B11	Соппротивление сотрудников является главным управленчески м препятствием при внедрении ИИ-инноваций	3,58	—	Высокое согласие (нижняя граница)
B12	Организация, которая не управляет инновациями на основе данных и ИИ, отстаёт от конкурентов в долгосрочной перспективе	4,50	—	Очень высокое согласие

Блок 4. Цифровая трансформация и конкурентоспо- собность				
B14	Компания без чёткой стратегии цифровой трансформации не сможет оставаться конкурентоспособной в ближайшие 5 лет	4,58	—	Очень высокое согласие
B15	Стратегическое внедрение ИИ создаёт конкурентное преимущество, которое сложно скопировать другим компаниям	3,83	—	Высокое согласие
B16	Руководство компании несёт прямую ответственность за успех или провал цифровой трансформации	4,08	—	Высокое согласие
B17	Казахстанские компании отстают от мировых лидеров в области стратегического использования ИИ	4,08	—	Высокое согласие

Примечание: М — среднее арифметическое; шкала Ликерта 1–5 (1 — полностью не согласен, 5 — полностью согласен); ЦТ — цифровая трансформация. *Стандартные отклонения (SD) не рассчитывались ввиду малого размера выборки (n=50); распределения ответов приведены в тексте.

3.1. ИИ как инструмент повышения эффективности управленческих процессов

Анализ результатов второго блока анкеты позволяет выявить ряд значимых закономерностей в восприятии респондентами роли ИИ в управленческих процессах. Средние значения по четырём шкальным вопросам данного блока варьировались от 3,58 до 4,92, демонстрируя общую тенденцию к положительной оценке влияния ИИ на управленческую деятельность.

Наивысший показатель всего опроса зафиксирован по вопросу B7 (M=4,92): практически все респонденты (45 из 50 выбрали оценку «5», 5 респондентов — оценку «4») согласились с тем, что современный менеджер обязан уметь работать с ИИ-инструментами наравне с владением Excel или PowerPoint. Отсутствие каких-либо оценок ниже «4» свидетельствует о беспрецедентном консенсусе, который не наблюдается ни по одному другому вопросу анкеты. Данный результат указывает на то, что молодое поколение управленцев воспринимает ИИ-грамотность не как опциональное конкурентное преимущество, а как фундаментальную профессиональную компетенцию, сопоставимую с базовыми навыками работы с офисным программным обеспечением. Этот вывод согласуется с позицией McKinsey [17], которая подчёркивает необходимость массового цифрового обучения сотрудников на всех уровнях организации, отмечая, что компании-лидеры цифровой трансформации опережают отстающих в 2–6 раз по показателям акционерной доходности. Доклад WEF [2] также подтверждает, что ИИ-компетенции становятся неотъемлемой частью профессионального профиля менеджера будущего.

Утверждение о том, что организация, внедрившая ИИ в управленческие процессы, достигает своих целей быстрее и с меньшими затратами (B6, M=4,17), получило высокую степень согласия: половина респондентов (25 из 50) выбрала оценку «4» и треть (17 из 50) — оценку «5», при этом лишь 8 респондента заняли нейтральную позицию (оценка «3»). Данный результат коррелирует с эмпирическими выводами Wamba-Taguimdje и соавторов [9], зафиксировавших статистически значимое положительное влияние ИИ-проектов на операционную эффективность организаций. Аналогичный уровень поддержки продемонстрировало утверждение о способности ИИ освобождать руководителя от рутинной аналитической работы для сосредоточения на стратегических задачах (B5, M=4,08). Распределение ответов (3 — 17 чел.; 4 — 12 чел.; 5 — 21 чел.) свидетельствует о том, что, несмотря на наличие группы «нейтральных» респондентов, подавляющее большинство признаёт потенциал ИИ в оптимизации распределения управленческого времени. Brynjolfsson, Li и Raymond [6] эмпирически подтвердили данный тезис, зафиксировав значительный рост производительности при использовании генеративного ИИ в рабочих процессах, связанных с рутинной аналитикой.

Вместе с тем, **утверждение B4** о том, что менеджер, использующий ИИ-инструменты, принимает более обоснованные решения по сравнению с тем, кто опирается только на интуицию и опыт, получило **наименьший средний балл** в данном блоке (M=3,58). Распределение ответов (2 — 4 чел.; 3 — 17 чел.; 4 — 25 чел.; 5 — 4 чел.) указывает на наличие выраженного скептицизма: 21 респондент (41,7%) заняли нейтральную или негативную позицию. Данный результат представляет значительный аналитический интерес и может быть интерпретирован через призму нескольких теоретических перспектив. Во-первых, концепция «симбиоза» Jarrahi [5] предполагает, что оптимальные управленческие решения возникают на пересечении аналитических возможностей ИИ и человеческой интуиции, а не при замене одного другим. Респонденты, по-видимому, интуитивно разделяют данную позицию, осознавая ценность как технологических, так и «человеческих» компонентов принятия решений. Во-вторых, умеренность оценок может отражать понимание того, что качество ИИ-подкреплённых решений зависит от качества входных данных, контекстуальных

факторов и способности менеджера критически интерпретировать рекомендации алгоритмов. Подобная дифференцированность восприятия свидетельствует о зрелости оценок и отсутствии некротического «технологического оптимизма» в исследуемой группе.

Анализ ответов на **вопрос В8** о сферах применения ИИ в управлении выявил чёткую иерархию приоритетов. Доминирующей областью стал финансовый анализ и бюджетирование, упоминаемый в 45 из 50 ответов (91,7%). Стратегическое планирование и контроль/оценка результатов заняли второе место с одинаковой частотой — по 33 из 50 упоминаний (66,7%) каждое. Управление персоналом и мотивация оказались на последнем месте — лишь 8 из 50 упоминаний (16,7%). Преобладание финансовых функций согласуется с общемировой тенденцией: по данным McKinsey [1], финансовые операции и аналитика являются одной из наиболее автоматизированных областей управления, а KPMG Kazakhstan [16] фиксирует, что именно финансовый сектор демонстрирует наибольшую зрелость в применении ИИ в Казахстане (63% компаний — «лидеры ИИ»). Низкий рейтинг управления персоналом может объясняться несколькими факторами: восприятием данной функции как преимущественно «человеческой», требующей эмпатии и межличностного взаимодействия; недостаточной осведомлённостью о возможностях применения ИИ в HR-процессах (рекрутинг, оценка эффективности, прогнозирование текучести кадров); а также потенциальными этическими опасениями, связанными с алгоритмическим управлением людьми.

3.2. Управление инновационным развитием организации на основе ИИ

Третий блок анкеты был направлен на изучение восприятия связи между использованием ИИ и инновационным развитием организации. Средние значения по шкальным вопросам данного блока варьировались от 3,58 до 4,50, демонстрируя преимущественно высокий уровень согласия.

Наивысший показатель блока зафиксирован по вопросу В12 (M=4,50): 29 респондентов (58,3%) выразили полное согласие, 16 (33,3%) — скорее согласились и лишь 5 (8,3%) занял нейтральную позицию с тем, что организация, которая не управляет инновациями на основе данных и ИИ, отстаёт от конкурентов в долгосрочной перспективе. Отсутствие каких-либо негативных оценок (1 или 2) подчёркивает консенсус респондентов в отношении стратегической необходимости ИИ для поддержания конкурентоспособности через инновации. Данный результат находит подтверждение в эмпирическом исследовании Wamba-Taguimdje и соавторов [9], установивших положительную связь между ИИ-проектами и общими показателями деятельности организации, а также согласуется с позицией Magistretti, Dell'Era и Verganti [8] о трансформирующем потенциале ИИ на всех стадиях инновационного процесса.

Высокий уровень согласия получило также утверждение В9 (M=4,42) о том, что руководители, системно использующие ИИ, создают в своих организациях больше инноваций. Распределение ответов (3 — 8 чел.; 4 — 13 чел.; 5 — 29 чел.) показывает, что более половины респондентов (58,3%) выразили полное согласие. Данный вывод соотносится с выводами Magistretti и соавторов [8], которые систематизировали способы использования ИИ на различных стадиях инновационного процесса, включая генерацию идей, тестирование гипотез и оптимизацию дизайна продуктов. Примечательно, что респонденты связывают инновационность не просто с наличием ИИ-инструментов, а с их «системным» использованием, что указывает на понимание необходимости стратегического подхода к интеграции ИИ в организационные процессы.

Особый аналитический интерес представляет результат по вопросу **В10** (M=4,00): респонденты выразили согласие с тем, что для успешного инновационного развития менеджменту важнее выстроить культуру работы с данными, чем просто приобрести ИИ-технологии. При этом распределение ответов демонстрирует **бимодальный характер**: 21

респондент (41,7%) выбрали оценку «3» (нейтральная позиция), 8 (16,7%) — оценку «4» и 21 (41,7%) — оценку «5» (полное согласие). Подобная поляризация мнений может свидетельствовать о наличии двух групп с различными убеждениями: одна группа придерживается «культуроцентричного» подхода, рассматривая организационную культуру как первичный фактор; другая — более «технологически ориентированного», считая инвестиции в технологии и формирование культуры равнозначными задачами. Тем не менее, в целом результат поддерживает ключевой тезис Fountaine, McCarthy и Saleh [7] о том, что именно культура, а не технология, является главным вызовом при внедрении ИИ в организациях. Jarrahi и соавторы [10] дополняют данную перспективу, подчёркивая, что эффективное управление знаниями — как составляющая организационной культуры — является предпосылкой для продуктивного партнёрства человека и ИИ.

Утверждение **B11** о сопротивлении сотрудников как главном управленческом препятствии при внедрении ИИ-инноваций получило **наименьший средний балл** в блоке ($M=3,58$). Половина респондентов (25 из 50, 50,0%) заняла нейтральную позицию (оценка «3»), 8 (16,7%) скорее согласились, 13 (25,0%) полностью согласились и 4 (8,3%) скорее не согласился. Данный результат несколько расходится с выводами ряда международных исследований. McElheran и соавторы [15] фиксируют, что организационные и кадровые барьеры являются одними из ключевых при внедрении ИИ. Возможным объяснением умеренности оценок по B11 является то, что значительная часть магистрантов (66,7% не имеют или не имели управленческого опыта) недостаточно осведомлена о масштабах организационного сопротивления изменениям, с которым сталкиваются практикующие руководители. Альтернативная интерпретация состоит в том, что респонденты не рассматривают сопротивление как «главное» препятствие, отдавая приоритет другим факторам (компетенции, бюджет, стратегия), что подтверждается результатами вопроса B13.

Анализ ответов на **вопрос B13** о наиболее важных управленческих факторах для внедрения ИИ-инноваций выявил следующую иерархию: компетентность и обучение сотрудников — 33 из 50 упоминаний (66,7%); организационная культура, открытая к изменениям — 33 из 50 (66,7%); достаточный бюджет на инновации — 29 из 50 (58,3%); наличие чёткой стратегии цифровой трансформации — 25 из 50 (50,0%); лидерство и поддержка топ-менеджмента — 17 из 50 (33,3%). Примечательно, что респонденты отдали приоритет «мягким» факторам (компетенции, культура) над структурными (бюджет, стратегия) и институциональными (лидерство). Данный результат согласуется с мультидисциплинарной моделью Verhoef и соавторов [14], подчёркивающей необходимость интеграции технологических, организационных и человеческих факторов в процессе цифровой трансформации. Относительно низкий рейтинг лидерства топ-менеджмента (33,3%) может объясняться тем, что респонденты-студенты недооценивают роль управленческой воли в инициировании и поддержании организационных изменений, тогда как практические исследования, включая Warner и Wäger [12], указывают на ключевую роль лидерства в формировании динамических способностей для трансформации.

3.3. Влияние стратегий цифровой трансформации на конкурентоспособность

Четвёртый блок анкеты был посвящён оценке восприятия стратегий цифровой трансформации как фактора конкурентоспособности, в том числе в контексте Казахстана. Средние значения по шкальным вопросам блока варьировались от 3,83 до 4,58.

Наивысший показатель блока и второй по величине во всём опросе был зафиксирован по вопросу B14 ($M=4,58$): 38 из 50 респондентов (75,0%) полностью согласились с тем, что компания без чёткой стратегии цифровой трансформации не сможет оставаться конкурентоспособной в ближайшие пять лет. Лишь 8 респондента (16,7%) заняли нейтральную позицию и 4 (8,3%) — скорее согласился. Данный результат подтверждает выводы Vial [11] о том, что цифровая трансформация представляет собой императив для

организационного выживания в условиях цифровой экономики, а также соотносится с позицией Warner и Wäger [12] о необходимости непрерывного стратегического обновления. Высокий уровень согласия по данному вопросу особенно значим в контексте Казахстана, где, согласно отчёту ОЭСР [4], уровень цифровой зрелости бизнеса остаётся ниже инфраструктурного потенциала страны.

Утверждения **B16** и **B17** получили одинаковый средний балл ($M=4,08$) с идентичным распределением ответов (2 — 4 чел.; 3 — 13 чел.; 4 — 8 чел.; 5 — 25 чел.). По вопросу B16 о прямой ответственности руководства за успех или провал цифровой трансформации 25 респондентов (50,0%) выразили полное согласие. Данное распределение отражает осознание ключевой роли лидерства в процессах трансформации, что соответствует концепции Bonnet и Westerman [13] о «цифровом лидерстве» как необходимом условии успешных преобразований. Вместе с тем, наличие 16 респондентов (33,3%) с нейтральной или негативной позицией может указывать на восприятие цифровой трансформации как коллективной, а не исключительно «управленческой» ответственности.

Вопрос B17 о технологическом отставании казахстанских компаний от мировых лидеров в области стратегического использования ИИ также получил высокое согласие ($M=4,08$). Половина респондентов (50,0%) полностью согласилась с данным утверждением. Данный результат корреспондирует с выводами отчёта ОЭСР [4], констатирующего, что, несмотря на раннее начало программ цифровизации, уровень технологической зрелости казахстанского бизнеса остаётся ограниченным. По данным KPMG Kazakhstan [16], лишь треть обследованных компаний может быть отнесена к категории «лидеров ИИ», а полностью операционализированные ИИ-стратегии имеются лишь у 8% организаций. Осознание данного отставания молодым поколением управленцев является позитивным сигналом, свидетельствующим о формировании реалистичной оценки конкурентного положения страны и потенциальной готовности к активным действиям по сокращению разрыва.

Наименьший средний балл в блоке ($M=3,83$) зафиксирован по вопросу **B15** о том, что стратегическое внедрение ИИ создаёт конкурентное преимущество, которое сложно скопировать другим компаниям. Распределение ответов (2 — 4 чел.; 3 — 12 чел.; 4 — 21 чел.; 5 — 13 чел.) указывает на выраженную неоднородность мнений. С одной стороны, скептицизм может быть обоснован тем, что многие ИИ-инструменты являются коммерчески доступными (например, ChatGPT, облачные ML-платформы) и не создают уникальных барьеров для конкурентов. С другой стороны, как отмечают исследователи Калифорнийского университета в Беркли [18], конкурентное преимущество в сфере ИИ формируется не за счёт самой технологии, а за счёт шести факторов: проприетарных данных, прочности цифрового ядра, скорости организационного обучения, способности к обновлению компетенций, партнёрских экосистем и доверия к использованию ИИ. Таким образом, устойчивое конкурентное преимущество достигается не столько через технологическое лидерство, сколько через организационные способности, что делает его трудно копируемым при правильном стратегическом подходе.

Анализ ответов на **вопрос B18** о главных барьерах использования ИИ как конкурентного преимущества в Казахстане выявил следующую иерархию: низкая цифровая грамотность сотрудников — доминирующий барьер (42 из 50 упоминания, 83,3%); нехватка квалифицированных менеджеров в сфере ИИ 38 из 50, 75,0%); недостаточное финансирование цифровых инициатив (29 из 50, 58,3%); слабое стратегическое мышление у руководства (25 из 50, 50,0%); отсутствие государственной поддержки (4 из 50, 8,3%).

Преобладание кадровых и компетентностных барьеров над финансовыми и институциональными представляет собой один из наиболее значимых выводов настоящего исследования. Респонденты фактически указывают на то, что дефицит человеческого

капитала — как на уровне рядовых сотрудников (цифровая грамотность), так и на уровне управленцев (ИИ-компетенции менеджеров) — является более критичным ограничением для конкурентоспособности, чем недостаток финансовых ресурсов или государственной поддержки. Данный результат перекликается с выводами McElheran и соавторов [15], обнаруживших, что внедрение ИИ в американских компаниях критически зависит от наличия квалифицированных кадров, а также с позицией McKinsey [17] о необходимости массового цифрового обучения.

Особого внимания заслуживает крайне низкий рейтинг государственной поддержки (8,3% — лишь 4 из 50 респондентов). Данный результат может свидетельствовать о восприятии ИИ-трансформации как преимущественно корпоративной, а не государственной задачи. Респонденты, по-видимому, возлагают основную ответственность за внедрение ИИ на сами организации и их менеджмент, а не на регулятора. Данная позиция контрастирует с опытом некоторых стран (например, Китая, Сингапура), где государственная политика играет ключевую роль в стимулировании ИИ-внедрения, однако может отражать специфику казахстанского контекста, где программа «Цифровой Казахстан» уже обеспечила базовую инфраструктурную поддержку [4].

4. Заключение

Проведённое пилотное исследование позволяет сформулировать три ключевых вывода, каждый из которых соответствует одной из трёх исследуемых тем.

Во-первых, в отношении ИИ как инструмента управленческих процессов зафиксировано практически единогласное признание ИИ-грамотности в качестве базовой компетенции современного менеджера (M=4,92) — наивысший показатель всего опроса. При этом респонденты демонстрируют дифференцированное восприятие: высоко оценивая роль ИИ в автоматизации рутинных задач (B5, M=4,08) и повышении организационной эффективности (B6, M=4,17), они проявляют умеренную сдержанность в отношении безусловного превосходства ИИ-подкреплённых решений над решениями, основанными на интуиции и опыте (B4, M=3,58). Финансовый анализ и бюджетирование (91,7%) выделены как приоритетная область применения ИИ в управлении, значительно опережая управление персоналом (16,7%).

Во-вторых, в сфере управления инновационным развитием респонденты выражают устойчивое убеждение в том, что организации, не использующие ИИ для управления инновациями, обречены на долгосрочное отставание (B12, M=4,50). Культура работы с данными рассматривается как более значимый фактор инновационного развития, чем технологические инвестиции (B10, M=4,00), хотя по данному вопросу наблюдается поляризация мнений. Компетентность сотрудников и организационная культура, открытая к изменениям, выделены в качестве приоритетных управленческих факторов для внедрения ИИ-инноваций (по 66,7%), тогда как сопротивление сотрудников не воспринимается как главное препятствие (B11, M=3,58).

В-третьих, стратегия цифровой трансформации воспринимается как критическое условие конкурентоспособности (B14, M=4,58). Респонденты осознают технологическое отставание казахстанских компаний от мировых лидеров (B17, M=4,08), при этом уникальность ИИ как источника трудно копируемого конкурентного преимущества вызывает определённые сомнения (B15, M=3,83). Низкая цифровая грамотность сотрудников (83,3%) и нехватка ИИ-компетентных менеджеров (75,0%) идентифицированы как главные барьеры для Казахстана, значительно опережая финансовые и институциональные факторы.

Практические рекомендации

На основании полученных результатов могут быть сформулированы следующие практические рекомендации:

1. *Для образовательных учреждений:* интеграция курсов по ИИ-инструментам и аналитике данных в программы подготовки менеджеров представляется неотложной задачей, учитывая единогласное признание респондентами данной компетенции как базовой. Рекомендуется разработка междисциплинарных модулей, сочетающих технические навыки работы с ИИ и управленческие компетенции их стратегического применения.

2. *Для руководителей организаций:* приоритет следует отдавать формированию культуры работы с данными и повышению цифровой грамотности сотрудников всех уровней, а не исключительно закупке ИИ-технологий. Системный подход к внедрению ИИ, интегрированный в общую бизнес-стратегию, является предпосылкой для реализации инновационного потенциала.

3. *Для разработчиков стратегий цифровой трансформации в Казахстане:* необходимо формирование целостных стратегий, включающих развитие кадрового потенциала в области ИИ как ключевого элемента национальной конкурентоспособности. Преодоление кадрового дефицита требует скоординированных усилий бизнеса, образовательных институтов и государства.

Ограничения исследования

Основные ограничения настоящего исследования включают: малый размер выборки ($n=50$), что не позволяет обобщать результаты на генеральную совокупность и применять инференциальные статистические методы; однородность выборки (студенты одного университета); преобладание магистрантов направления «Маркетинг» (66,7%); использование метода самооценки, подверженного систематическим искажениям; а также отсутствие данных о стандартных отклонениях, что ограничивает анализ вариабельности ответов. Данные ограничения определяют пилотный характер исследования и требуют осторожности в интерпретации результатов.

Направления будущих исследований

Перспективными направлениями дальнейших исследований представляются: расширение выборки с привлечением магистрантов и практикующих менеджеров из нескольких вузов и организаций Казахстана; применение инференциальных статистических методов (t -тесты, дисперсионный анализ, корреляционный анализ) для выявления значимых различий между подгруппами (по опыту работы, направлению обучения, уровню ИИ-грамотности); проведение лонгитюдных исследований для отслеживания динамики восприятия ИИ по мере его всё более широкого внедрения; сравнительные межстрановые исследования в контексте Центральной Азии; а также качественные исследования (интервью, фокус-группы) для углублённого понимания мотивов и установок респондентов.

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Восприятие роли искусственного интеллекта в управлении электронной коммерцией: результаты эмпирического опроса среди студентов магистратуры Казахстана

Perception of Artificial Intelligence Role in E-Commerce Management: Empirical Survey Evidence from Graduate Students in Kazakhstan

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Аннотация

Стремительное развитие технологий искусственного интеллекта (ИИ) трансформирует глобальную индустрию электронной коммерции, одновременно формируя новые требования к управленческим компетенциям в розничной торговле. Настоящее исследование направлено на заполнение эмпирического пробела, связанного с отсутствием систематизированных данных о восприятии роли ИИ в управлении электронной коммерцией среди будущих менеджеров Казахстана. Для достижения поставленной цели проведён количественный описательный онлайн-опрос с использованием сервиса Google Forms, в котором приняли участие 71 магистрант Almaty Management University (апрель 2026 г.). Инструментарий включал 20 вопросов по шкале Ликерта (1–5) и вопросы с вариантами ответов; применялись методы описательной статистики и частотного анализа. Результаты свидетельствуют о преобладании умеренно-скептических оценок: наиболее высокая поддержка зафиксирована в отношении необходимости владения ИИ-компетенциями менеджерами e-commerce ($M = 3,40$), тогда как эффективность ИИ-персонализации в повышении лояльности оценена критически низко ($M = 2,56$; 44,4% не согласны). Главным барьером внедрения ИИ признано отсутствие готовой цифровой инфраструктуры (28,2%), а не финансовые ограничения; при этом 70,4% респондентов видят умеренные или высокие перспективы развития ИИ в e-commerce Казахстана на горизонте пяти лет. Полученные результаты обладают практической значимостью для руководителей розничных компаний, образовательных учреждений и регуляторов цифровой экономики Казахстана.

Ключевые слова: искусственный интеллект; электронная коммерция; розничная торговля; управление e-commerce; цифровая трансформация; Казахстан; опрос; восприятие ИИ.

1. Введение

Глобальная индустрия электронной коммерции в последние годы демонстрирует устойчивый рост при одновременной интенсификации процессов цифровой трансформации, в которой технологии искусственного интеллекта (ИИ) играют центральную роль. Как отмечено в фундаментальной работе Т. Давенпорта и соавторов [1], ИИ

существенным образом трансформирует функции маркетинга и управления взаимоотношениями с клиентами, обеспечивая беспрецедентный уровень персонализации, предиктивной аналитики и автоматизации операционных процессов. В систематизированном библиометрическом обзоре Р. Э. Бавака и соавторов [2] подчёркнуто, что научный дискурс об ИИ в электронной коммерции развивается исключительно интенсивно, при этом наибольшее внимание уделяется рекомендательным системам, чат-ботам и анализу потребительского поведения. Ю. Дживеди и соавторы [3] в масштабном мультидисциплинарном исследовании зафиксировали, что ИИ формирует принципиально новую повестку для науки, практики и государственного регулирования, охватывая одновременно вопросы технологической зрелости, этики и организационной адаптации.

В казахстанском контексте динамика развития электронной коммерции характеризуется высокими темпами роста. По данным аналитического отчёта PwC Kazakhstan [4], объём розничного рынка e-commerce в первом полугодии 2025 г. достиг 1,7 трлн тенге (около 3,4 млрд долл. США), увеличившись на 19% в годовом выражении, а доля электронной торговли в общем объёме розничных продаж составила 17,1%. Как указано в официальных материалах Международной торговой администрации США [5], объём e-commerce в Казахстане в 2024 г. достиг 3,2 трлн тенге, что семикратно превышает показатели 2020 г.; при этом страна занимает 24-е место в UN E-Government Development Index (2024) и 34-е место в IMD World Digital Competitiveness (2025). Программа «Цифровой Казахстан» [6] и принятый в 2025 г. Закон об искусственном интеллекте [7] закрепляют стратегический вектор государства на повсеместное внедрение ИИ-решений в экономику, включая розничную торговлю.

Анализ существующей литературы позволяет выделить несколько ключевых направлений изучения ИИ в электронной коммерции. Д. Гревал и соавторы [8] подчёркивают, что искусственный интеллект несёт в себе как положительные эффекты — повышение эффективности, улучшение клиентского опыта, — так и «теневые стороны»: риски конфиденциальности, предвзятость алгоритмов и эрозия потребительского доверия. Исследование Ф. Столкампа и соавторов [9] демонстрирует, что чрезмерная персонализация способна вызывать у потребителей ощущение вторжения в частную жизнь, что подавляет формирование лояльности. С. Ф. Вамба и соавторы [10] показали, что качество ИИ-решений и наличие динамических способностей организации являются критическими предикторами результативности фирм, активно использующих большие данные. В работе К. Кунья-Баумбах и соавторов [11] установлено, что антропоморфизм ИИ-чат-ботов повышает социальное присутствие и доверие потребителей, однако данный эффект варьируется в зависимости от эмоционального состояния покупателя. Авторы, исследовавшие компетентностный срез проблемы [12], выявили, что уровень знакомства с ИИ-инструментами существенно влияет на восприятие будущей управленческой практики и готовность к применению ИИ в профессиональной деятельности.

Отдельного внимания заслуживают исследования, посвящённые барьерам внедрения ИИ в условиях развивающихся рынков. Анализ фирм развивающихся стран [13] показал, что решающую роль в адопции ИИ играют факторы цифровой инфраструктуры, кадрового потенциала и организационной готовности, причём в условиях ограниченных ресурсов эти факторы нередко оказываются более значимыми, чем стоимость самих ИИ-решений. Э. Картал и соавторы [14], применив интегрированную модель TAM–UTAUT к сегменту малых и средних предприятий, выявили, что воспринимаемая полезность, социальное влияние и условия обеспечивающей инфраструктуры определяют намерение использовать ИИ. В региональном разрезе отчёт Всемирного банка [15] констатирует, что цифровизация частного сектора в Центральной Азии сталкивается с системными ограничениями — разрывом между крупными и малыми фирмами, недостатком кадров и

неравномерным покрытием инфраструктуры. Согласно Аналитическому обзору OECD Digital Economy Outlook [16], страны с переходными экономиками сохраняют значительный разрыв в ИИ-грамотности и навыках цифрового управления по сравнению с лидерами ОЭСР, что создаёт специфические ограничения для восприятия и адаптации ИИ.

Несмотря на значительный массив работ, посвящённых ИИ в e-commerce, в литературе выявлен заметный пробел: отсутствуют эмпирические исследования, посвящённые восприятию роли ИИ в управлении электронной коммерцией со стороны будущих казахстанских менеджеров — студентов магистратуры, которые в ближайшей перспективе займут позиции, определяющие стратегии цифровой трансформации розничных компаний. Учитывая, что управленческие решения в условиях ограниченных ресурсов во многом определяются индивидуальными установками лиц, принимающих решения [8; 13], изучение восприятия ИИ среди данной референтной группы представляется актуальным как с научной, так и с практической точки зрения.

Цель настоящего исследования состоит в эмпирическом определении восприятия роли ИИ в управлении электронной коммерцией среди магистрантов Almaty Management University и в интерпретации выявленных тенденций в контексте стратегического развития розничной торговли Республики Казахстан. В соответствии с поставленной целью сформулированы следующие исследовательские задачи: (1) охарактеризовать социально-демографический и профессиональный профиль респондентов; (2) выявить восприятие ИИ как инструмента управления e-commerce; (3) оценить восприятие роли ИИ в управлении клиентским опытом; (4) идентифицировать барьеры внедрения ИИ-технологий и оценить перспективы их преодоления; (5) сформулировать практические рекомендации для менеджеров розничных компаний и образовательных учреждений.

2. Материалы и методы

Методологический дизайн исследования выстроен в парадигме количественной описательной стратегии с применением метода онлайн-опроса. Выбор такого дизайна обусловлен необходимостью получения стандартизированных и сопоставимых данных, характеризующих восприятие ИИ в относительно большой и однородной группе респондентов. Онлайн-опрос обеспечивает высокую скорость сбора данных, анонимность ответов и снижение эффекта социальной желательности, что особенно важно при изучении оценочных суждений по шкале Ликерта.

Инструментарий исследования представлен авторским опросником, разработанным в сервисе Google Forms. Структура опросника включает 20 вопросов, распределённых по пяти тематическим блокам: (1) социально-демографический профиль (направление обучения, опыт работы в e-commerce, уровень понимания ИИ); (2) восприятие ИИ как инструмента управления e-commerce; (3) восприятие ИИ в управлении клиентским опытом; (4) барьеры внедрения ИИ; (5) перспективы развития ИИ-технологий. В блоках 2–5 использовались утверждения, оцениваемые по пятибалльной шкале Ликерта (1 — полностью не согласен, 5 — полностью согласен), а также вопросы с одиночным выбором варианта ответа.

Выборочная совокупность сформирована методом целенаправленной выборки (purposive sampling) и включает 71 магистранта Almaty Management University (AlmaU), обучающегося по различным управленческим и смежным программам. Сбор данных осуществлён в апреле 2026 г. Участие в опросе было анонимным и добровольным, что соответствует принципам этики социально-экономических исследований. Перед заполнением формы респондентам предоставлялась краткая аннотация исследования, обеспечивавшая информированное согласие на участие. Выбор AlmaU обусловлен тем, что университет специализируется на подготовке управленческих кадров и является одной из

ведущих бизнес-школ Казахстана, а его магистранты представляют ближайший резерв руководящего состава розничных и e-commerce-компаний страны.

Анализ данных выполнен с применением методов описательной статистики и частотного анализа. Для вопросов по шкале Ликерта рассчитывались средние значения (M), а также процентные распределения ответов в трёх агрегированных категориях: «согласны» (оценки 4–5), «нейтрально» (оценка 3) и «не согласны» (оценки 1–2). Для вопросов с одиночным выбором определялись абсолютные и относительные частоты. Интерпретация средних значений осуществлялась по следующей условной шкале: $M \geq 3,50$ — устойчивое согласие; $3,00 \leq M < 3,50$ — умеренное согласие; $2,50 \leq M < 3,00$ — умеренный скептицизм; $M < 2,50$ — выраженный скептицизм. Такая схема широко используется в социологических и маркетинговых исследованиях при работе с пятибалльной шкалой Ликерта.

3. Результаты и обсуждение

3.1. Характеристика выборки

Социально-демографическая характеристика выборки отражает структуру магистерских программ, сфокусированных на подготовке управленческих кадров. Согласно B1, наибольшая доля респондентов приходится на направление «Менеджмент» — 24 человека (33,8%), что соответствует исследовательской цели. Вторую группу составляют магистранты IT и технических специальностей — 14 человек (19,7%), затем «Маркетинг» и «HR/Управление персоналом» — по 10 человек (14,1% каждая), «Финансы/Бухгалтерский учёт» — 9 человек (12,7%) и иные направления — 4 человека (5,6%). Многопрофильная структура выборки обеспечивает межпрофессиональный разрез восприятия ИИ и повышает содержательную валидность исследования.

Анализ B2 показывает, что 34 респондента (47,9%) обладают практическим опытом в сфере e-commerce или розничной торговли: 18 человек (25,4%) проходили стажировку, 16 человек (22,5%) работают или работали в соответствующих компаниях. Одновременно 37 респондентов (52,1%) практического опыта не имеют: 19 человек (26,8%) интересуются темой, а 18 человек (25,4%) отметили её новизну для себя. Такое соотношение «опытных» и «теоретических» носителей суждений позволяет сопоставить оценки, сформированные непосредственной практикой, с представлениями, основанными на академическом знании.

Согласно B3, самооценка уровня понимания ИИ распределилась следующим образом: «средний» уровень указали 21 человек (29,6%), «низкий» — 19 человек (26,8%), «нулевой» — 17 человек (23,9%), «высокий» — 14 человек (19,7%). Суммарно базовым и более высоким уровнем понимания ИИ обладают 35 респондентов (49,3%). Согласно данным OECD Digital Economy Outlook [16], страны с переходными экономиками демонстрируют существенный разрыв в ИИ-компетенциях по сравнению с ведущими цифровыми экономиками, что согласуется с полученными результатами и указывает на необходимость усиления программ цифровой грамотности в казахстанских университетах.

3.2. Восприятие ИИ как инструмента управления e-commerce

Анализ восприятия ИИ как инструмента управления e-commerce (B4–B8) выявил общий паттерн умеренного скептицизма относительно операционной эффективности ИИ-решений при одновременном признании необходимости управленческих компетенций в области ИИ.

Утверждение B4 («Внедрение ИИ позволяет принимать более точные операционные решения») получило $M = 3,11$, при этом лишь 36,4% выразили согласие, 32,7% заняли нейтральную позицию, а 30,9% не согласились. Аналогичная картина наблюдается для B6 («Автоматизация на основе ИИ снижает операционные издержки»): $M = 3,11$, согласных 37,0%. Утверждение B5 о повышении эффективности управления интернет-магазином получило наименьшую поддержку в блоке — $M = 2,89$, при этом доля несогласных (36,8%) превысила долю согласных (31,6%). Полученные результаты контрастируют с выводами Т.

Давенпорта и соавторов [1] о существенном приросте операционной эффективности при внедрении ИИ, а также с библиометрическим обзором [2], зафиксировавшим устойчивую ассоциацию ИИ с повышением результативности e-commerce. Расхождение объясняется ограниченным практическим опытом респондентов и преобладанием лиц с низким уровнем понимания ИИ (совокупно 50,7%).

Исключением в блоке является В7 («Менеджеры e-commerce должны владеть навыками работы с ИИ»): $M = 3,40$ — наивысший показатель блока. Доля согласных достигает 47,3%, нейтральных — 25,5%, несогласных — 27,3%. Результат согласуется с выводами Э. Картала и соавторов [14] о том, что воспринимаемая необходимость обладать ИИ-компетенциями положительно коррелирует с намерением использовать ИИ в управленческой практике, а также поддерживает концепцию «ИИ-грамотности» (AI literacy) как ключевого компонента современной управленческой подготовки [12].

Данные В8 показали лидирующее положение логистики: «Управление складскими запасами и логистикой» выбрали 24 человека (33,8%), «Персонализация рекомендаций» — 16 (22,5%), «Клиентский сервис» и «Анализ спроса» — по 11 (15,5%), «Ценообразование» — 9 (12,7%). В условиях Казахстана с протяжёнными расстояниями и неоднородной транспортной инфраструктурой ИИ-решения в логистике способны приносить наиболее очевидный и измеримый экономический эффект, что согласуется с данными [5] об ускоренном росте внутренних логистических потоков и с результатами С. Ф. Вамбы и соавторов [10] о критической роли качества ИИ-решений в операционном управлении.

3.3. Восприятие ИИ в управлении клиентским опытом

Блок В9–В13, посвящённый восприятию роли ИИ в управлении клиентским опытом, оказался наиболее скептическим разделом опроса, что противоречит сложившемуся академическому консенсусу о персонализации как «флагмане» применения ИИ в электронной коммерции [1; 2]. Наиболее показательным является утверждение В9 («ИИ для персонализации повышает лояльность покупателей»), получившее минимальную оценку во всём опросе: $M = 2,56$. Согласились лишь 22,2% респондентов, нейтральную позицию заняли 33,3%, а не согласились 44,4%.

Данный результат интерпретируется в контексте трёх объяснительных линий. Во-первых, выявленный скептицизм согласуется с работой Ф. Столкампа и соавторов [9], зафиксировавших «парадокс персонализации»: чрезмерная тонкая настройка контента вызывает ощущение слежения и нарушения частной жизни, что подавляет лояльность. Во-вторых, как отметили Д. Гревал и соавторы [8], «тёмные стороны» ИИ в маркетинге — предвзятость алгоритмов, опасения конфиденциальности, эмоциональное отчуждение — ослабляют потенциальные лояльные эффекты персонализации. В-третьих, с учётом того что 50,7% респондентов имеют низкий или нулевой уровень понимания ИИ, критическая оценка частично обусловлена собственным клиентским опытом в казахстанских онлайн-магазинах, где алгоритмическая персонализация пока не достигла зрелых международных стандартов.

Остальные утверждения блока получили умеренные оценки. Утверждение В10 («ИИ точнее предсказывает покупательское поведение»): $M = 3,08$ при равном распределении согласных (34,6%) и нейтральных (34,6%). В11 («ИИ-чат-боты улучшают обслуживание клиентов»): $M = 3,16$ и 40,0% согласных — относительно более высокий результат, согласующийся с выводами К. Кунья-Баумбах и соавторов [11] о значимости антропоморфного дизайна чат-ботов. В12 («Динамическое ценообразование повышает выручку»): $M = 3,15$ при 37,0% согласных — соответствует результатам обзора [2].

Вопрос В13 о наиболее значимом аспекте клиентского опыта показал следующее распределение: «Удобство и безопасность оплаты» — 18 чел. (25,4%, лидер); «Скорость обработки заказов и доставки» — 16 (22,5%); «Скорость и удобство поиска товаров» — 14

(19,7%); «Точность персональных рекомендаций» — 13 (18,3%); «Качество службы поддержки» — 10 (14,1%). Примечательно, что безопасность оплаты (25,4%) оценена выше персонализации (18,3%), что отражает выявленную Д. Гревалом и соавторами [8] иерархию: доверие и защищённость выступают базовыми условиями принятия ИИ-решений, тогда как функции персонализации приобретают значимость лишь после удовлетворения первичных потребностей в безопасности.

3.4. Барьеры внедрения и перспективы ИИ

Анализ блока В14–В17 установил, что ключевым барьером внедрения ИИ в казахстанскую электронную коммерцию, по мнению респондентов, выступает отсутствие готовой цифровой инфраструктуры, а не финансовые ограничения. Структура ответов на В17: «Отсутствие готовой цифровой инфраструктуры» — 20 чел. (28,2%, лидер); «Высокие затраты на разработку» — 14 (19,7%); «Недоверие руководства» — 14 (19,7%); «Недостаточный объём и качество данных» — 12 (16,9%); «Дефицит квалифицированных кадров» — 11 (15,5%). Указанное распределение коррелирует с выводами Всемирного банка [15] о системных инфраструктурных ограничениях в Центральной Азии и с наблюдениями применительно к развивающимся рынкам [13], где именно инфраструктурный разрыв, а не финансовые ресурсы, определяет темп цифровой трансформации.

Утверждение В14 о стоимости как основном барьере получило умеренную оценку: $M = 3,04$ при 30,4% согласных и необычно высокой доле нейтральных (41,1%), что свидетельствует о неопределённости респондентов в отношении реальной стоимости ИИ-проектов. Такая структура ответов согласуется со структурным разрывом между академической осведомлённостью о ИИ и непосредственным опытом бюджетного управления. Утверждение В16 («Нехватка специалистов сдерживает внедрение ИИ») получило максимальную оценку в блоке — $M = 3,42$ при 41,5% согласных, что согласуется с результатами Э. Картала и соавторов [14] и данными [5] о необходимости масштабной подготовки ИТ-специалистов в Казахстане.

Утверждение В15 о готовности казахстанских компаний к внедрению ИИ получило $M = 3,34$ при 41,5% согласных. Такая относительно оптимистичная оценка частично связана с восприятием программы «Цифровой Казахстан» [6] и нового Закона об ИИ [7] как индикаторов ускоренной институциональной трансформации. Вместе с тем несогласных насчитывается 24,5%, что свидетельствует о существующих сомнениях в операциональной готовности компаний к реальному масштабированию ИИ-инициатив.

Блок В18–В20 раскрывает паттерн «перспективного оптимизма при текущем скептицизме». Утверждение В18 («Компании с ИИ имеют устойчивое конкурентное преимущество»): $M = 2,84$ при 40,0% несогласных — указывает на сомнение в реальной способности ИИ формировать устойчивые конкурентные преимущества в текущих условиях, что согласуется с аргументацией Д. Гревала и соавторов [8] о необходимости комплементарных ресурсов. Утверждение В19 («Через 5 лет ИИ станет стандартным инструментом управления»): $M = 3,04$ при почти равном распределении — 33,3% согласных, 35,2% нейтральных, 31,5% несогласных — свидетельствует о высокой неопределённости относительно скорости диффузии ИИ. Вопрос В20 о перспективах ИИ в казахстанском e-commerce показал более оптимистичную картину: «Умеренные» — 26 чел. (36,6%, лидер); «Очень высокие» — 24 (33,8%); «Низкие» — 12 (16,9%); «Затрудняюсь ответить» — 9 (12,7%). В совокупности позитивно и умеренно перспективы оценивают 70,4% респондентов, тогда как пессимистично — лишь 16,9%.

Таблица 1. Сводные результаты опроса: средние значения, доли согласных и интерпретация

Блок	№	Утверждение	М	Согласны, %	Интерпретация
Блок 2. ИИ в управлении e-commerce	B4	Более точные операционные решения	3,11	36,4	Умеренный скептицизм; доля несогласных сопоставима с долей согласных.
	B5	Повышение эффективности управления	2,89	31,6	Минимум блока; несогласных 36,8% против 31,6% согласных.
	B6	Снижение операционных издержек	3,11	37,0	Умеренное согласие; ожидания относительно экономии сдержанные.
	B7	Необходимость ИИ-компетенций у менеджеров	3,40	47,3	Наивысшая оценка блока; признание стратегической роли ИИ-грамотности.
	B8	Лидер: управление запасами и логистикой	—	33,8	Логистика — наиболее ожидаемый эффект ИИ в условиях казахстанской географии.
Блок 3. ИИ и клиентский опыт	B9	Персонализация повышает лояльность	2,56	22,2	Минимум всего опроса; «парадокс персонализации» и низкая ИИ-грамотность.
	B10	Предсказание поведения покупателей	3,08	34,6	Сдержанное согласие; мнения разделились почти поровну.
	B11	ИИ-чат-боты улучшают обслуживание	3,16	40,0	Относительно высокое согласие; важность антропоморфного дизайна.
	B12	Динамическое ценообразование и выручка	3,15	37,0	Согласуется с академическими данными о эффективности динамических цен.
Блок 4. Барьеры	B14	Высокая стоимость как барьер	3,04	30,4	Неопределённость: 41,1% нейтральных ответов.
	B15	Готовность компаний к внедрению ИИ	3,34	41,5	Умеренно-оптимистичная оценка рыночной готовности.

Блок	№	Утверждение	М	Согласны, %	Интерпретация
	B16	Нехватка специалистов сдерживает ИИ	3,42	41,5	Лидер блока; кадровый дефицит признан системным барьером.
Блок 5. Перспективы	B18	ИИ как устойчивое конкурентное преимущество	2,84	32,0	Скептицизм: 40% несогласных; сомнение в реализуемости преимущества.
	B19	Через 5 лет ИИ — стандартный инструмент	3,04	33,3	Мнения разделились почти поровну; высокая доля неопределённости.

Обобщение данных табл. 1 позволяет выделить три сквозных паттерна. Первый — умеренный скептицизм в операционном измерении ($M = 2,89–3,40$) при явном признании стратегической значимости ИИ-компетенций для менеджеров (B7, $M = 3,40$, 47,3% согласных). Второй — выраженная критика функции персонализации (B9, $M = 2,56$), нетипичная на фоне международного академического консенсуса об эффективности ИИ-персонализации и объяснимая сочетанием «парадокса персонализации» [9], ограниченной ИИ-грамотности и незрелости локальных платформ. Третий — паттерн «перспективного оптимизма при текущем скептицизме»: умеренная или слабая поддержка настоящего конкурентного преимущества ИИ (B18, $M = 2,84$), но 70,4% позитивных оценок перспектив на горизонте пяти лет (B20). Выявленные результаты в целом согласуются с теоретическими предсказаниями модели TAM–UTAUT [14], согласно которым воспринимаемая полезность выступает центральным детерминантом намерения использовать технологию, тогда как низкая осведомлённость формирует устойчивый барьер для позитивной оценки.

4. Заключение

Данное исследование продолжает линию эмпирических работ, изучающих восприятие ИИ в электронной коммерции на развивающихся рынках [8; 13; 15], и фиксирует специфику этого восприятия среди будущих казахстанских менеджеров. В ранее опубликованных работах был зафиксирован пробел: отсутствие эмпирических данных о восприятии ИИ в e-commerce среди студентов-управленцев Казахстана, что ограничивало возможности формирования обоснованных рекомендаций для образовательных учреждений и практики. Для заполнения выявленного пробела был проведён количественный описательный онлайн-опрос ($N = 71$, AlmaU, апрель 2026 г.) с применением шкалы Ликерта и методов описательной статистики. Анализ данных позволил установить: умеренный скептицизм в операционном измерении ($M = 2,89–3,40$); критически низкую оценку персонализации ($M = 2,56$, 44,4% несогласных); лидерство логистики как ожидаемого направления эффекта ИИ (33,8%); приоритет инфраструктурного барьера (28,2%) над финансовым; «перспективный оптимизм» — 70,4% позитивных ожиданий на горизонте пяти лет. Полученные результаты дополняют концепцию «парадокса персонализации» [9] и концепцию ИИ-грамотности [12] эмпирическими данными с развивающегося рынка, расширяя понимание детерминант восприятия ИИ в студенческой среде с управленческой специализацией. Для менеджеров розничных e-commerce компаний Казахстана рекомендуется сосредоточить первоочередные ИИ-инвестиции на логистике и управлении запасами; выстраивать доверие к алгоритмической персонализации через прозрачность и защиту данных; развивать ИИ-компетенции сотрудников как стратегический приоритет. К

ограничениям исследования относятся: целенаправленная студенческая выборка одного университета, ограничивающая обобщаемость результатов на практикующих менеджеров; субъективный характер самооценки ИИ-грамотности; поперечный дизайн, не позволяющий отслеживать динамику восприятия. Перспективными направлениями дальнейших исследований являются: (1) сравнительный опрос практикующих менеджеров казахстанских e-commerce компаний; (2) лонгитюдное исследование изменения восприятия ИИ по мере роста цифровой грамотности; (3) качественное изучение факторов, формирующих «парадокс персонализации» в казахстанском потребительском контексте; (4) межстрановое сравнение восприятия ИИ в e-commerce среди будущих менеджеров стран Центральной Азии.

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Global Challenges of Digital Transformation

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Abstract

This article explores the key global challenges of digital transformation in the context of the Fourth Industrial Revolution, characterized by the convergence of digital, physical, and biological systems. It focuses on the evolution of cybersecurity from a reactive defense model to a predictive and resilient architecture, the integration of artificial intelligence into data protection systems, and the transformation of digital forensics in distributed and encrypted environments. It also examines the risks of expanding the attack surface due to the development of the Internet of Things and Industrial IoT, as well as the vulnerabilities of critical infrastructure in the context of smart cities and smart energy systems. Based on an analysis of international and Kazakhstani cases, it demonstrates that cybersecurity is becoming not only a technological but also a strategic factor, impacting economic stability, state sovereignty, and public trust. It concludes that a comprehensive approach is needed that combines technological innovation, regulatory mechanisms, and principles of transparent governance of digital systems.

Keywords:

Digital transformation, cybersecurity, artificial intelligence, digital forensics, Internet of Things (IoT), smart cities, critical infrastructure, cyber threats, machine learning, system resilience, Zero Trust architecture, digital economy.

The current stage of the Fourth Industrial Revolution is characterized by the unprecedented convergence of digital, physical, and biological systems, fundamentally transforming the architecture of global infrastructures. This article analyzes the systemic challenges associated with securing highly interconnected environments, with a particular focus on the integration of artificial intelligence into cybersecurity systems, the evolution of digital forensics in distributed systems, and the resilience of smart city ecosystems. Based on a study of global and regional cases, including digital initiatives in Kazakhstan, the study demonstrates that cybersecurity has evolved from a technical function to a strategic area shaping economic stability, national sovereignty, and public trust.

Introduction: The Architecture of Digital Trust

The modern technological paradigm is defined by the shift from isolated information systems to complex, interdependent digital ecosystems, where data flows continuously across organizational, national, and infrastructural boundaries. While this increased connectivity enables efficiency and innovation, it also expands the attack surface, creating systemic vulnerabilities that can no longer be limited to a single organization or sector. Cyber threats extend beyond isolated unauthorized access incidents, posing potential triggers for supply chain disruptions that can disrupt logistics networks, healthcare systems, energy distribution, and government administration. A striking example of such a systemic vulnerability was the NotPetya cyberattack,

which spread through a compromised software supply chain and caused widespread operational paralysis, including significant disruptions at Maersk. This event highlighted the inadequacy of traditional perimeter-based security models and revealed the need to rethink cybersecurity as an integral part of digital infrastructure design. In this context, the primary objective of this study is to explore how the convergence of scientific research, industrial innovation, and public policy can ensure the creation of resilient and robust digital environments.

Cybersecurity: From Reactive Defense to Predictive Resilience

The evolution of cybersecurity reflects a fundamental paradigm shift from reactive incident response to predictive and adaptive resilience. Traditional approaches rely heavily on signature-based threat detection and post-incident mitigation, becoming increasingly ineffective against sophisticated threats exploiting zero-day vulnerabilities, polymorphic malware, and supply chain infiltration. The emergence of large-scale cyber incidents, such as the SolarWinds attack, demonstrates how attackers can exploit trusted update mechanisms to gain persistent and undetected access to critical systems in both the public and private sectors. In response to these challenges, modern cybersecurity architectures incorporate advanced analytics, machine learning models, and automated orchestration platforms that enable continuous monitoring and real-time response. The concept of cyber resilience extends beyond simple defense to encompass the ability of systems to maintain operational continuity under attack, dynamically adapt to evolving threats, and quickly recover from disruptions. In the context of Kazakhstan, national initiatives led by organizations such as the State Technical Service of Kazakhstan, along with the development of secure digital platforms such as the e-Government of Kazakhstan, represent strategic efforts to strengthen national cyber defense capabilities while supporting the expansion of digital government services.

Digital Forensics: Investigating in a Distributed and Encrypted Environment

As computing environments shift towards cloud architectures, virtualization, and decentralized data storage, digital forensics has undergone significant changes. Unlike traditional forensic methods based on static disk analysis, modern investigations must consider volatile data, encrypted communications, and geographically distributed infrastructures. The increasing use of end-to-end encryption and ephemeral computing environments complicates evidence gathering and often requires the real-time capture and analysis of system memory and network traffic.

The Mt. Gox case illustrates the complexity of investigating financial crimes in decentralized systems where blockchain transactions, while transparent, are masked using anonymization techniques. Advances in blockchain analytics have made it possible to reconstruct transaction flows and identify illicit actors, but this process remains technically complex and resource-intensive. Tools like EnCase and FTK Imager continue to play a crucial role in evidence gathering, particularly in the context of memory forensics, where significant data can be lost when a system is shut down. The integration of AI into forensic workflows further enhances investigative capabilities by enabling automated pattern recognition, timeline reconstruction, and anomaly detection in large datasets.

AI: Protective Infrastructure and New Threat Vectors

AI has become a central component of modern cybersecurity strategies, providing the computational power needed to analyze large volumes of data and identify anomalies in real time. In sectors such as finance, AI-based systems developed by companies like Kaspersky and Group-IB use behavioral biometrics to distinguish legitimate users from fraudsters by analyzing subtle indicators such as typing dynamics and interaction patterns. In the healthcare sector, solutions like Cerebra demonstrate how AI can improve diagnostic accuracy, while also raising serious concerns about the protection of sensitive medical data. However, the integration of AI into security infrastructure also creates new vulnerabilities. Data-driven attacks can manipulate machine learning models by injecting malicious data, leading to misclassifications and disrupting

decision-making processes. Furthermore, the proliferation of AI-generated content, including deepfakes and automated phishing campaigns, is increasing the scale and complexity of social engineering attacks. These developments necessitate a comprehensive AI governance approach that considers accountability, data protection, and transparency of algorithmic processes—essential for maintaining public trust in automated systems.

Internet of Things (IoT) and Industrial IoT: Expanding Attack Surface

The rapid proliferation of IoT devices has revealed a vast and heterogeneous layer of interconnected endpoints, many of which lack adequate security mechanisms due to limited processing resources and cost constraints. This structural weakness was exploited in large-scale cyber incidents such as the Mirai botnet attack, which used compromised devices to compromise major online platforms such as Twitter and Netflix, becoming a distributed attack. To address these vulnerabilities, the edge computing paradigm, which allows data processing and proactive security controls to be implemented closer to the source of data generation, has gained importance. By reducing dependence on centralized cloud infrastructures, edge computing not only improves system responsiveness, but also increases security by limiting the exposure of sensitive data. However, to effectively protect IoT ecosystems, standardized security protocols are needed that ensure timely updates and vulnerability mitigation, continuous device authentication, and lifecycle management strategies.

Smart Cities and Critical Infrastructure Resilience

Smart city initiatives are among the most sophisticated manifestations of digital transformation, integrating data from transportation systems, energy grids, public safety networks, and city services into unified management platforms. While these systems have significantly improved efficiency, their central role in public service delivery makes them highly attractive targets for cyberattacks. The cyberattack on the Ukrainian power grid is a notable example of how cyber operations can directly impact physical infrastructure and lead to widespread service disruptions.

The concept of smart grids further illustrates the dual nature of digitalization in the energy sector; real-time data enables optimized distribution, but also opens up new vulnerabilities. Conversely, the development of decentralized energy systems, including microgrids, offers a mechanism for increasing resilience by providing local, autonomous operation in the event of a larger system failure. In Kazakhstan, urban digitalization efforts supported by technologies such as Sergek in cities such as Almaty illustrate the opportunities and security challenges associated with smart city development.

Conclusion: Strategic Trajectory

Cybersecurity has moved beyond being a technical discipline and has become central to the architecture of modern states and economies. The convergence of AI, cybersecurity, and Smart City technologies requires a holistic approach that integrates technological innovation with regulatory frameworks and human-centered design principles. The increasing reliance on automated systems highlights the importance of ensuring accountability in decision-making processes, adequate protection of sensitive data, and transparency in algorithmic processes to maintain public trust.

The future of digital transformation will be shaped not only by the resilience of systems to cyber threats, but also by their ability to adapt and evolve in response. The emergence of Zero Trust architectures and self-healing systems signals a broader shift toward proactive and autonomous security models, with resilience built into the core of system design. Consequently, competitive advantage will belong to societies that successfully integrate security into the core logic of their digital ecosystems, thereby transforming vulnerability into a strategic asset.

The integration of AI into national digital ecosystems is particularly evident in emerging economies, where technological breakthroughs are enabling rapid adoption of cutting-edge

solutions. Kazakhstan provides a clear example of how AI-powered innovation can improve public services and introduce new dimensions to cybersecurity and data management. One of the most prominent examples is Cerebra, an AI-based medical platform for early stroke diagnosis using neuroimaging data. Using deep learning algorithms, the system analyzes computed tomography scans in real time, significantly reducing diagnostic delays and increasing the likelihood of timely medical intervention. The large-scale implementation of this technology in dozens of stroke centers across Kazakhstan demonstrates the transformative potential of AI in healthcare infrastructure.

However, the implementation of such systems also presents significant security vulnerabilities associated with the processing of sensitive medical data. Healthcare data is one of the most valuable categories of personal information, making it a prime target for cybercriminals. Unauthorized access, data breaches, or manipulation of diagnostic results can have serious consequences not only for individual patients, but also for institutional trust in digital healthcare systems. This requires the implementation of robust encryption protocols that meet international standards, secure data transmission channels, and strict access control mechanisms.

Beyond healthcare, Kazakhstan is actively pursuing digital transformation with large-scale government initiatives, most notably the national e-government platform. This ecosystem integrates a wide range of government services, increasing efficiency and transparency by enabling citizens to access administrative procedures online. In addition, the centralization of such services creates a high-value target for cyberattacks, requiring the integration of continuous monitoring, incident response capabilities, and artificial intelligence-based threat detection systems.

Urban digitalization initiatives further demonstrate the intersection of innovation and security. The deployment of intelligent traffic management and control systems in cities like Almaty has improved public safety and optimized urban mobility. These systems are often based on real-time data collection and processing, supported by IoT devices and distributed network architectures. While increasing operational efficiency, they also expand the attack surface. Since every connected device is a potential entry point for attackers, protecting such infrastructure requires a multi-layered security approach, including network segmentation, device authentication, and anomaly detection.

From a strategic perspective, Kazakhstan's experience highlights the importance of aligning technological developments with cybersecurity governance and regulatory frameworks. The rapid introduction of artificial intelligence and digital platforms should be accompanied by the development of national standards for data protection, algorithmic reporting, and coordinated incident response. In addition, developing local expertise in cybersecurity and digital forensics is essential to reduce dependence on foreign technologies and strengthen digital sovereignty.

In conclusion, Kazakhstan's digital transformation trajectory highlights the opportunities and risks associated with the integration of artificial intelligence into key sectors. Solutions like Cerebra demonstrate how innovation can directly improve quality of life, and also highlight the need for a stable, secure, and reliable digital infrastructure. This case reinforces the broader argument that cybersecurity should be at the heart of digital development strategies, especially in environments characterized by rapid technology adoption and increasing system connectivity.

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БЮДЖЕТТІК МЕКЕМЕЛЕРДЕ БУХГАЛТЕРЛІК ЕСЕП, АУДИТ ЖӘНЕ САЛЫҚ САЛУ ЖҮЙЕЛЕРІН ҰЙЫМДАСТЫРУ МЕН ЖЕТІЛДІРУ ЖОЛДАРЫ

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Аннотация. Мақалада Қазақстан Республикасының бюджеттік мекемелеріндегі бухгалтерлік есеп, мемлекеттік аудит және салықтық әкімшілендіру жүйелерін жетілдіру мәселелері қарастырылған. Зерттеу Индустрия 4.0 жағдайындағы цифрлық трансформация контекстінде жүргізілді. Бюджеттік ұйымдардағы қаржылық басқарудың тиімділігін арттыру мақсатында бухгалтерлік есепті цифрландыру, тиімділік аудитін енгізу және салықтық бақылауды оңтайландыру бағыттары негізделді. Зерттеу барысында Деректерді қамту талдауы (DEA) әдісі қолданылып, өңірлік деңгейдегі бюджеттік инвестициялардың тиімділігі бағаланды. Нәтижесінде мемлекеттік қаржыны басқару жүйесін жетілдіруге бағытталған ғылыми негізделген ұсыныстар ұсынылды.

Түйін сөздер: бюджеттік мекемелер, бухгалтерлік есеп, мемлекеттік аудит, салықтық әкімшілендіру, цифрландыру, Индустрия 4.0, DEA.

Аннотация. В статье рассматриваются вопросы совершенствования бухгалтерского учета, государственного аудита и налогового администрирования в бюджетных учреждениях Республики Казахстан. Исследование проведено в контексте цифровой трансформации в условиях Индустрии 4.0. Обоснованы направления повышения эффективности финансового управления, включая цифровизацию бухгалтерского учета, внедрение аудита эффективности и оптимизацию налогового контроля. В работе использован метод анализа охвата данных (DEA), позволивший оценить эффективность бюджетных инвестиций на региональном уровне. В результате разработаны научно обоснованные рекомендации по совершенствованию системы управления государственными финансами.

Ключевые слова: бюджетные учреждения, бухгалтерский учет, государственный аудит, налоговое администрирование, цифровизация, Индустрия 4.0, DEA.

Abstract. This article examines the improvement of accounting, public audit, and tax administration systems in budgetary institutions of the Republic of Kazakhstan. The study is conducted within the context of digital transformation under Industry 4.0. Key directions for enhancing financial management efficiency are substantiated, including the digitalization of accounting processes, implementation of performance auditing, and optimization of tax control mechanisms. The research employs Data Envelopment Analysis (DEA) to assess the efficiency of

budget investments at the regional level. As a result, scientifically grounded recommendations for improving public financial management are proposed.

Keywords: budgetary institutions, accounting, public audit, tax administration, digitalization, Industry 4.0, DEA.

Кіріспе

Қазіргі жаһандық экономикалық өзгерістер мен цифрлық трансформация жағдайында мемлекеттік басқару тиімділігін арттыру мәселесі ерекше өзектілікке ие. Бюджеттік мекемелер – қоғамдық маңызы бар қызметтерді жүзеге асыратын коммерциялық емес ұйымдар ретінде мемлекеттік ресурстарды тиімді пайдаланудың негізгі субъектілері болып табылады.

Алайда, дәстүрлі бухгалтерлік есеп жүйесі, мемлекеттік аудит және салықтық әкімшілендіру механизмдері қазіргі технологиялық талаптарға толық сәйкес келмейді. Бұл өз кезегінде қаржылық ресурстарды басқарудың тиімділігін төмендетеді.

Осы зерттеудің мақсаты – Қазақстан Республикасындағы бюджеттік мекемелерде бухгалтерлік есеп, аудит және салық жүйелерін жетілдірудің теориялық және практикалық аспектілерін зерттеп, оларды цифрлық трансформациялау бойынша ғылыми негізделген ұсыныстар әзірлеу.

Қазіргі заманғы жаһандық экономикалық сын-қатерлер мен технологиялық трансформация жағдайында мемлекеттік басқарудың тиімділігін арттыру, оның ішінде бюджеттік мекемелердің қаржылық-экономикалық қызметін оңтайландыру мәселесі барынша өзектілікке ие болып отыр. Бюджеттік ұйымдар мемлекеттік билік органдары тарапынан құрылатын, негізгі қызметі қоғамдық және мемлекеттік маңызы бар қызметтерді көрсетуге бағытталған коммерциялық емес ұйымдар болып табылады. Олардың басты мақсаты – мемлекеттік бюджеттен қаржыландырылатын әлеуметтік-мәдени, басқарушылық, ғылыми-техникалық және өзге де коммерциялық емес сипаттағы іргелі жобаларды іске асыру. Алайда, шектеулі мемлекеттік ресурстарды бөлу және олардың мақсатты әрі тиімді жұмсалуды қамтамасыз ету процестері күрделі құрылымдық кедергілерге тап болуда.

Бұл іргелі мәселелер Индустрия 4.0, жасанды интеллект, цифрлық платформалар мен экономиканың орнықты трансформациясы контекстінде жаңаша шешімдерді талап етеді. Төртінші өнеркәсіптік революцияның жетістіктері мемлекеттік секторды басқару парадигмасын түбегейлі өзгертіп, бюджеттік мекемелердің қаржылық қауіпсіздігі мен тұрақты дамуын қамтамасыз етудің жаңа модельдерін ұсынып отыр. Сонымен қатар, цифрлық экономикадағы инновациялық басқару үлгілерін енгізу арқылы есеп жүргізу мен мемлекеттік аудиттің ашықтығын арттыруға болады.

Осы орайда, зерттеудің негізгі проблемасы бюджеттік ұйымдардағы дәстүрлі бухгалтерлік есептің, мемлекеттік аудиттің және салықтық әкімшілендірудің қазіргі жағдайы мен Индустрия 4.0 талаптары арасындағы алшақтықта жатыр. Тиімді басқару шешімдерін қабылдау, мекеменің қаржылық тұрақтылығын, өтімділігін және төлем қабілеттілігін бағалау үшін халықаралық стандарттарға негізделген жаңа нормативтік базаны және озық цифрлық әдістерді қолдану маңызды. Жергілікті бюджеттерді басқарудың тиімділігін қамтамасыз ету мемлекеттік қызметтерді ұсыну мен тұрақты дамудың негізгі кепілі болып саналады. Аудит институттарын күшейту, еңбекақы төлеу жүйелерін оңтайландыру және салықтық тәуекелдерді азайту бағытындағы кешенді шаралар тікелей әлеуметтік-экономикалық әсерге ие.

Осы мақаланың мақсаты – Қазақстан Республикасының бюджеттік мекемелеріндегі бухгалтерлік есеп, аудит және салық жүйелерін цифрлық трансформациялаудың теориялық-әдіснамалық негіздерін терең зерттеу, мемлекеттік бақылаудың озық халықаралық

тәжірибелерін талдау және салалық нормативтік-құқықтық базаны жетілдіру бойынша нақты ғылыми негізделген ұсыныстар әзірлеу.

Әдебиеттерге шолу

Қоғамдық сектордағы қаржылық процестерді басқару, аудиттеу және салықтық әкімшілендіру мәселелері халықаралық және отандық академиялық ортада кеңінен зерттелген. Бұл зерттеулерді мазмұнына қарай бірнеше ірі бағыттарға бөліп қарастыруға болады.

Бірінші бағыт бюджеттік ұйымдардағы қаржылық менеджмент және еңбекақы төлеу жүйесін жетілдіруге арналған. Ғылыми еңбектерде бюджеттік ұйымдардағы кадрлық ресурстардың сапасы, олардың қозғалысы және жоғары білікті мамандармен қамтамасыз етілу деңгейіне тік талдау (vertical analysis) жасалады. Зерттеушілер бюджеттік сектордағы еңбекақы төлеу жүйесінің қатаңдығы кадрлардың тұрақтамауына әкелетінін айта келіп, еңбек ресурстарын әрбір құрылымдық бөлімше ішінде, сондай-ақ әрбір қызметкер бойынша жеке бағалау әдіснамасын (сауалнама, тестілеу, бағалау сұхбаттары арқылы) ұсынады. Бұл процестерді халықаралық қаржылық есептілік стандарттары (ХҚЕС) аясында қарастыру қазіргі таңдағы өзекті мәселелердің бірі.

Екінші ірі бағыт мемлекеттік аудиттің рөлі мен тиімділігіне қатысты іргелі зерттеулерді қамтиды. Қазіргі ғылыми парадигма аудит институттарының күшті әрі тәуелсіз болуы жергілікті бюджетті басқарудың тиімділігімен тікелей байланысты екенін көрсетеді. Ғалымдар мемлекеттік аудитті қоғамдық қаржыны басқару жүйесіндегі «эндогендік иммундық жүйе» (endogenous immune system) ретінде сипаттайды. Бұл иммундық жүйе қаржылық заң бұзушылықтарды әшкерелеп, тиісті санкциялар қолданумен шектелмейді; ол сонымен қатар жүйелі жақсартуларды ұсыну арқылы болашақтағы өкілеттіктерді асыра пайдаланудың алдын алатын кіріктірілген түзетуші және алдын алушы күш ретінде қызмет етеді. Қазақстан сияқты бюджетаралық трансферттерге тәуелді аймақтарда тәуелсіз аудит институттарын салықтық ынталандыру саясатымен біріктіретін кешенді реформалар жүргізу қажеттілігі негізделген. Сонымен қатар, бюджеттік инвестициялардың тиімділігіне жүргізілетін аудит (performance audit) абсолютті көрсеткіштерді ғана емес, техникалық тиімділікті де бағалауы тиіс екендігі туралы ғылыми пікірлер басым.

Үшінші бағыт салық жүйесін реформалау мен салықтық әкімшілендіруді цифрландыру мәселелерін қамтиды. Зерттеулер экономикалық қызметке негізделген дәстүрлі есептен салықтық есепке жедел көшудің маңыздылығын алға тартады. Бұл тәсіл компанияның барлық есептік жүйелерінде қалыптасатын ақпараттың сенімділігін арттырып, салық тәуекелдерін төмендетуге ықпал ететіні дәлелденген. Салықтық әкімшілендіруді жетілдірудің бейімделген басқару тәсілдері ақпараттық технологияларды мемлекеттік аппаратқа енгізумен қатар жүруі тиіс.

Төртінші, жаңашыл бағыт – Индустрия 4.0 тұжырымдамасының бухгалтерлік есеп пен мемлекеттік бақылауға тигізетін әсері. Үлкен деректер (Big Data), бұлтты есептеулер (Cloud Computing), жасанды интеллект (AI), блокчейн (Blockchain), заттар интернеті (IoT) және роботтандырылған процестерді автоматты түрде басқару (Robotic Process Automation - RPA) сияқты технологиялар бухгалтер мен аудитор мамандығының сипатын түбегейлі өзгертуде. Бұл технологиялық ауысу өнімділікті, икемділікті және тұрақтылықты арттыруға мүмкіндік береді. Роботтар мен автономды жүйелер арқылы жазбаларды жылдам жасау, жіктеу және синтездеу бухгалтерлерге есептерді талдауға және шешім қабылдаушыларға стратегиялық кеңес беруге көбірек уақыт бөлуге жол ашады. Дегенмен, әдебиеттерде Индустрия 4.0 технологияларының еңбек нарығындағы құрылымдық жұмыссыздық қаупі де жан-жақты талданады. Зерттеулер көрсеткендей, технологиялық жұмыссыздық әкімшілік және қарапайым рутиналық процестерді қысқартқанымен, ішкі аудит, деректер аналитикасы және

цифрлық маркетинг салаларында жаңа интеллектуалды жұмыс орындарының ашылуына түрткі болады.

Зерттеу әдістемесі

Бұл зерттеу бюджеттік ұйымдардың есеп, аудит және салық жүйелерін кешенді бағалау мақсатында сандық және сапалық әдістердің (mixed-methods research) интеграцияланған жиынтығына негізделген. Зерттеудің әдіснамалық аппараты кросс-кантри индикаторларын талдаудан бастап, нақты математикалық модельдеуге дейінгі кең ауқымды қамтиды.

Негізгі аналитикалық құрал ретінде бюджеттік инвестициялар мен мемлекеттік шығыстардың техникалық тиімділігін бағалауға арналған бейпараметрлік әдіс – Деректерді қамту талдауы (Data Envelopment Analysis - DEA) алгоритмі таңдалды. Бұл әдіс мемлекеттік аудитте айрықша маңызға ие, себебі ол өзара сызықтық корреляциясына қарамастан, кіріс (бюджеттік шығындар мен инвестициялар көлемі) және шығыс (жалпы өңірлік өнім, жұмыспен қамту деңгейі, жеке инвестициялар) деректерінің шектеулілігі жағдайында әлеуметтік-экономикалық көрсеткіштерді барынша дәл бағалауға мүмкіндік береді. Дәстүрлі параметрлік әдістерден айырмашылығы, DEA әртүрлі өлшем бірліктері бар көрсеткіштерді бір модельге біріктіріп, ең жоғары тиімділік шекарасын (efficiency frontier) құру арқылы әрбір өңірдің немесе мекеменің салыстырмалы техникалық тиімділігін анықтайды. Бұл аудиторларға бюджет қаражатының нақты әлеуметтік-экономикалық әсерін дәлелдейтін қосымша аналитикалық құрал ұсынады.

Сонымен қатар, зерттеу барысында статистикалық, салыстырмалы және құрылымдық талдау әдістері қолданылды. Еңбек ресурстарының тиімділігін бағалау үшін ұйымдық құрылымдардың ішкі ортасын зерттеуге бағытталған эмпирикалық құралдар (сауалнамалар, тестілеу) теориялық тұрғыдан қарастырылды. Бюджет қаражатының мақсатты жұмсалудың және оның қоғамдық әсерін анықтау үшін Қазақстан Республикасының салық заңнамасына, Бюджет кодексіне және халықаралық мемлекеттік аудит стандарттарына құқықтық-нормативтік талдау жасалды. Жергілікті бюджеттерді басқарудың тиімділігін сандық түрде өлшеу үшін 2021–2023 жылдардағы аудиттік қадағалау мен бюджет ашықтығы бойынша жаһандық индекстердің кросс-кантри (cross-country) мәліметтері негізге алынды.

Зерттеудің негізгі статистикалық және ақпараттық базасын Қазақстан Республикасының Стратегиялық жоспарлау және реформалар агенттігінің Ұлттық статистика бюросының ресми мәліметтері (2025-2026 жылдардағы макроэкономикалық көрсеткіштер) құрады. Бұл эмпирикалық деректер өңірлік дамудағы диспропорцияларды анықтауға және мемлекеттік қаржылық бақылаудың тиімділігін дәлелдеуге қызмет етті.

Зерттеу барысында сандық және сапалық әдістер кешені қолданылды.

Негізгі әдіс ретінде Деректерді қамту талдауы (DEA) пайдаланылды. Бұл әдіс бюджеттік шығындардың тиімділігін бағалауға мүмкіндік береді.

DEA моделінің жалпы формасы:

$$Efficiency = \sum u_i y_i / \sum v_j x_j$$

мұнда:

- y_i, u_i – нәтижелер (ЖӨӨ, жұмыспен қамту),
- x_j, v_j – ресурстар (бюджеттік шығындар),
- u_i, v_j – салмақ коэффициенттері.

Зерттеу деректері ретінде Қазақстан Республикасының ресми статистикалық мәліметтері (2025–2026 жж.) пайдаланылды.

Зерттеу нәтижелері мен талдау

Бюджеттік мекемелердегі қаржылық басқару жүйесін жетілдіру көпөлшемді процесті білдіреді. Зерттеу нәтижелері бұл процестің төрт негізгі құрылымдық бағыттан тұратынын көрсетті: бухгалтерлік есепті халықаралық стандарттарға бейімдеу және цифрландыру,

адами капитал мен еңбекақы жүйесін оңтайландыру, тиімділік аудитін жаңа парадигмаға көшіру, сондай-ақ салықтық әкімшілендіруді Индустрия 4.0 талаптарына сай трансформациялау.

Бухгалтерлік есептің ұйымдастырушылық негіздері және цифрлық трансформациясы

Қазақстанның бюджеттік ұйымдарында бухгалтерлік есепті ұйымдастырудың басты ерекшелігі – оның коммерциялық емес сипаты және толығымен жоғары тұрған органдар бекіткен қаржыландыру жоспарларына тәуелділігі. Бүгінгі таңда бухгалтерлік және салықтық есепті жүргізуде «1С: Кәсіпорын 8» бағдарламасы сияқты арнайы автоматтандырылған жүйелер ұйымның қысқа мерзімді және ұзақ мерзімді активтерін, меншікті және қарыз көздерін, сондай-ақ кірістері мен шығыстарын басқарудың іргетасы болып саналады. Дегенмен, күрделенген экономикалық транзакциялар мен Индустрия 4.0 жағдайында дәстүрлі бағдарламалық жасақтамалардың әлеуеті жеткіліксіз болуда.

Цифрлық экономика талаптарына сәйкес, қаржылық ақпаратты өңдеуде бұлтты есептеулер, блокчейн және жасанды интеллект жүйелерін тікелей біріктіру қажет. Индустрия 4.0 тұжырымдамасы физикалық және цифрлық әлемді біріктіре отырып, барлық секторларға, соның ішінде ШОБ пен мемлекеттік ұйымдарға орасан зор әсер ететін жаңа мүмкіндіктер жасайды. Мысалы, блокчейн технологиясы транзакциялардың өзгертілмеуін және толық ашықтығын қамтамасыз етіп, бюджет қаражатын жымқыру немесе мақсатсыз пайдалану тәуекелдерін технологиялық деңгейде нөлге дейін төмендетеді. Ал роботтандырылған процестерді автоматтандыру (RPA) алғашқы құжаттарды тіркеу, бухгалтерлік шоттарға жіктеу және жиынтық есептілікті синтездеу процестерін автономды түрде орындайды. Бұл өзгерістер мамандық сипатына тікелей әсер етіп, бухгалтерлерге рутиналық мәліметтерді енгізумен емес, алынған есептерді талдаумен, түсіндірумен және басқарушылық стратегиялық шешімдер қабылдаумен айналысуға мүмкіндік береді.

Мұндай цифрлық интеграция халықаралық қаржылық есептілік (ХҚЕС - IFRS) және аудит стандарттарын жергілікті нарыққа бейімдеуді айтарлықтай жеңілдетеді. Бухгалтерлік есептің бұл жаңа моделі тек қаржылық ақпаратты тіркеп қана қоймай, өндіріс шығындары туралы деректерді жүйелеу, шығарылатын өнімнің өзіндік құнын бағалау, пайданы анықтау және жаңа өнімдердің немесе қоғамдық қызметтердің рентабельділігін есептеу сияқты басқарушылық есептің (management accounting) тереңдетілген элементтерін де қамтиды. Бұл өз кезегінде еншілес ұйымдардың немесе құрылымдық бөлімшелердің шоғырландырылған қаржылық есептілігін дайындауды, оларды салық, статистика және министрлік органдарына мінсіз дәлдікпен тапсыруды қамтамасыз етеді.

Еңбекақы төлеу жүйесі және кадрлық ресурстарды басқару

Бюджеттік ұйымдардың стратегиялық мақсаттарына (әлеуметтік-мәдени, ғылыми жобаларды іске асыру) қол жеткізу тиімділігі олардың жоғары білікті мамандармен қамтамасыз етілу деңгейіне тікелей тәуелді. Мемлекеттік сектордағы еңбекақы төлеу жүйесі қатаң тарифтік торлармен және базалық лауазымдық айлықақылармен шектелгендіктен, қызметкерлерді қаржылық ынталандыру мәселесі әлі де күрделі күйінде қалып отыр. Еңбек ресурстарын басқарудың тиімділігін арттыру үшін ұйымның адам ресурстары қаншалықты мақсатты пайдаланылып жатқанын анықтап, әрбір құрылымдық бөлімше мен әрбір қызметкерді жеке бағалау әдіснамасын енгізу қажет. Ол үшін сауалнама, психометриялық тестілеу және KPI-ге негізделген бағалау сұхбаттары сияқты заманауи HR-технологиялар қолданылуы тиіс.

Бұл үдеріс Индустрия 4.0 дәуіріндегі еңбек нарығындағы ауқымды трансформациялармен тұспа-тұс келуде. Дәстүрлі әкімшілік және қарапайым есеп айырысу қызметтері автоматтандырылған сайын, бұл салалардағы жұмыс орындары құрылымдық жұмыссыздық қаупіне ұшырайды. Жаңа өндірістік модель өмір салтын, өндіріс пен еңбек қатынастарын бірінші өнеркәсіптік революция секілді терең өзгертеді. Дегенмен, бұл қауіп

жаңа зияткерлік және жоғары технологиялық секторлардағы жұмыс орындарының пайда болуымен өтеледі. Техникалық мамандықтарға, ақпараттық технологиялар мамандарына, ішкі аудит сарапшыларына, цифрлық адами ресурстарды (Digital HR) басқарушыларға және Big Data аналитиктеріне сұраныс күрт артады. Зерттеулер мен болжамдар көрсеткендей, математика және информатика саласындағы жұмыс орындарының 4,6%-ға, ал қаржы секторы мен басқару саласында 1,4%-ға өсу тенденциясы байқалуда. Қазақстан үшін бұл трансформацияны кешіктіру ұзақ мерзімді әлеуметтік шығындардың артуына әкеп соғуы мүмкін. Сондықтан мемлекеттік бюджеттік мекемелер жаңа технологиялық инфрақұрылымдарды құрып қана қоймай, осы инфрақұрылымдармен жұмыс істей алатын мамандарды (сарапшыларды) даярлау мен ынталандыруды бірінші кезектегі басымдық етіп қоюы керек.

Мемлекеттік аудиттің заманауи парадигмалары: тиімділік аудиті

Мемлекеттік аудит жүйесі эволюциялық дамудың жаңа кезеңіне қадам басты. Ол бюджет қаражатының тек заңды және мақсатты жұмсалуды бақылаудан (сәйкестік аудиті) олардың түпкілікті әлеуметтік-экономикалық нәтижесін бағалауға (тиімділік аудитіне) ауысуда. Бұл тұрғыда аудит мекемелері мемлекеттік қаржыны басқару жүйесінің ішіндегі кіріктірілген «эндогендік иммундық жүйе» қызметін атқарады. Тиімділік аудиті қоғамдық бағдарламалардың немесе мемлекеттік іс-шаралардың үнемділігін (economy), өнімділігін (efficiency) және нәтижелілігін (effectiveness) анықтауға арналған объективті және жүйелі бағалау болып табылады. Оның негізгі мақсаты – шығындар мен қол жеткізілген нәтижелер арасындағы арақатынасты, яғни «қаражаттың қадірін» (value-for-money) бағалау.

Қазақстанның бюджеттік жүйесіндегі басты мәселелердің бірі – мемлекеттік бағдарламаларға бөлінетін қыруар қаражаттың халықтың өмір сүру сапасын арттыруға тигізетін әсерінің (socio-economic impact) айқын болмауында. Осыған байланысты, ғалымдар мен сарапшылар Қазақстан Республикасының Бюджет кодексіне «бюджеттік инвестициялар» ұғымының тұжырымдамалық анықтамасына қатысты түбегейлі өзгерістер енгізуді ұсынады. Қазіргі қолданыстағы заңнама инвестицияларды жай ғана «қаржыландыру» құралы ретінде қарастырса, жаңа тәсіл оларды нақты макроэкономикалық нәтижеге қол жеткізуге бағытталған күрделі «процесс» ретінде тануы тиіс. Бұл өзгеріс мемлекеттік аудиторларға аудит тапсырмаларын дұрыс қоюға және мемлекеттік шығыстардың халықтың мақсатты топтарына тигізетін әсерін дұрыс бағалау үшін тиісті нысаналы индикаторларды орнатуға мүмкіндік береді.

Осы мақсатта Қазақстан өңірлеріндегі бюджеттік инвестициялардың техникалық тиімділігін бағалау үшін Деректерді қамту талдауы (DEA) әдісін қолдану ұсынылады. Бұл алгоритм кіріс және шығыс деректерінің шектеулі жағдайында аудиторларды қосымша аналитикалық дәлелдемелермен қамтамасыз етіп, бағалау деңгейін және ұсынымдардың сапасын арттырады. Мемлекеттік инвестициялардың тиімділігі мен макроэкономикалық көрсеткіштердің байланысын дәлелдеу үшін өңірлік деректерді талдау өте маңызды. Төменде келтірілген 1-кестеде Қазақстанның кейбір өңірлері бойынша 2025-2026 жылдардағы негізгі әлеуметтік-экономикалық көрсеткіштер берілген.

1-кесте. Қазақстан Республикасы өңірлерінің әлеуметтік-экономикалық көрсеткіштері (2025 жылғы IV тоқсан - 2026 жылғы қаңтар-ақпан мәліметтері негізінде)

Өңір атауы	Жұмыссыздық деңгейі (%)	ЖӨӨ нақты көлем индексі (%)	Жан басына шаққандағы ЖӨӨ (мың теңге)
Атырау облысы	4,9	109,6	16 205,5
Алматы қаласы	4,5	106,7	8 826,7
Ұлытау облысы	4,1	100,4	7 444,4
Астана қаласы	4,3	111,5	7 354,0
Қарағанды облысы	4,0	104,1	5 732,4
Батыс Қазақстан облысы	4,6	103,6	5 037,3
Маңғыстау облысы	5,0	102,9	5 025,6
Шығыс Қазақстан облысы	4,6	99,0	4 865,2
Павлодар облысы	4,9	104,1	4 667,9
Ақтөбе облысы	4,7	103,9	4 293,2
Қостанай облысы	4,6	108,0	4 276,0
Абай облысы	4,7	101,5	3 975,9
Солтүстік Қазақстан облысы	4,4	106,2	3 907,0
Ақмола облысы	4,5	106,2	3 781,5
Алматы облысы	4,6	104,5	2 972,7
Шымкент қаласы	4,6	108,5	2 890,9
Қызылорда облысы	4,5	102,6	2 643,6
Жетісу облысы	4,7	106,8	2 407,5
Жамбыл облысы	4,8	106,1	2 158,8
Түркістан облысы	4,6	110,1	1 667,0

Ескерту: Деректер Ұлттық статистика бюросының ресми мәліметтері негізінде жинақталған.

Кестедегі деректерді терең талдау өңірлер арасындағы экономикалық дамудың күрделі диспропорцияларын көрсетеді. Мысалы, Атырау облысында жан басына шаққандағы ЖӨӨ (16 205,5 мың теңге) елдегі ең жоғарғы көрсеткіш болғанымен, жұмыссыздық деңгейі (4,9%) орташа республикалық көрсеткіштен (4,6%) айтарлықтай жоғары. Бұл мұнай-газ секторына бағытталған инвестициялардың капиталды көп қажет ететіндігін, бірақ жаңа жұмыс орындарын құрудағы әлеуметтік тиімділігінің төмендігін білдіреді. Керісінше, Қарағанды облысында жұмыссыздық ең төменгі деңгейде (4,0%) тіркелгенімен, ЖӨӨ көлемі мен нақты көлем индексі (104,1%) орташа деңгейде қалып отыр. Түркістан облысы ЖӨӨ өсімі бойынша (110,1%) көшбасшылардың бірі болғанымен, жан басына шаққандағы кіріс (1 667,0 мың теңге) бойынша ең төменгі орында тұр. Шығыс Қазақстан облысында тіпті ЖӨӨ-нің құлдырауы (99,0%) байқалады.

Бұл макроэкономикалық қайшылықтар бюджеттен бөлінетін қаржының, соның ішінде бюджетаралық субвенциялардың мақсатты бағыттары қаншалықты дұрыс таңдалғанын және олардың нақты экономикалық өсімге қаншалықты әсер етіп жатқанын талдау үшін DEA сияқты математикалық модельдеуді қолданудың өміршеңдігін дәлелдейді. Бұған қоса, жалпыұлттық табыс пен инфляция көрсеткіштері де халықтың әлеуметтік

жағдайына макроэкономикалық қысымды көрсетеді: 2026 жылғы ақпандағы жағдай бойынша ел халқының саны 20,5 миллионнан асса, жылдық инфляция деңгейі 111,7%-ға жеткен (оның ішінде азық-түлік тауарлары 112,7%-ға қымбаттаған). Осындай жоғары инфляциялық ортада және нақты ақшалай табыс индексінің төмендеуі (90,8%) жағдайында мемлекеттік бағдарламалардың әрбір тиынының қалай жұмсалып жатқанын қатаң бақылау мемлекеттік аудиттің стратегиялық басты міндетіне айналады.

Атап айтқанда, Қазақстан Республикасындағы агроөнеркәсіптік кешенді (АӨК) дамытуға бағытталған бюджет қаражатын пайдаланудың тиімділігін аудиттеу айрықша назар аударуды талап етеді. Бұл салаға бөлінетін субсидиялар мен инвестициялар көлемі өте ауқымды. Тиімділік аудиті бөлінген қаражаттың бағыты мен көлемін ғана емес, олардың бекітілген мақсаттарға сәйкестігін де егжей-тегжейлі талдайды. Аудит қорытындыларының, әсіресе қолайсыз аудит есептерінің жариялануы агроөнеркәсіптік кешенге қатысушылардың беделі мен қаржылық жағдайына, несиелік рейтингтеріне айтарлықтай кері әсер етуі мүмкін. Сондай-ақ, қаржының тиімсіз жұмсалуды фактілері анықталған жағдайда, мемлекеттік органдар мен кәсіпорындар қоғамдық, экономикалық және экологиялық қысымға ұшырайды. Мұндай қысым бюджет қаражатын пайдаланушыларды озық тәжірибелерді көрсетуге және қаражатты өте мұқият пайдалануға ынталандырады. Бұл механизм аудиттің жазалаушы ғана емес, профилактикалық және тәрбиелік рөлін толық ашады.

Салықтық әкімшілендіруді оңтайландыру және цифрлық салықтық бақылау

Бюджеттік ұйымдарда салық жүйесін реформалау – елдің жаһандық нарықтық экономикаға толыққанды кірігуінің ажырамас бөлігі болып саналады. Салық есебінің тиімділігін қамтамасыз ету үшін ұйымдар шаруашылық қызметке негізделген дәстүрлі есептен тікелей салықтық есепке (tax accounting) жедел көшу процесін ұйымдастыруы қажет. Бұл көшу моделі компанияның барлық есептік жүйелерінде қалыптасатын ақпараттың сенімділігін арттырып, салық тәуекелдерін төмендетуге, салық төлемдерінің дұрыс формасын әзірлеу үшін деректерді пайдалану тиімділігін жақсартуға ықпал етеді.

Бюджеттік ұйымның бухгалтері заңды тұлғаның жалпы табысынан шегерімдер бойынша жұмысты дұрыс бағалауы, бейінді емес қызметтерден (non-core activities) түсетін кірістер мен шығыстар есебін нақты қалыптастыруы және салықтық есепке алудың арнайы регистрлерін тәжірибеде көрсете білуі тиіс. Салық салудың негізгі түрлерінің (табыс салығы, корпоративтік салық, капитал өсіміне салынатын салық) қаржылық шешімдерге тигізетін әсері туралы кәсіби пайымдауларды қолдану, Салық кодексінің талаптарын, қосымша жеңілдіктер мен босатуларды дұрыс түсіндіру басқарушылық есептің ажырамас бөлігіне айналуға. Сондай-ақ, корпоративтік есептердің, соның ішінде кіріктірілген есептіліктің (Integrated Reporting) мүдделі тараптарға ұйымның болашағын бағалауға қаншалықты көмектесетінін талдау талап етіледі.

Қазақстанда салықтық әкімшілендіруді жетілдіру мақсатында қазіргі нысандар мен әдістердің тиімділігін бағалау аса маңызды. Қазіргі экономикалық жағдай мемлекеттік бюджет кірістерінің уақытылы түсуін қамтамасыз етуді және жиналатын салықтар көлемін арттыруды қатаң талап етеді. Мемлекет өзінің экономиканы және қаржы жүйесін тұрақтандырудағы функцияларын тиісінше орындауы үшін қажетті қаражат жинақталып, мемлекеттік қолдауды қажет ететін салаларға бағытталуы тиіс. Бұл мақсатта салық органдарының бейімделген басқару тәсілдерін (adaptive management) қолдануы және белгілі бір өңірдегі жағдайды ескере отырып салық әлеуетін қалыптастыруы оң нәтиже береді. Бұған салық органдарының құрылымдарын жаңғырту және заманауи ақпараттық технологияларды енгізу тәжірибесі тікелей ықпал етеді.

Салық бақылауының маңызды формаларына тоқталатын болсақ, Қазақстан Республикасы Салық кодексінің 555-бабына сәйкес, салық органдары салықтық бақылауды

жүргізуге, уақытылы орындалмаған салық міндеттемелерін мәжбүрлеп өндіріп алу шараларын қолдануға және мемлекеттік қызметтерді ұсынуға міндетті.

Салықтық бақылау формалары келесідей негізгі бағыттарды қамтиды:

— **Салық төлеушілерді тіркеу:** Жеке тұлғаны, заңды тұлғаны, заңды тұлғаның құрылымдық бөлімшелерін салық төлеушілердің мемлекеттік дерекқорына енгізу, өзгертулер жасау және одан шығару. Тіркеу бірнеше санат бойынша жүзеге асады: (1) жеке кәсіпкер, жеке нотариус, адвокат, жеке сот орындаушысы ретінде; (2) қосылған құн салығы (ҚҚС/VAT) бойынша төлеуші ретінде; (3) электронды салық төлеуші ретінде; (4) қызметтің белгілі бір түрлерін жүзеге асыратын төлеуші ретінде; (5) салық салу объектісінің орналасқан жері бойынша.

— **Камералдық бақылау (in-house audit):** Салық төлеушілердің ұсынған салық есептіліктерін салық органдарының ішкі ақпараттық жүйелері арқылы автоматты түрде талдау және сәйкессіздіктерді анықтау.

— **Әлеуметтік және зейнетақы аударымдарын бақылау:** Міндетті зейнетақы жарналарын, әлеуметтік аударымдарды есептеу, ұстап қалу және аудару бойынша міндеттемелердің орындалуын қадағалау.

Мөлдір әрі әділ салық салу азаматтар мен бизнестің мемлекетке деген сенімін арттырып, бизнестің тұрақты дамуына негіз болады. Алайда, Қазақстанды қоса алғанда, бірқатар елдерде салық саясатының негізгі бағыттарын білдіретін, салықтық-құқықтық саясатты нақты реттейтін тиісті саяси және құқықтық актілердің жетіспеушілігі байқалады. Бұл заң шығарушы топтардың жұмысын қиындатады. Салық заңнамасын қалыптастыру процесін нормативтендіру, оның ішінде оңтайлы салықтық әкімшілендіру жүйесін құру салық реформасының сәтті жүзеге асуының маңызды шарты ретінде қарастырылуы қажет.

Индустрия 4.0: Тұрақты даму мен цифрлық платформалар трансформациясы

Мемлекеттік сектор мен шағын және орта бизнес үшін (ШОБ) Индустрия 4.0-ді енгізу өнімділік пен тұрақтылықты арттыруға, икемділікті жақсартуға, білімге негізделген экономика мен қоғамды дамытуға үлкен септігін тигізеді. Әсіресе, COVID-19 пандемиясының әлеуметтік және экономикалық зардаптарынан кейін цифрландыруды енгізу тек дамып келе жатқан тренд емес, әрбір ұйым үшін өмірлік қажеттілікке айналды. Бұл процестер бюджеттік мекемелерге жаңа нарықтық тауашаларды игеруге, құндылық құру шығындарын азайтуға және операциялық өнімділікті жақсартуға көмектеседі. Сонымен қатар, сыртқы баға қысымы, күтпеген климаттық оқиғалар және заңнамадағы өзгерістер сияқты экологиялық және реттеуші факторлар да цифрландыруға итермелейді (мысалы, жаңа заң талаптарына сай тауарларды қадағалау жүйелерін орнату).

Кейбір зерттеулер көрсеткендей, технологияларды қолдану орташа фирмалар мен мекемелерге өндіріс тиімділігін 12%-ға, өнім немесе қызмет сапасын 40%-ға арттыруға және деректерді уақытылы жеткізуді қамтамасыз етуге мүмкіндік берді. Бюджеттік ұйымдарда бұл тиімділік көрсетілетін мемлекеттік қызметтердің жылдамдығы мен сапасынан, қағазбастылықтың жойылуынан және адами фактордың рөлі төмендегендіктен сыбайлас жемқорлық қаупінің азаюынан көрініс табады. Сонымен қатар, өнімнің өмірлік циклдерінің қысқару тенденциясы және жаһандық бәсекелестік жағдайында қызметтерді жекелендіруге (customization) деген сұраныс артып келеді. Жекелендіру құндылық құру процестеріне тікелей әсер етеді және өндірістік процестерді тиімді жолмен өзгертуді талап етеді. Цифрлық трансформация заманауи басқару әдістерін, оның ішінде икемді жаппай жекелендіруді енгізуге айтарлықтай үлес қоса алады.

Алайда, бұл процестерге кедергі келтіретін негізгі факторлар да жоқ емес. Көптеген ұйымдар жаңа инновациялық белсенділікті игергенімен, оны коммерциялық немесе практикалық мақсатта толық пайдалануда қиындықтарға тап болады. Жүйені енгізу бағдарламалық қамтамасыз ету, аппараттық құралдар және инфрақұрылым тұрғысынан үлкен шығындарды талап етеді. Бұған қоса, ұйымдарда ұзақ мерзімді стратегияның болмауы

және көшбасшылық қолдаудың төмендігі цифрлық бейімделуге кедергі келтіреді. Бұл мәселені шешу үшін мемлекеттік органдар жаңа технологиялық инфрақұрылымдарды құрып қана қоймай, үздіксіз білім беру және біліктілікті арттыру бағдарламалары арқылы онымен жұмыс істей алатын сарапшыларды даярлауды бірінші кезектегі міндет етіп қоюы тиіс.

Қорытынды. Қазақстан Республикасының бюджеттік мекемелерінде қаржылық есеп, мемлекеттік аудит және салық жүйелерін ұйымдастыру мен жетілдіру аса күрделі, көп деңгейлі және жүйелі тәсілді талап ететін стратегиялық міндет. Жүргізілген кешенді зерттеу барысында анықталғандай, дәстүрлі бақылау тетіктері, қатаң еңбекақы төлеу жүйелері және қағазбасты есептік процедуралар Индустрия 4.0 дәуірінің, жаһандық бәсекелестіктің және цифрлық экономиканың сын-қатерлеріне толыққанды жауап бере алмайды. Бюджет қаржысының экономикалық өсімге, жұмыссыздықты азайтуға және инфляциялық қысымды төмендетуге тигізетін нақты әсері өңірлік кесіндіде айтарлықтай диспропорцияларға ие екені дәлелденді. Осы мәселелерді еңсеріп, орнықты трансформацияны жүзеге асыру үшін келесідей іргелі ғылыми-практикалық ұсыныстар тұжырымдалды:

— Біріншіден, қаржылық ашықтық пен басқарушылық сенімділікті қамтамасыз ету мақсатында бюджеттік мекемелердің бухгалтерлік есеп процестерін толығымен цифрландыру қажет. Бұлтты жүйелер, роботтандырылған процестерді автоматтандыру (RPA) және жасанды интеллект арқылы халықаралық қаржылық есептілік стандарттарын (ХҚЕС) ішкі нарыққа терең бейімдеу міндетті. Бұл қадам бухгалтерлік құжаттаманың жылдамдығын арттырып қана қоймай, есеп мамандарына рутиналық жұмыстан арылып, жоғары деңгейлі аналитикалық және басқарушылық кеңес беру бағытында жұмыс істеуге толық мүмкіндік береді.

— Екіншіден, мемлекеттік инвестициялар мен шығыстардың тиімділігін бағалау парадигмасын заңнамалық деңгейде өзгерту қажет. Қазақстан Республикасының Бюджет кодексінде «бюджеттік инвестицияларға» концептуалды жаңа анықтама беріп, оларды тек қана қаржылық ресурстарды бөлу актісі емес, халықтың өмір сүру сапасын арттыруға әкелетін тізбекті «процесс» ретінде бекіту ұсынылады. Бұл ретте, мемлекеттік аудит практикасында Деректерді қамту талдауы (DEA) сияқты озық математикалық-статистикалық алгоритмдер аудиторлардың негізгі әдіснамалық құралдар тақтасына міндетті түрде енгізілуі тиіс. Бұл аудит институттарын экономикалық қауіпсіздіктің сенімді «эндогендік иммундық жүйесіне» айналдырады.

— Үшіншіден, салықтық әкімшілендіруді бейімдеп басқару және камералдық бақылау жүйелерін блокчейн технологияларымен кіріктіру арқылы салықтық тәуекелдерді азайту маңызды. Шаруашылық қызметтің есебі мен тікелей салық есебінің арасындағы алшақтықты жоятын жаңа есеп үлгілері мемлекеттік органдар тарапынан бірыңғайландырылуы шарт. Сонымен қатар, салық заңнамасын реттейтін саяси-құқықтық актілердің мақсаттарын нақтылап, заң шығару процесін нормативтендіру қажет.

— Төртіншіден, кадрлық әлеуетті және еңбекақы төлеу жүйесін қайта құрылымдау кезек күттірмейтін шара. Мемлекеттік ұйымдар Индустрия 4.0 тудыратын технологиялық жұмыссыздық пен мамандықтардың жойылу сын-қатерлеріне дайын болуы керек. Қатаң тарифтік торлардан бас тартып, қызметкерлерді жеке бағалауға (KPI) негізделген ынталандыру жүйелеріне көшу қажет. Басқару, IT-құрылымдар, ішкі аудит және деректер аналитикасы (Big Data) саласындағы цифрлық сауатты мамандардың үлесін арттыру бюджеттік мекемелердің ұзақ мерзімді институционалдық тұрақтылығының іргетасы болып табылады. Осы аталған кешенді шараларды толыққанды іске асыру ел экономикасының орнықты өсуіне, бюджет қаржысының әлеуметтік бағдарланған оңтайлы жұмсалыуына және жалпы мемлекеттік басқару жүйесінің қоғам алдындағы ашықтығы мен есептілігін арттыруға тікелей әрі сөзсіз ықпал етеді.

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Institutional Development and Investment Strategy of the Islamic Development Bank in Central Asian Countries: Global Trends and Regional Specifics

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Abstract:

This article is devoted to a comprehensive study of the institutional role and investment strategy of the Islamic Development Bank (IsDB) within the context of post-Soviet Central Asian countries. Amidst global economic instability and the search for alternative sources of infrastructure project financing, the IsDB's activities have gained particular relevance as a mechanism for aligning the capital of the Islamic world with the emerging markets of the Central Asian region. The study aims to identify the essential characteristics and patterns of the IsDB Group's investment policy regarding Kazakhstan, Uzbekistan, Turkmenistan, Tajikistan, and Kyrgyzstan, and to assess its impact on the region's socio-economic development.

Keywords: Islamic Development Bank, Islamic finance, investment strategy, infrastructure projects, financial integration, OIC, sustainable development

Global Context and Institutional Profile of the IsDB

The declared objective of the IsDB is to "foster socio-economic development of the 57 member countries and Muslim communities in non-member countries". Any OIC member state may join the IsDB, provided it contributes to the bank's subscribed capital and accepts the terms issued by the Board of Governors. As of 2026, the IsDB includes all 57 OIC member countries from Africa, Asia, Europe, Latin America, and the Middle East, as well as Turkey, an OECD member.

By April 2026, the IsDB maintains its premier investment-grade credit ratings of Aaa (Moody's) and AAA (S&P, Fitch). This allows the bank to raise resources on international markets under highly favorable conditions. The current key shareholders are:

- Saudi Arabia — 23.5%
- Libya — 9.43%
- Iran — 8.25%
- Nigeria — 7.66%
- UAE — 7.51%
- Qatar — 7.18%
- Egypt — 7.07%
- Kuwait — 6.92%
- Turkey — 6.45%

By the end of 2022, the subscribed capital amounted to \$70 billion, and by 2026, the IsDB Group's total approvals exceeded \$194.8 billion. The Bank is funded not only through contributions but also through the issuance of Sukuk (Islamic bonds), which are in high demand among global investors.

It is worth noting that the IsDB plays a crucial role in promoting Islamic finance, which is identified in some of the bank's documents as one of the institution's "pillars." The bank's

headquarters remains in Jeddah (Saudi Arabia), while regional offices are located in Rabat (Morocco), Kuala Lumpur (Malaysia), Almaty (Kazakhstan), and Dakar (Senegal). The Almaty office opened in 1997, two years after Kazakhstan joined the IsDB. It coordinates the bank's operations in Eastern Europe, the CIS, Mongolia, and China.

The IsDB has also played a leading role in the creation and development of several Islamic financial institutions: the Accounting and Auditing Organization for Islamic Financial Institutions (AAOIFI, founded in 1991), the General Council for Islamic Banks and Financial Institutions (CIBAFI, 2001), the International Islamic Financial Market (IIFM, 2002), the Liquidity Management Centre (LMC, 2002), the Islamic Financial Services Board (IFSB, 2003), the Islamic International Rating Agency (IIRA, 2005), the International Islamic Centre for Reconciliation and Arbitration (IICRA, 2005), and the International Islamic Liquidity Management Corporation (IILM, 2010). As a multilateral development financial institution, the IsDB Group is a source of both concessional and non-concessional financing. Specifically, concessional financing instruments include technical assistance and loans, while non-concessional instruments include *Ijarah* (Islamic leasing), *Mudarabah* (equity participation), *Murabaha* (installment sale), *Istisna* (commissioned manufacture), *Musharakah* (profit sharing), and lines of financing.

Let us consider the IsDB's concessional financing practices: Concessional loans are directed toward financing development projects for basic social infrastructure and rural areas. The maturity of such loans ranges from 15 to 25 years, including a grace period of 3 to 7 years. Even more favorable terms (a maturity of 30 years with a 10-year grace period and a service fee of 0.75%) apply to the least developed countries. These loans are provided to governments or state institutions under a government guarantee. The service fee for the loans typically covers only the bank's administrative expenses incurred during the preparation of the transaction.

IsDB's non-concessional forms of financing involve generating a profit (or markup) on financial operations and include: *Istisna* (sale and purchase of assets), *Ijarah* (Islamic leasing), and *Murabaha* (installment sale).

Lines of financing are typically provided to local financial institutions (most often banks) to enhance the role of small and medium-sized enterprises and promote the principles of Islamic finance.

It should be noted that the same investment project may receive different types of financing from the IsDB. For example, Islamic leasing companies in CIS countries were supported by the IsDB through a combination of equity (*Mudarabah*) and trade (*Murabaha*) financing. Overall, the types of financing discussed above indicate that in its operations, the IsDB emphasizes compliance with Islamic financial principles, risk balancing, development of the real sector of the economy, and the avoidance of speculative capital. Regarding the geographical distribution of IsDB investments, they are primarily concentrated in highly populated countries such as Bangladesh (\$24.4 billion), Egypt (\$18.6 billion), Pakistan (\$14.8 billion), and Turkey (\$12.1 billion), where nearly a third of the world's total Muslim population resides.

Evolution of Regional Presence in Central Asia

Research has shown that the combined share of post-Soviet Central Asian countries in the IsDB's subscribed capital is 0.24%. According to estimates, as of the first half of 2026, the total volume of approved financing by the IsDB Group in the region (Kazakhstan, Uzbekistan, Turkmenistan, Tajikistan, and Kyrgyzstan) has exceeded \$10.6 billion USD. This growth is driven by a transition from small grant-based projects to large-scale infrastructure tranches. Based on an analysis of a portfolio consisting of more than 340 transactions and the sharp increase in financing volumes, the average size of a single transaction in the region has risen to \$31.2 million USD.

An analysis of the empirical database of 340 transactions funded by the IsDB in the study region—ranging from the construction of Islamic schools (madrasas) to the laying of main gas pipelines—has allowed us to identify the following patterns:

- First, the IsDB provides concessional long-term loans to Central Asian governments for periods of up to 25–30 years, of which up to 10 years typically serve as a grace period.
- Second, the IsDB invests in consortiums with other international development banks, including the World Bank (WB), the International Bank for Reconstruction and Development (IBRD), the International Finance Corporation (IFC), the Asian Development Bank (ADB), the European Bank for Reconstruction and Development (EBRD), the European Investment Bank (EIB), and others.
- Third, the IsDB involves members of The Arab Coordination Group in its deals, such as the Saudi Fund for Development, the OPEC Fund for International Development, the Abu Dhabi Fund for Development, and the Kuwait Fund for Arab Economic Development. On one hand, this allows for risk-sharing and increased project funding; on the other, it expands bilateral investment ties between the Persian Gulf countries and Central Asia.
- Fourth, a condition for providing capital from the IsDB is co-financing by the local government, which includes tax breaks and exemptions from other mandatory payments to the national budget.
- Fifth, for the direct development of the Islamic finance industry in the region, the IsDB has allocated nearly \$160 million USD in the form of grants. These funds were directed toward developing necessary legislation and funding Islamic financial structures such as Islamic banks, leasing companies, and funds.
- Sixth, the three largest recipients of IsDB investments are Uzbekistan, Kazakhstan, and Turkmenistan, which account for 85% of the IsDB's total cumulative inflows into the region.
- Seventh, despite the large number of projects in the financial, industrial, and agricultural sectors, the bulk of the investment volume (\$4.75 billion USD, or 70%) in this region was allocated to financing physical infrastructure, including roads, water supply, oil and gas pipelines, energy, housing, telecommunications, medicine, and education.

The largest share of investments is concentrated in Uzbekistan and Kazakhstan, where record-breaking agreements have been signed over the past two years.

Table 1

IsDB in Central Asian Countries*

Country	Total Approved Financing (\$ billion)	Key Projects (2024–2026)
Uzbekistan	5	Road modernization in the Jizzakh region (\$192 million), and the "SmartEd" project
Kazakhstan	2,8	Infrastructure for Special Economic Zones (SEZ) and industrial zones (\$1.3 billion)
Turkmenistan	1,7	Maritime transport development and gas transportation infrastructure
Tajikistan	0,65	Additional financing for the CASA-1000 project (\$40 million in 2026)
Kyrgyzstan	0,5	Rural water supply systems and irrigation infrastructure

* Source: Compiled by the author based on Islamic Development Bank statistical data - Islamic Development Bank. Statistical Addendum to the Annual Report 2025. — Jeddah: IsDB Institute, 2026

Next, let us consider the country-specific aspects of the IsDB's investment strategy in post-Soviet Central Asia, presented in descending order of the bank's investment volume.

Uzbekistan

Uzbekistan became a member of the IsDB later than any other state in the region, joining in 2003. As A. Wolters noted in his research, "while neighboring countries utilized the opportunities provided by IsDB financing for nearly a whole decade, Tashkent only watched." It is known that following its accession to the IsDB, the first lines of financing were allocated to two financial institutions in the republic: "Ipak Yuli Bank" and "Uzbek Leasing International."

In general, the policy of Uzbekistan's first president regarding everything related to Islam was always cautious, and Islamic finance was no exception. However, even prior to official membership, the IsDB directed small grants to Uzbekistan: for example, for the restoration of madrasas and dormitories at the "Mir-i-Arab" and "Dar al-Hadith" madrasas in the ancient city of Bukhara, as well as for the purchase of medical equipment for surgical departments. Nonetheless, after Uzbekistan became a full member of the bank, cooperation evolved into the substantive financing of periodic three-year development programs. Over the years, the country has managed to catch up; today, Uzbekistan is the largest recipient of IsDB capital. Analysis has shown that the republic attracted nearly \$2 billion USD for the implementation of more than 100 projects (excluding investments from IsDB subsidiaries). Consequently, the average transaction size exceeds \$19 million USD. Meanwhile, the country's share in the bank's subscribed capital is 0.03% (with a contribution of \$13.4 million USD). Thus, among all CIS countries, Uzbekistan has attracted the most capital from this development bank.

Regarding the specifics of IsDB investments in Uzbekistan, unlike other CIS countries, a large number of transactions were financed in the industrial sector, which is linked to the growing role of SMEs in the economy. Furthermore, Uzbekistan was allocated financing to establish international research centers for the study of, for example, the religious and spiritual heritage of the Islamic culture of Imam Al-Bukhari in Samarkand (\$280,000 USD in 2018) and the ecological consequences of the desiccation of the Aral Sea (\$278,000 USD in 2019). Overall, concessional long-term financing is directed to the country for terms of up to 16 years, with a maximum grace

period typically of four years. Additionally, a condition for providing concessional loans from the IsDB is co-financing by the local government at a ratio of no less than 1:4 (Uzbek government funds to IsDB investments), including tax benefits and exemptions from other mandatory payments to the republic's budget.

Today, Uzbekistan is the largest recipient of funds in the CIS. In 2026, the active phase of projects for the modernization of rural infrastructure and the creation of centers for Islamic civilization continues.

Kazakhstan

In 1995, Kazakhstan became a member of the OIC. In 2017, within the framework of this organization, the country hosted the Summit on Science and Technology, and in 2011, it initiated the Islamic Organization for Food Security (IOFS). More than 30 OIC member states joined the latter, and its headquarters was opened directly in Astana. In recent years, Kazakhstan has positioned itself as a food hub and a center for agricultural policy planning within the OIC. Consequently, in 2019, former President N. Nazarbayev initiated a new project—Islamic Infrastructure Integration—aimed at facilitating trade flows within the Islamic world. Kazakhstan's share in the IsDB's subscribed capital is 0.11%, with a paid-up capital contribution of \$54 million USD. These are the highest indicators among the countries of the post-Soviet space.

Our analysis, which covered nearly 90 transactions financed by the IsDB in Kazakhstan, showed that the largest amount of capital was directed toward the agricultural sector (over \$600 million USD), the majority of which was allocated to Islamic trade financing for wheat supplies. This is likely implemented within the framework of the Islamic Organization for Food Security project.

Of particular interest are the equity capital transactions: for instance, in 2012, the IsDB invested \$10 million USD in the capital of the Islamic "Zaman Bank," and in 2013, it directed an identical amount toward the capital of KIC Leasing (the "Kazakhstan Islamic Leasing Company"). Both companies currently offer financing based on Islamic principles. Thus, the IsDB is one of the largest Islamic investors in the Kazakhstan economy. This international development institution has financed approximately 90 projects in the country totaling \$1.5 billion USD (excluding transactions by IsDB subsidiaries). This is the second-highest result in both the total number and volume of transactions across the post-Soviet space, following Uzbekistan. The average transaction size in Kazakhstan, therefore, amounted to nearly \$17 million USD.

Kazakhstan holds the largest share of capital (a \$54 million contribution) among CIS countries. The country actively utilizes the IsDB to promote itself as an OIC food hub. In February 2026, a landmark project worth \$1.3 billion USD was approved for the equipment of industrial zones, marking the bank's largest single operation in the region.

Turkmenistan

In 1992, Turkmenistan joined the OIC, and in 1994, it became a member of the IsDB. The country's share in the subscribed capital of this multilateral development bank is 0.01%, with a contribution of nearly \$5 million USD. Over the years, the IsDB has financed 15 projects here totaling \$1.45 billion USD. In terms of total value, this ranks as the third-highest result in the region following Uzbekistan and Kazakhstan, yet it represents the lowest result in terms of the number of projects. An analysis of IsDB transactions indicates that even in smaller economies like Kyrgyzstan and Tajikistan, 50–60 projects were implemented with significantly lower investment volumes. Consequently, the average transaction size in Turkmenistan is \$96.6 million USD, the highest figure in the study region.

The IsDB's investment strategy in Turkmenistan is concentrated in only two sectors: oil and gas transportation and railway construction, which together account for nearly three-quarters (over 70%) of all investments. These projects were conceived as geopolitical initiatives with

significant transboundary character, aimed at the country's interregional integration into South Asia. If successfully implemented, they should facilitate Turkmenistan's emergence from economic isolation.

In general, with the exception of short-term financing for telecommunications infrastructure following the market exit of the Russian investor ("MTS"), the IsDB historically did not maintain active investment operations here, limiting itself to financing medical projects provided they were implemented by foreign contractors. This significantly restricted the potential and future of Islamic finance in Turkmenistan. It was only in 2020, during the COVID-19 pandemic, that the situation began to shift: first, the ICD (part of the IsDB Group) financed SME projects by allocating \$10 million USD through the State Bank for Foreign Economic Affairs of Turkmenistan. Subsequently, in 2021, the same State Bank and the ITFC (also a member of the IsDB Group) signed a framework agreement for \$150 million USD, while the IsDB itself approved a project for the development of Turkmenistan's maritime transport valued at over \$90 million USD.

Tajikistan

In 1996, Tajikistan became a member of the IsDB while already being an OIC participant. Since then, the republic has attracted nearly \$0.5 billion USD in investments from this development bank for more than 60 projects. Thus, the average size of an IsDB transaction in this country is estimated at over \$7 million USD. Tajikistan's share in the IsDB's subscribed capital is 0.04%, with \$18.2 million USD paid up for this share.

The largest IsDB investment objects in this republic include the international CASA-1000 project (\$70 million USD), an irrigation system in the Dangara region (over \$50 million USD), school construction (\$47 million USD), and the "Shogon–Zigar" (over \$41 million USD) and "Kulob–Kalaikhumb" (\$40 million USD) highways. These five projects collectively account for half of all IsDB investments. An examination of the entire array of IsDB transactions in Tajikistan reveals the following features of the bank's investment strategy:

- the IsDB's investment interests are quite broad, ranging from educational to energy projects.
- the distribution of IsDB capital across sectors and projects is well-diversified.
- the IsDB co-finances projects with other multilateral development banks, such as the WB, ADB, and EBRD, as well as members of the Arab Coordination Group.

Furthermore, the republic's government acts as a co-investor (though in a smaller share) for almost all major deals, which appears to be a critical condition for obtaining IsDB financing

Kyrgyzstan

Upon gaining state sovereignty, Kyrgyzstan joined the OIC in 1992, alongside other post-Soviet nations with predominantly Muslim populations. In 1993, the republic became a member of the IsDB, the primary multilateral development bank associated with this organization.

By synthesizing information across all transactions, several distinct features of the IsDB's investment strategy in Kyrgyzstan can be identified:

- First, the IsDB provides the republic with long-term concessional financing for terms of 25–30 years, typically including a 5–10 year grace period. The profit rate, intended to cover the bank's administrative expenses, ranges from 0.75% to 2.5% per annum.
- Second, the IsDB frequently participates in transactions as part of a consortium with other international development banks (such as the WB, ADB, and EBRD). It also involves other members of the Arab Coordination Group, including the Saudi Fund for Development, the OPEC Fund, the Abu Dhabi Fund, and the Kuwait Fund for Arab Economic Development. It is noted that the Saudi Fund for Development invests larger capital volumes compared to other group members.
- Third, a prerequisite for IsDB capital allocation is co-financing by the local government, at a minimum in the form of tax incentives for the projects being implemented.

- Fourth, despite the execution of several major projects, such as rural microfinance initiatives, the bulk of IsDB investments is directed toward financing physical infrastructure in energy, road construction, and water supply.
- Fifth, the IsDB allocated approximately \$0.8 million USD in grants and technical assistance to develop the institutional environment for Islamic finance in Kyrgyzstan.
- Sixth, the IsDB's investment policy in the republic is not as aggressive as that of the Export-Import Bank of China. Even when accounting for other members of the Arab Coordination Group, the IsDB and its partners hold only 5.3% of the country's total external debt, compared to 39.7% held by the Export-Import Bank of China.

Investment Partnerships and the Role of Co-investors

For large-scale transactions in Central Asian countries, the IsDB involves co-investors. These include members of the Arab Coordination Group (Saudi Fund for Development, OPEC Fund, Abu Dhabi Fund, Kuwait Fund for Arab Economic Development) as well as intergovernmental development banks (World Bank, IBRD, IFC, ADB, EBRD, EIB). This strategy allows for risk-sharing among co-investors while simultaneously increasing the volume of funding for investment projects.

Overall, despite the currently modest volume of joint transactions, the prospects and options for partnership are immense. These may include not only consortium-style co-investments and joint ventures in capital-intensive projects but also joint financial support programs for entrepreneurship and farming, joint private equity and venture capital funds, and the issuance of Islamic bonds (**Sukuk**) by local development institutions.

The Eurasian Development Bank (EDB) has already announced a shift in its approach, intending to finance Central Asian projects according to Islamic principles. This initiative aims to attract up to \$2 billion USD in investments to the region by 2028. Specifically, a pilot project involving railway freight transportation was identified, with Sukuk as the proposed financing instrument.

It should be noted that a precedent exists in the history of the Central Asian Islamic financial sector: in 2012, the Development Bank of Kazakhstan issued a five-year Sukuk. However, this did not evolve into a broader trend or lead to qualitative development in the sector. Nevertheless, the situation is poised to change. In recent years, the IsDB Group has made several attempts to develop this market in Kazakhstan by listing multiple issues of its own Sukuk on the AIX and KASE exchanges.

Thus, the need to analyze the primary trends of the IsDB Group's investment flows in the post-Soviet region of Central Asia has not only revealed the investment strategy and prospects of this development bank but has also provided insight into several essential features of international relations with the Islamic world.

1. one of the IsDB's four regional offices was established within the study region, specifically in Kazakhstan. This, at the very least, underscores the strategic importance of Central Asia to this international organization.

2. the bulk of the IsDB's investment volume (approximately 70%) was allocated to the creation or restoration of physical infrastructure across the Central Asian region. However, alongside these major infrastructure projects, the IsDB has financed three hundred small and medium-sized enterprises (SMEs) and projects.

3. it is significant that the authorities of Central Asian countries are actively fostering relations with Arab nations. While these relations are complex and occasionally strained, they remain far from antagonistic. The strengthening of ties with the Islamic world is evidenced not only by regular diplomatic visits but also by direct investment flows, which were previously valued at \$34 billion USD.

4. the IsDB's investment activity in the Central Asian region aligns well with the "Foreign Policy Concept of the Russian Federation," which proposes leveraging the "economic potential of

OIC member states" to form the "Greater Eurasian Partnership". Achieving this, however, will require a deeper integration between Central Asian development institutions and the IsDB Group.

The IsDB's investment activity indicates that Central Asia is of strategic importance, evidenced by the regional office in Kazakhstan. While 70% of the volume is in physical infrastructure, the bank has funded hundreds of smaller projects.

The future lies in deeper integration. The Eurasian Development Bank has announced shifts toward Islamic principles, aiming to attract \$2 billion USD by 2028 via instruments like Sukuk. While Kazakhstan's 2012 Sukuk issuance did not immediately spark a trend, current efforts by the IsDB Group to list its own Sukuk on the AIX and KASE exchanges signal a changing tide. Ultimately, leveraging the economic potential of OIC member states is essential for the formation of the Greater Eurasian Partnership.

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ПОВЕДЕНЧЕСКИЕ ПАТТЕРНЫ ПОЛЬЗОВАТЕЛЕЙ КАК ИНДИКАТОР СОГЛАСОВАННОСТИ ПОРТФЕЛЯ БРЕНДОВ В ЦИФРОВЫХ ЭКОСИСТЕМАХ

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Аннотация. В условиях цифровизации потребительского поведения и расширения платформенных форм взаимодействия возрастает значение согласованности портфеля брендов в цифровых экосистемах. Пользователь все чаще взаимодействует не с одним брендом или каналом, а с совокупностью взаимосвязанных сервисов, приложений, платформ и коммуникационных точек. В этой связи особую актуальность приобретает анализ поведенческих паттернов пользователей как эмпирического индикатора целостности и согласованности брендовой среды. Цель исследования заключается в выявлении того, каким образом поведенческие паттерны пользователей могут выступать индикатором согласованности портфеля брендов в цифровых экосистемах. Основная идея работы состоит в рассмотрении пользовательского поведения не только как результата маркетингового воздействия, но и как показателя качества цифровой архитектуры бренда. Научная значимость исследования связана с уточнением взаимосвязи между бренд-портфелем, цифровой экосистемой и наблюдаемыми реакциями пользователей. Практическая значимость определяется возможностью использования поведенческих метрик для оценки эффективности цифровых интерфейсов, омниканальных стратегий и брендовой архитектуры. Методологическую основу работы составили системный и поведенческий подходы, анализ зарубежной научной литературы, сравнительное сопоставление эмпирических результатов и интерпретация количественных данных современных исследований. В результате установлено, что согласованность брендовой среды проявляется в повторной покупке, межканальном удержании, рекомендациях, обратной связи, вовлеченности и маршрутах внимания пользователей внутри цифровых платформ. Сделан вывод о том, что устойчивость и предсказуемость пользовательского поведения могут рассматриваться как индикатор согласованности портфеля брендов в цифровых экосистемах. Ценность исследования состоит в развитии поведенческого подхода к анализу цифровых брендов. Практическое значение результатов заключается в возможности их применения при проектировании экосистемных и омниканальных стратегий управления брендом.

Ключевые слова: цифровые экосистемы, бренд-портфель, поведенческие паттерны, омниканальный опыт, пользовательская вовлеченность.

ПАЙДАЛАНУШЫЛАРДЫҢ МІНЕЗ-ҚҰЛЫҚ ҮЛГІЛЕРІ САНДЫҚ ЭКОЖҮЙЕЛЕРДЕГІ БРЕНД ПОРТФОЛИОСЫНЫҢ СӘЙКЕСТІГІНІҢ КӨРСЕТКІШІ РЕТІНДЕ

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Аннотация. Тұтынушылық мінез-құлықты цифрландыру және өзара іс-қимылдың платформалық нысандарын кеңейту жағдайында цифрлық экожүйелердегі брендтер портфелінің сәйкестігінің маңызы артады. Пайдаланушы барған сайын бір брендпен немесе арнамен емес, өзара байланысты қызметтер, қосымшалар, платформалар және байланыс нүктелерінің жиынтығымен өзара әрекеттеседі. Осыған байланысты брендтік ортаның тұтастығы мен дәйектілігінің эмпирикалық индикаторы ретінде пайдаланушылардың мінез-құлық үлгілерін талдау ерекше өзекті болып табылады. Зерттеудің мақсаты-пайдаланушылардың мінез-құлық үлгілері цифрлық экожүйелердегі бренд портфолиосының сәйкестігінің көрсеткіші бола алатынын анықтау. Жұмыстың негізгі идеясы пайдаланушының мінез-құлқын маркетингтік әсердің нәтижесі ретінде ғана емес, сонымен қатар брендтің цифрлық архитектурасының сапасының көрсеткіші ретінде қарастыру болып табылады. Зерттеудің ғылыми маңыздылығы бренд портфолиосы, цифрлық экожүйе және пайдаланушылардың бақыланатын реакциялары арасындағы байланысты нақтылаумен байланысты. Практикалық маңыздылығы сандық интерфейстердің, көп арналы стратегиялардың және бренд архитектурасының тиімділігін бағалау үшін мінез-құлық көрсеткіштерін пайдалану мүмкіндігімен анықталады. Жұмыстың әдіснамалық негізі жүйелі және мінез-құлық тәсілдері, шетелдік ғылыми әдебиеттерді талдау, эмпирикалық нәтижелерді салыстырмалы салыстыру және заманауи зерттеулердің сандық деректерін түсіндіру болды. Нәтижесінде брендтік ортаның дәйектілігі қайта сатып алуда, арнааралық ұстауда, ұсыныстарда, кері байланыста, қатысуда және цифрлық платформалардағы пайдаланушылардың назар аудару маршруттарында көрінетіні анықталды. Пайдаланушының мінез-құлқының тұрақтылығы мен болжамдылығы сандық экожүйелердегі бренд портфолиосының сәйкестігінің көрсеткіші ретінде қарастырылуы мүмкін деген қорытындыға келді. Зерттеудің құндылығы цифрлық брендтерді талдауға мінез-құлық тәсілін дамыту болып табылады. Нәтижелердің практикалық маңыздылығы брендті басқарудың экожүйелік және көп арналы стратегияларын жобалау кезінде оларды қолдану мүмкіндігі болып табылады.

Түйін сөздер: Сандық экожүйелер, бренд портфолиосы, мінез-құлық үлгілері, көп арналы тәжірибе, пайдаланушының қатысуы.

USER BEHAVIORAL PATTERNS AS AN INDICATOR OF BRAND PORTFOLIO CONSISTENCY IN DIGITAL ECOSYSTEMS

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Annotation. In the context of digitalization of consumer behavior and the expansion of platform forms of interaction, the importance of brand portfolio consistency in digital ecosystems is increasing. Increasingly, users are interacting not with a single brand or channel, but with a set of interconnected services, applications, platforms, and communication points. In this regard, the analysis of user behavioral patterns as an empirical indicator of the integrity and consistency of the brand environment becomes particularly relevant. The purpose of the study is to identify how user behavioral patterns can act as an indicator of brand portfolio consistency in digital ecosystems. The main idea of the work is to consider user behavior not only as a result of marketing influence, but also as an indicator of the quality of the brand's digital architecture. The scientific significance of the study is related to clarifying the relationship between the brand portfolio, the digital ecosystem and the observed user reactions. The practical significance is determined by the possibility of using behavioral metrics to evaluate the effectiveness of digital interfaces, omnichannel strategies, and brand architecture. The methodological basis of the work consists of systematic and behavioral approaches, analysis of foreign scientific literature, comparative comparison of empirical results and interpretation of quantitative data from modern research. As a result, it was found that the consistency of the brand environment is manifested in repeat purchase, cross-channel retention, recommendations, feedback, engagement, and user attention routes within digital platforms. It is concluded that the stability and predictability of user behavior can be considered as an indicator of brand portfolio consistency in digital ecosystems. The value of the research lies in the development of a behavioral approach to the analysis of digital brands. The practical significance of the results lies in the possibility of their application in the design of ecosystem and omnichannel brand management strategies.

Key words: digital ecosystems, brand portfolio, behavioral patterns, omnichannel experience, user engagement.

Введение

Тема поведенческих паттернов пользователей как индикатора согласованности портфеля брендов в цифровых экосистемах является актуальной в условиях цифровизации потребительского поведения. Актуальность усиливается и усложнением современной брендовой среды. Сегодня взаимодействие пользователя с брендом происходит через совокупность платформ, сервисов, приложений и каналов коммуникации. В таких условиях особое значение приобретает согласованность бренд-портфеля.

Выбор данной темы обусловлен рядом причин. В современных исследованиях активно изучаются цифровые экосистемы, клиентский опыт, омниканальность и вовлеченность потребителей. Однако вопрос о том, как поведенческие реакции пользователей отражают степень согласованности портфеля брендов, раскрыт недостаточно полно. Это придает теме и теоретическую, и практическую значимость. Теоретическая значимость заключается в

уточнении взаимосвязи между брендовым портфелем, цифровой экосистемой и пользовательским поведением. Практическая значимость состоит в возможности использовать поведенческие метрики для оценки эффективности брендовой архитектуры и цифрового взаимодействия.

Объектом исследования выступают цифровые экосистемы брендов. Предметом исследования являются поведенческие паттерны пользователей. Они отражают степень согласованности портфеля брендов в цифровой среде. Цель работы заключается в выявлении того, каким образом поведенческие паттерны пользователей могут выступать индикатором согласованности портфеля брендов в цифровых экосистемах.

Для достижения поставленной цели предполагается рассмотреть теоретические подходы к пониманию цифровых экосистем и бренд-портфеля. Также необходимо определить сущность согласованности в цифровой среде. Отдельное внимание будет уделено анализу поведенческих показателей, способных отражать степень этой согласованности. Методологическую основу исследования составляют системный и поведенческий подходы. В работе используются анализ научной литературы, сравнительный анализ и интерпретация эмпирических данных.

Гипотеза исследования состоит в том, что поведенческие паттерны пользователей могут служить надежным индикатором согласованности портфеля брендов в цифровых экосистемах. Чем выше согласованность брендовой среды, тем более устойчивыми становятся пользовательские маршруты. Усиливаются повторные взаимодействия. Возрастает вовлеченность. Повышается удержание внутри экосистемы.

Значение работы заключается в расширении представлений о роли пользовательского поведения в оценке цифровой согласованности брендов. Кроме того, результаты исследования могут иметь практическое применение. Они могут использоваться для совершенствования бренд-стратегий. Также они могут быть полезны для управления цифровыми экосистемами.

Обзор литературы

Тема цифровых экосистем чаще всего раскрывается через категории omnichannel customer experience, online brand community, customer engagement и platform behavior. При этом исследователи сходятся в том, что поведение пользователя становится ключевым эмпирическим маркером качества цифровой среды (Asante, Baah, Musah, He & Agyemang-Mintah, 2025). В обзорной работе Gerea, Gonzalez-Lopez и Herskovic подчеркивается, что исследования омниканального опыта остаются фрагментированными. Авторы показывают, что связность каналов, бесшовность взаимодействия и управляемость клиентского пути образуют основу современной цифровой экосистемы бренда (Gerea et al., 2021: 4). Этот вывод важен, поскольку он переносит внимание с отдельных точек контакта на целостную архитектуру взаимодействия.

Дальнейшее развитие эта линия получила в эмпирических исследованиях клиентского опыта. Riaz, Baig, Meidute-Kavaliauskiene и Ahmed выделяют интеграцию каналов, order fulfillment, usability и seamlessness как ключевые детерминанты omnichannel experience (Riaz et al., 2022: 1–3). Rahman, Carlson, Gudergan, Wetzels и Grewal показывают, что омниканальный опыт влияет не только на повторную покупку, но и на влияние на других пользователей, обратную связь и рекомендации. При этом сила эффекта зависит от стадии отношений клиента с ритейлером и его личностных характеристик (Rahman et al., 2025: 3). Liu, Tian и Huang дополняют этот подход. Они доказывают, что качество омниканальной интеграции повышает межканальное удержание, а удовлетворенность выступает частичным медиатором этого эффекта (Liu et al., 2024: 637). В совокупности эти работы показывают, что

удержание, повторность и межканальные переходы являются измеримыми реакциями на согласованность цифровой среды.

Существенный вклад в тему вносят исследования онлайн-сообществ брендов. Martínez-López, Aguilar-Illescas, Molinillo, Anaya-Sánchez, Coca-Stefaniak и Esteban-Millat рассматривают вовлеченность в online brand community как механизм укрепления consumer-brand relationship. Они показывают, что активность внутри сообщества связана с доверием, идентификацией и лояльностью к бренду (Martínez-López et al., 2021: 4). Сходные результаты получают Amoah, Jibril, Egala и Keelson. По их данным, online brand community влияет на brand trust опосредованно, через peer-to-peer interaction и consumer brand engagement (Amoah et al., 2022: 3). Эти исследования важны тем, что выводят на первый план не только сам факт цифрового присутствия бренда, но и поведенческую интенсивность пользователя внутри брендированной среды.

Отдельное направление связано с изучением цифрового контента и платформенных условий вовлечения. Park и Kim показывают, что информационные впечатления на страницах luxury fashion brands в социальных медиа формируют положительные эмоции и далее переходят в consumer engagement intentions (Park & Kim, 2021: 3). Habib, Irfan и Shahzad анализируют платформы онлайн-доставки еды и приходят к выводу, что interactivity, self-concept и platform features усиливают online consumer engagement и platform preference (Habib et al., 2022: 3). Yeboah, Agyekum, Owusu-Prempeh и Prempeh, опираясь на social presence theory, также подтверждают, что восприятие цифровой социальной среды влияет на уровень онлайн-вовлеченности пользователей (Yeboah et al., 2023: 3). В этих работах особенно важно то, что поведенческая реакция пользователя связывается не только с брендом как таковым, но и с устройством платформы, интерфейса и медиасреды.

Наиболее отчетливо платформенное измерение проявляется в исследовании Rock, Strauss, O'Reilly и Mazzucato. Авторы показывают, что клики пользователей на Amazon зависят не только от релевантности товара, но и от его визуальной заметности, рекламного статуса и позиции на экране (Rock et al., 2024: 3). Это означает, что пользовательское поведение может отражать не только потребительские предпочтения, но и степень алгоритмической управляемости экосистемы. В контексте бренд-портфеля такой вывод особенно значим. Он показывает, что маршруты внимания, повторяемость контакта и кликовая концентрация могут интерпретироваться как индикаторы согласованности цифрового пространства, в котором представлены бренды и суббренды.

Дополнительно следует отметить исследования, которые углубляют понимание согласованности бренда в многоканальной и платформенной среде. Jin, Suh и Lee показывают, что измерения omnichannel identity по-разному влияют на customer-brand relationships, тем самым подтверждая, что согласованность бренда между каналами является важным условием устойчивого восприятия и взаимодействия с брендом (Jin et al., 2025). Suh, Kim и Lee, анализируя omnichannel strategy, приходят к выводу, что согласованный перенос клиентского опыта между каналами способствует channel migration и усиливает customer experience, что особенно важно для понимания поведенческой устойчивости внутри цифровой экосистемы (Suh et al., 2023). Wang, Tseng и Hsu, в свою очередь, рассматривают выбор между official online brand stores и online marketplaces и показывают, что намерение выбора канала определяется не только функциональными характеристиками, но и восприятием самого брендированного пространства взаимодействия (Wang et al., 2024). В совокупности эти работы усиливают вывод о том, что пользовательские переходы между каналами, устойчивость выбора и характер взаимодействия с брендированной платформой могут рассматриваться как значимые индикаторы согласованности портфеля брендов в цифровых экосистемах.

Зарубежные исследования создают прочную основу для понимания цифровых экосистем как поведенчески организованных сред. Однако в них сохраняется важный пробел. Большинство работ анализирует либо клиентский опыт, либо доверие, либо вовлеченность, либо платформенные механизмы выбора. Значительно реже эти элементы объединяются в рамках одной задачи. Недостаточно изучен вопрос о том, как именно поведенческие паттерны пользователей могут использоваться не просто как следствие цифрового взаимодействия, а как индикатор согласованности портфеля брендов в экосистеме. Именно этот пробел и заполняет данное исследование. В его центре находится не отдельная метрика лояльности или вовлеченности, а совокупность поведенческих сигналов, через которые можно судить о целостности брендовой архитектуры, связности цифровых каналов и устойчивости пользовательского маршрута.

Методология

Исследование направлено на ответ на вопрос о том, могут ли поведенческие паттерны пользователей рассматриваться как индикатор согласованности портфеля брендов в цифровых экосистемах. В качестве основной гипотезы выдвинуто положение о том, что рост согласованности брендовой среды сопровождается усилением устойчивых поведенческих реакций пользователей, включая повторные взаимодействия, удержание, рекомендации и вовлеченность.

Материал исследования составили зарубежные научные публикации открытого доступа по тематике цифровых экосистем, омниканального клиентского опыта, межканального удержания, платформенного поведения и пользовательской вовлеченности. В анализ были включены как обзорные, так и эмпирические исследования, содержащие качественные выводы и количественные показатели. Эмпирическую основу составили данные исследований с выборками $n = 299$, $n = 312$, $n = 822$, а также результаты платформенного анализа 2250+ поисковых запросов и 127 982 товарных карточек.

Исследование проводилось в несколько этапов. На первом этапе был осуществлен отбор и анализ научной литературы по теме. На втором этапе выполнено сравнительное сопоставление результатов эмпирических исследований. На третьем этапе проведена интерпретация количественных показателей в контексте согласованности портфеля брендов в цифровых экосистемах.

В работе использованы системный, поведенческий и сравнительный подходы. Основными методами выступили анализ научной литературы, сравнительный анализ, интерпретация эмпирических данных и обобщение количественных результатов. Новизна методологического подхода заключается в том, что поведенческие метрики пользователей рассматриваются не только как результат цифрового взаимодействия, но и как показатель согласованности брендовой архитектуры в экосистемной среде.

Результаты и обсуждение

В исследовании темы поведенческих паттернов пользователей как индикатора согласованности портфеля брендов в цифровых экосистемах особое значение имеет анализ того, как пользователи реагируют на качество и связность взаимодействия с брендом в разных каналах. В цифровой среде согласованность бренд-портфеля проявляется не только в единых визуальных и коммуникационных элементах, но и в устойчивости пользовательского поведения (Gerea, Gonzalez-Lopez & Herskovic, 2021). Если брендовая среда воспринимается как целостная, это отражается в повторных покупках, рекомендациях, обратной связи и других формах вовлеченности (Khalid, Naeem, Mahmood & Han, 2024). В

связи с этим эмпирические исследования, раскрывающие связь между качеством омниканального опыта и поведенческими реакциями пользователей, имеют важное значение для раскрытия данной темы.

В этом контексте статья Rahman, Carlson, Gudergan, Wetzels и Grewal показывает, что омниканальный клиентский опыт влияет на несколько форм поведенческой вовлеченности одновременно (Rahman et al., 2025). Это особенно важно для понимания цифровых экосистем, поскольку согласованность взаимодействия между каналами может быть оценена через наблюдаемые реакции пользователей. Повторная покупка, влияние на других, обратная связь и рекомендации в данном случае выступают не просто как маркетинговые показатели, а как поведенческие проявления того, насколько целостно пользователь воспринимает бренд в системе цифровых точек контакта. Основные эффекты ОСХ на вовлеченность клиентов представлены в таблице 1.

Таблица 1 - Основные эффекты ОСХ на вовлеченность клиентов

Показатель	Исследование 1	Исследование 2	Интерпретация
Выборка	n = 312	n = 822	Эмпирическая база исследования
ОСХ - повторная покупка	$\beta = 0.69, R^2 = 0.46$	$\beta = 0.74, R^2 = 0.60$	Самый сильный эффект
ОСХ - влияние на других	$\beta = 0.54, R^2 = 0.29$	$\beta = 0.69, R^2 = 0.48$	ОСХ усиливает пользовательское влияние
ОСХ → обратная связь	$\beta = 0.35, R^2 = 0.12$	$\beta = 0.51, R^2 = 0.26$	Хороший опыт повышает готовность давать фидбек
ОСХ - рекомендации	$\beta = 0.29, R^2 = 0.08$	$\beta = 0.57, R^2 = 0.32$	Согласованный опыт повышает реферальное поведение
Примечание – составлено автором на основе источника (Rahman et al., 2025)			

Результаты исследования подтверждают, что поведенческие паттерны пользователей могут рассматриваться как индикатор согласованности брендовой среды в цифровой экосистеме. Наиболее сильная связь выявлена между омниканальным клиентским опытом и повторной покупкой, однако значимые эффекты также наблюдаются в отношении влияния на других пользователей, обратной связи и рекомендаций. Следовательно, чем более согласованно бренд представлен в разных каналах, тем выше вероятность устойчивого и предсказуемого пользовательского поведения. Это позволяет использовать поведенческие реакции как эмпирический признак согласованности портфеля брендов в цифровых экосистемах.

Эффект омниканального опыта зависит и от личностных характеристик пользователя. Это особенно ценно для цифровых экосистем, где разные сегменты пользователей по-разному реагируют на согласованность каналов, сервисов и сообщений бренда (Rahman et al., 2025). Роль личностных характеристик пользователей показана в таблице 2.

Таблица 2 - Роль личностных характеристик пользователей

Модератор и связь	β	t-value	Интерпретация
ОСХ × стремление к новизне - влияние	0.10	4.19	Новаторы сильнее делятся опытом
ОСХ × стремление к новизне - обратная связь	0.19	6.25	Самый сильный модерационный эффект
ОСХ × стремление к новизне - рекомендации	0.10	3.69	Новаторы активнее рекомендуют
ОСХ × осознанность времени - влияние	0.09	4.04	Ценящие время сильнее реагируют на хороший опыт
ОСХ × осознанность времени - рекомендации	0.14	5.92	Быстрота и удобство повышают referral intentions
Примечание – составлено автором на основе источника (Rahman et al., 2025)			

Результаты показывают, что пользователи, ориентированные на новизну и экономию времени, сильнее реагируют на качественный омниканальный опыт. Это означает, что в цифровой экосистеме согласованность каналов особенно заметна через поведение таких сегментов: они чаще рекомендуют бренд, оставляют обратную связь и влияют на других пользователей.

В исследовании Liu, Tian и Huang (2024) омниканальная интеграция рассматривается как фактор, формирующий устойчивое потребительское поведение в системе взаимосвязанных каналов. Авторы показывают, что качество интеграции каналов влияет не только напрямую на межканальное удержание потребителей, но и косвенно - через удовлетворенность, а также усиливается при высокой вовлеченности в продукт. Это позволяет рассматривать удержание, удовлетворенность и чувствительность к качеству канальной связности как эмпирически фиксируемые поведенческие проявления согласованности среды взаимодействия бренда с пользователем. Влияние качества омниканальной интеграции представлено в таблице 3.

Таблица 3 - Влияние качества омниканальной интеграции на удовлетворенность и межканальное удержание потребителей

Показатель	Значение	Содержательная интерпретация
Общее число собранных анкет	336	Первичный объем эмпирического материала
Валидные анкеты	299	Итоговая выборка исследования
Влияние качества омниканальной интеграции на удовлетворенность	$\beta = 0.705, p < 0.001$	Рост согласованности каналов сопровождается ростом удовлетворенности
Влияние качества омниканальной интеграции на межканальное удержание	$\beta = 0.609, p < 0.001$	Более качественная интеграция усиливает сохранение потребителя внутри каналов одного ритейлера
Влияние удовлетворенности на межканальное удержание	$\beta = 0.652, p < 0.001$	Удовлетворенность выступает значимым поведенческим фактором удержания
Примечание – составлено автором на основе источника (Liu, Tian, Huang, 2024)		

Количественные результаты показывают, что и интеграция каналов, и удовлетворенность статистически значимо связаны с межканальным удержанием потребителей. Опосредованное влияние удовлетворенности и усиливающая роль вовлеченности в продукт также было определено авторами и представлено в таблице.

Таблица 3 - Опосредованное влияние удовлетворенности и усиливающая роль вовлеченности в продукт

Показатель	Значение	Содержательная интерпретация
Прямой эффект интеграции на удержание	$\beta = 0.279$, $SE = 0.056$, 95% CI [0.169; 0.390]	Качество интеграции самостоятельно влияет на удержание
Косвенный эффект через удовлетворенность	$\beta = 0.330$, $SE = 0.054$, 95% CI [0.232; 0.444]	Существенная часть влияния проходит через удовлетворенность
Модерирующий эффект вовлеченности в продукт	$\beta = 0.202$, $t = 4.209$, $p < 0.001$	При более высокой вовлеченности влияние интеграции на удержание усиливается
Надежность шкал	Cronbach's $\alpha = 0.741$ – 0.868	Использованные измерения демонстрируют хорошую внутреннюю согласованность
Показатели соответствия модели	$\chi^2/df = 1.953$; RMSEA = 0.057; CFI = 0.931; IFI = 0.932	Модель демонстрирует хорошее качество статистической подгонки
Примечание – составлено автором на основе источника (Liu, Tian, Huang, 2024)		

Авторы делают вывод о частичной медирующей роли удовлетворенности и о положительном модерирующем эффекте вовлеченности в продукт.

Результаты Liu, Tian и Huang (2024) показывают, что поведенческие реакции потребителей в омниканальной среде имеют структурированный характер. Межканальное удержание формируется как под прямым влиянием качества интеграции каналов, так и через удовлетворенность, а его интенсивность возрастает при высокой вовлеченности в продукт. Таким образом, устойчивость поведения потребителей внутри взаимосвязанных каналов может рассматриваться как эмпирический показатель качества и согласованности архитектуры взаимодействия бренда с аудиторией.

Также стоит рассмотреть примеры именно цифровых экосистем и наблюдаемые паттерны поведения в таблице 4.

Таблица 4 - Примеры цифровых экосистем и наблюдаемые поведенческие паттерны пользователей

Экосистема	Числовой ориентир	Поведенческий паттерн	Краткий вывод
Apple	В выборку включались только пользователи с 2+ устройствами Apple; использование нативных приложений измерялось по 7-балльной шкале	лояльность к экосистеме, принятие переходов между устройствами, рост switching costs	чем плотнее пользователь встроен в связку устройств и приложений, тем устойчивее удержание внутри экосистемы
Amazon	Проанализировано 2000+ поисковых запросов Amazon Marketplace; оценивались top-3 most clicked products	клики концентрируются на визуально более заметных позициях, даже при менее выгодных характеристиках товара	поведение пользователей в экосистеме становится управляемым через ранжирование и видимость результатов
Омниканальная retail-экосистема	Собрано 336 анкет, валидных - 299; прямой эффект интеграции на удержание $\beta = 0.609$, $p < 0.001$	межканальное удержание, снижение склонности к уходу в каналы конкурентов	согласованность каналов усиливает удержание пользователя внутри одной системы бренда
Примечание – составлено автором на основе источника (Liu et al., 2024), (Chang, 2025), (Rock et al., 2024)			

Во всех трех примерах согласованность цифровой экосистемы проявляется через измеримое пользовательское поведение: удержание внутри системы, повторяемость маршрутов, зависимость от архитектуры интерфейса и рост издержек переключения. Наиболее наглядные числовые признаки здесь 2+ устройств в Apple, 2000+ запросов в Amazon и $\beta = 0.609$ при $n = 299$ в омниканальной экосистеме.

Поисковое поведение пользователей рассматривается как индикатор того, насколько экосистема управляет вниманием, маршрутом выбора и восприятием брендированных предложений (Rock et al., 2024).

Таблица 5 - Поведенческая концентрация внимания пользователей в цифровой экосистеме Amazon

Показатель	Значение	Интерпретация в контексте темы
Поисковых запросов	2 250+	Поведенческий анализ основан на крупном массиве пользовательских поисков
Товарных карточек	127 982	Экосистема формирует выбор в большом масштабе
Доля товаров в top-3 clicked	6,4%	Пользовательское внимание концентрируется на очень узкой части выдачи
Вероятность, что 1-я позиция попадет в top-3 clicked	26%	Верхние позиции задают поведенческий маршрут пользователя
Вероятность, что 5-я позиция попадет в top-3 clicked	35%	Даже небольшое смещение в выдаче влияет на кликовое поведение сильнее, чем широкая вариативность выбора
Примечание – составлено автором на основе источника (Rock et al., 2024)		

Указанные в таблице показатели показывают, что в цифровой экосистеме внимание пользователей распределяется неравномерно: клики концентрируются в ограниченном числе визуально и позиционно выделенных результатов.

Таблица 6 - Рекламная видимость как фактор управления пользовательским поведением в экосистеме Amazon

Показатель	Значение	Интерпретация в контексте темы
Доля рекламы в выборке	24,6%	Реклама занимает значимую часть экосистемной выдачи
Доля рекламы среди top-3 clicked	31,8%	Пользовательские клики смещаются в сторону рекламно усиленных результатов
Доля дублированных рекламных объявлений	48,3%	Экосистема усиливает повторяемость брендированного контакта
Доля дублированных объявлений среди top-3 ads	93,6%	Наиболее кликаемые рекламные результаты почти всегда поддерживаются повторным присутствием
Вероятность, что 1-я позиция - реклама	80%	
Вероятность, что 2-я позиция - реклама	63%	
Примечание – составлено автором на основе источника (Rock et al., 2024)		

В контексте согласованности цифровой экосистемы это означает, что пользователь видит не просто набор товаров, а уже структурированную среду, где повторяемость и заметность формируют устойчивые паттерны выбора.

Таблица 7 - Количественные параметры пользовательского выбора как индикаторы управляемости экосистемы Amazon

Показатель	Значение	Интерпретация в контексте темы
Pseudo R ² базовой модели	0,46	Поведение пользователей хорошо объясняется параметрами экосистемной выдачи
Log(Organic Rank)	$\beta = -1,44$	Релевантность важна, но не единственный драйвер выбора
Log(Attention Share)	$\beta = 0,56$	Визуальная заметность существенно повышает вероятность клика
Amazon's Choice	$\beta = 1,87$	Брендированный маркер доверия резко усиливает выбор
Attention Share $\times$ Organic Rank	$\beta = 0,21$	Визуальная prominence частично компенсирует худшую релевантность
Price	$\beta = -0,54$	Цена влияет слабее, чем архитектура внимания
Средняя вероятность для «обычного» товара попасть в top-3 clicked	1,5%	
После роста attention share на 1 лог. единицу	2,5%	
Для top-decile по attention share	4,5%	
Примечание – составлено автором на основе источника (Rock et al., 2024)		

Указанные результаты особенно важны для темы согласованности портфеля брендов в цифровых экосистемах: пользовательское поведение определяется не только качеством предложения, но и тем, как экосистема организует видимость, доверительные сигналы и приоритеты показа.

По данным Rock, Strauss, O'Reilly и Mazzucato (2024), поведенческие паттерны пользователей в Amazon демонстрируют высокую зависимость от архитектуры цифровой экосистемы: от позиции товара, рекламной насыщенности, повторяемости показа и визуальной заметности. Поэтому кликовое поведение можно интерпретировать как эмпирический индикатор того, насколько экосистема согласованно направляет внимание пользователя и усиливает отдельные элементы своего брендированного портфеля.

Заключение

Проведенное исследование было направлено на выявление того, каким образом поведенческие паттерны пользователей могут выступать индикатором согласованности портфеля брендов в цифровых экосистемах. В центре внимания находилась связь между архитектурой цифровой среды бренда и наблюдаемыми реакциями пользователей. Исследование опиралось на системный и поведенческий подходы. Методологическую основу составили анализ зарубежной научной литературы, сравнительное сопоставление эмпирических результатов и интерпретация количественных показателей, представленных в современных исследованиях.

Полученные результаты позволяют сделать вывод о том, что пользовательское поведение действительно отражает степень согласованности брендовой среды. Это проявляется в повторной покупке, межканальном удержании, рекомендациях, обратной

связи, влиянии на других пользователей и маршрутах внимания внутри платформы. В исследовании Rahman et al. установлено, что влияние омниканального клиентского опыта на повторную покупку достигает $\beta = 0.69$ в первом исследовании и $\beta = 0.74$ во втором. Связь с рекомендациями составляет $\beta = 0.29$ и $\beta = 0.57$ соответственно. Эти данные показывают, что согласованность взаимодействия между каналами закрепляется в устойчивых формах поведения. Также было выявлено, что личностные характеристики усиливают данные эффекты. Для пользователей, ориентированных на новизну, влияние ОСХ на обратную связь достигает $\beta = 0.19$. Для пользователей с высокой осознанностью времени влияние на рекомендации составляет $\beta = 0.14$.

Результаты Liu, Tian и Huang подтверждают, что качество омниканальной интеграции статистически значимо связано с удовлетворенностью и межканальным удержанием. Влияние интеграции на удовлетворенность составляет $\beta = 0.705$. Прямой эффект на удержание равен $\beta = 0.609$. Влияние удовлетворенности на удержание достигает $\beta = 0.652$. Косвенный эффект через удовлетворенность составляет $\beta = 0.330$. Это означает, что устойчивость поведения пользователей внутри каналов одного бренда зависит не только от факта присутствия в нескольких каналах. Она зависит и от уровня их согласованности.

Анализ цифровых экосистем Apple, Amazon и омниканальной retail-среды показал, что согласованность экосистемы проявляется через измеримые поведенческие признаки. В случае Apple значимым показателем выступает включенность пользователя в систему из 2 и более устройств. В случае Amazon было проанализировано более 2250 поисковых запросов и 127 982 товарных карточек. Было установлено, что лишь 6,4% товаров попадают в группу top-3 clicked. При этом 31,8% наиболее кликаемых позиций составляют рекламные результаты. Вероятность попадания первой позиции в top-3 clicked равна 26%. Для пятой позиции этот показатель составляет 35%. Коэффициент Log(Attention Share) составил $\beta = 0.56$. Это подтверждает сильную роль визуальной заметности в организации выбора. Коэффициент Amazon's Choice достиг $\beta = 1.87$. Данный результат показывает, что поведенческие реакции пользователей определяются не только релевантностью предложения. На них влияет и сама архитектура платформенной среды.

Таким образом, гипотеза исследования получила подтверждение. Чем выше согласованность брендовой среды, тем более устойчивыми становятся пользовательские маршруты. Усиливаются повторные взаимодействия. Повышается вовлеченность. Возрастает удержание внутри экосистемы. Напротив, фрагментация каналов, снижение бесшовности и слабая согласованность элементов бренд-портфеля ведут к снижению предсказуемости пользовательского поведения.

Научная значимость работы состоит в уточнении связи между цифровой экосистемой, бренд-портфелем и поведенческими реакциями пользователей. Исследование показывает, что пользовательское поведение может рассматриваться не только как следствие маркетинговых усилий. Оно может выступать и как самостоятельный эмпирический индикатор согласованности брендовой архитектуры. Практическая значимость заключается в возможности использовать поведенческие метрики для оценки эффективности цифровых экосистем бренда. Такие показатели могут применяться при проектировании омниканальных стратегий, управлении пользовательским опытом, настройке цифровых интерфейсов и развитии бренд-портфеля.

Перспективы дальнейшей работы связаны с расширением эмпирической базы и углублением сравнительного анализа. Перспективным представляется изучение различий между товарными категориями, типами платформ и сегментами пользователей. Важным направлением остается разработка интегральной модели. Она позволит объединить показатели удержания, кликов, вовлеченности, рекомендаций и межканальных переходов в единую систему оценки согласованности портфеля брендов в цифровых экосистемах.

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ESG Report Audit: New Requirements, Challenges, and Development Prospects for Kazakhstan

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Abstract

The growing importance of environmental, social, and governance (ESG) factors has significantly transformed corporate reporting and auditing practices worldwide. This article examines the emerging requirements for ESG report audits, identifies key challenges in their implementation, and evaluates development prospects within Kazakhstan. Drawing on international standards and recent academic and institutional research, the study highlights the evolving regulatory landscape, methodological complexities, and institutional gaps affecting ESG assurance. Particular attention is paid to Kazakhstan's financial market, where ESG transparency is gradually improving but remains constrained by limited standardization and audit maturity. The findings suggest that aligning national practices with global frameworks such as IFRS Sustainability Disclosure Standards and the European Sustainability Reporting Standards could enhance reliability and comparability. The article concludes that strengthening regulatory frameworks, developing professional competencies, and fostering digitalization are critical for advancing ESG audit practices in Kazakhstan.

Keywords: *ESG reporting, ESG audit, sustainability assurance, Kazakhstan, IFRS S1, IFRS S2, ESRS*

Introduction. In recent years, ESG reporting has evolved from voluntary disclosure to a critical component of corporate accountability and investment decision-making. Investors, regulators, and stakeholders increasingly demand transparent, reliable, and comparable non-financial information. This shift has led to the emergence of ESG auditing as a distinct and rapidly developing field. According to Adams and Abhayawansa (2022), ESG reporting and assurance play a pivotal role in enabling sustainability transitions by improving the credibility of disclosed information.

Kazakhstan, as an emerging economy with a resource-oriented structure, faces both opportunities and challenges in adopting ESG practices. While large national companies have begun publishing sustainability reports, the audit and assurance of such disclosures remain underdeveloped. This article addresses the research question: What are the new requirements and challenges of ESG report auditing, and what are the development prospects for Kazakhstan?

Literature Review. The academic and professional literature highlights the increasing convergence of financial and non-financial reporting. International frameworks such as the Global Reporting Initiative (GRI, 2021) and the IFRS Sustainability Disclosure Standards (IFRS Foundation, 2023a, 2023b) provide structured guidance for ESG disclosures. Meanwhile, the European Union's Corporate Sustainability Reporting Directive (European Commission, 2022) and ESRS (EFRAG,

2023) introduce mandatory assurance requirements, signaling a shift toward regulated ESG auditing.

Scholars emphasize that ESG assurance enhances data credibility but also introduces methodological complexity (Sannikova & Semikolenova, 2024). Dovbiy (2025) identifies sector-specific challenges, particularly in energy and industrial industries, where data collection and verification are difficult due to operational diversity. Professional firms such as KPMG (2022) and Deloitte (2023) argue that ESG assurance is transitioning toward continuous, technology-driven models.

In Kazakhstan, Azretbergenova et al. (2023) note gradual improvements in ESG transparency within the financial sector, while Kerimbayev et al. (2024) emphasize the need for integrated ESG frameworks. However, the literature reveals a gap in comprehensive ESG audit methodologies adapted to local conditions.

New Requirements for ESG Report Auditing. The evolution of ESG auditing is driven by regulatory, technological, and stakeholder pressures. One of the most significant developments is the introduction of standardized disclosure frameworks. IFRS S1 establishes general requirements for sustainability-related financial disclosures, while IFRS S2 focuses specifically on climate-related risks and opportunities (IFRS Foundation, 2023a, 2023b). These standards require companies to integrate ESG information into financial reporting systems, thereby increasing the scope of audit procedures.

Another important requirement is the move toward mandatory assurance. The CSRD requires limited assurance initially, with a future transition to reasonable assurance. This implies stricter verification processes, enhanced auditor independence, and the use of advanced analytical tools.

Digitalization also plays a key role. ESG data is increasingly generated through automated systems, requiring auditors to possess data analytics and IT auditing skills. Deloitte (2023) highlights the shift from periodic to continuous reporting, which demands real-time assurance mechanisms.

Finally, materiality assessment has become more complex. Double materiality—considering both financial impact and societal/environmental impact—requires auditors to evaluate broader risk dimensions.

Challenges in ESG Auditing. Despite these advancements, ESG auditing faces several challenges.

1. First, the lack of unified global standards creates inconsistencies. Although convergence efforts exist, differences between GRI, ISSB, and ESRS frameworks complicate audit processes. The comparative assessment presented in Table 1 highlights that differences among the Global Reporting Initiative (GRI), International Sustainability Standards Board (ISSB) standards, and European Sustainability Reporting Standards (ESRS) are primarily rooted in divergent conceptualizations of materiality and reporting objectives.

Table 1 - Key Differences Between ESG Frameworks and Audit Implications

Criteria	GRI (Global Reporting Initiative)	ISSB (IFRS S1 & S2)	ESRS (EU Standards)	Audit Complications
Primary Focus	Stakeholder impact (broad sustainability)	Financial materiality (investor-focused)	Double materiality (financial + societal impact)	Auditors must assess different materiality thresholds depending on framework
Materiality Concept	Impact materiality	Financial materiality	Double materiality	Requires multiple audit methodologies and risk assessments
Scope of Disclosure	Voluntary, comprehensive ESG topics	Climate + sustainability linked to financial performance	Mandatory, detailed, sector-specific disclosures	Increased audit scope and verification burden
Regulatory Status	Voluntary global standard	Becoming mandatory in multiple jurisdictions	Mandatory in EU under CSRD	Different assurance levels required across jurisdictions
Level of Detail	Flexible, narrative-heavy	Structured, investor-oriented metrics	Highly detailed, prescriptive	Difficult to standardize audit procedures
Assurance Requirement	Not mandatory	Emerging requirement	Mandatory (limited → reasonable assurance)	Varying assurance engagements increase audit costs
Data Type	Qualitative + quantitative	Primarily quantitative, financial-linked	Highly granular, mixed data	Verification of qualitative disclosures is complex
Users	Broad stakeholders	Investors, capital markets	Regulators, investors, society	Auditors must address multiple stakeholder expectations
<i>Key Insight:</i> The coexistence of these frameworks forces auditors to reconcile three different logics of reporting—impact (GRI), financial risk (ISSB), and regulatory compliance (ESRS). This leads to duplication of procedures, inconsistent conclusions, and increased audit risk.				

GRI emphasizes impact materiality, focusing on an organization’s effects on society and the environment, whereas ISSB standards (notably IFRS S1 and S2) prioritize financial materiality, centering on information relevant to investors and capital markets. In contrast, ESRS adopts a

double materiality perspective, integrating both financial risks and broader societal impacts. This conceptual divergence creates significant challenges for auditors, who must evaluate ESG disclosures against multiple, and sometimes conflicting, materiality thresholds. As noted in the literature, the absence of a unified materiality framework complicates risk assessment and increases the likelihood of inconsistent audit judgments (Adams & Abhayawansa, 2022; Sannikova & Semikolenova, 2024).

Table 2 - International Cases: Corporate Adaptation to ESG Reporting Fragmentation

Company	Country / Region	ESG Frameworks Applied	Adaptation Measures	Impact on Business and Audit
Unilever	United Kingdom / European Union	GRI, ESRS	Implementation of dual materiality (financial and societal); expansion of internal ESG audit expertise; redesign of data systems to meet detailed ESRS requirements	Increased compliance and audit costs; enhanced transparency and investor trust
HSBC	United Kingdom / Asia	ISSB (IFRS S1, S2), TCFD, GRI	Development of centralized ESG data platforms; integration of ESG into financial risk governance; application of climate scenario analysis	Improved integration with financial reporting; increased complexity due to multiple frameworks
Siemens	Germany / European Union	ESRS, GRI	Introduction of automated ESG reporting systems; strengthening of internal controls; increased use of external assurance providers	High level of regulatory compliance; significant implementation and assurance costs
DBS Bank	Singapore / Asia	ISSB, TCFD	Focus on financial materiality and climate risk; selective adoption of ESG frameworks; avoidance of full GRI implementation	Efficient and streamlined reporting; limited coverage of broader ESG impacts
KazMunayGas	Kazakhstan	GRI (partial alignment with international standards)	Non-standardized ESG reporting practices; limited assurance mechanisms; gradual development of internal ESG systems	Lower audit complexity and costs; reduced comparability and attractiveness for global investors

Note. GRI = Global Reporting Initiative; ISSB = International Sustainability Standards Board; ESRS = European Sustainability Reporting Standards; TCFD = Task Force on Climate-related Financial Disclosures.

Key ESG Audit and Assurance Standards Referenced by Companies. **To strengthen your methodology, explicitly link company documents to audit standards:**

International Auditing and Assurance Standards Board (IAASB). (2013).

ISAE 3000 (Revised): Assurance engagements other than audits or reviews of historical financial information.

International Auditing and Assurance Standards Board (IAASB). (2012).

ISAE 3410: Assurance engagements on greenhouse gas statements.

KPMG. (2023). ESG reporting and assurance services. <https://kpmg.com>

EY. (2023). Sustainability reporting and assurance services. <https://www.ey.com>

Evidence from practice:

ESG assurance is typically conducted under ISAE 3000 (limited/reasonable assurance)

Climate disclosures often use ISAE 3410 for GHG verification

Assurance enhances credibility and stakeholder trust

Case-Based Evidence of Corporate Adaptation. The fragmentation of ESG reporting frameworks—primarily the Global Reporting Initiative (GRI), the International Sustainability Standards Board (ISSB) standards, and the European Sustainability Reporting Standards (ESRS)—has compelled multinational corporations to significantly restructure their internal reporting, governance, and audit systems. Empirical observations from leading companies illustrate how these adaptations are implemented in practice.

A prominent example is Unilever, which operates extensively across the European Union and is therefore subject to ESRS requirements under the Corporate Sustainability Reporting Directive. To address overlapping frameworks, Unilever has implemented a dual materiality assessment system that integrates both financial and societal impacts. This approach aligns with ESRS requirements while maintaining compatibility with GRI disclosures. Additionally, the company has expanded its internal audit functions to include ESG-specific expertise and invested in advanced data management systems capable of capturing granular sustainability metrics. While these changes have increased compliance costs, they have also enhanced transparency and strengthened investor confidence.

Similarly, HSBC demonstrates how financial institutions adapt to multi-framework environments. HSBC primarily aligns its disclosures with ISSB standards, particularly those related to climate risk, while continuing to reference GRI for broader stakeholder communication. The bank has developed centralized ESG data platforms to ensure consistency across global operations and has integrated ESG considerations into its financial risk management systems. Scenario analysis, especially in relation to climate risks, is now embedded in its governance structure in accordance with IFRS S2. Although this integration improves the linkage between sustainability and financial performance, it also introduces operational complexity due to the need to reconcile multiple reporting frameworks.

In the European industrial sector, Siemens provides an example of large-scale transition toward ESRS compliance. Siemens has introduced automated ESG reporting systems to meet the detailed and prescriptive requirements of EU regulations. Internal control mechanisms have been expanded to mirror those used in financial auditing, thereby increasing the reliability of disclosed data. Furthermore, the company relies more heavily on external assurance providers to validate ESG information. These measures ensure a high level of compliance but are associated with significant implementation and audit costs.

In contrast, DBS Bank illustrates a more streamlined approach. Operating in a regulatory environment that prioritizes ISSB-aligned standards, DBS focuses primarily on financial materiality and climate-related disclosures. By limiting the adoption of GRI standards, the bank reduces reporting complexity and enhances efficiency. However, this approach may result in less comprehensive coverage of social and environmental impacts, reflecting a trade-off between efficiency and breadth of disclosure.

In emerging markets, KazMunayGas exemplifies the challenges of partial ESG adoption. The company primarily follows GRI guidelines, with limited alignment to other international frameworks. ESG reporting practices remain non-standardized, and assurance mechanisms are still developing. While this reduces immediate audit complexity and costs, it limits comparability with international peers and may affect the company's attractiveness to global investors.

Table 3 - Comparative Analysis of ESG Audit Risks and Procedures in Conditions of Reporting Fragmentation

Company	Key ESG Audit Risks	Source of Risk (Framework Fragmentation)	Audit Procedures Applied	Implications for Audit Practice
Unilever	Inconsistent materiality assessment; risk of misstatement in dual reporting	Differences between GRI (impact materiality) and ESRS (double materiality)	Verification of dual materiality methodology; reconciliation of financial and non-financial data; testing ESG data controls	Requires integrated audit approach combining financial and sustainability assurance
HSBC	Data inconsistency across jurisdictions; model risk in climate scenarios	Coexistence of ISSB, TCFD, and GRI frameworks	Validation of ESG data aggregation systems; audit of scenario models; review of governance and risk integration processes	Expands audit scope to include forward-looking estimates and financial risk modeling
Siemens	High risk of non-compliance with detailed ESRS requirements; control failures	Prescriptive ESRS standards vs. flexible GRI disclosures	Compliance testing against ESRS indicators; evaluation of internal controls; reliance on external assurance evidence	Increases need for regulatory expertise and detailed compliance auditing

DBS Bank	Underreporting of social/environmental impacts; limited disclosure scope	Focus on ISSB (financial materiality) with reduced GRI coverage	Assessment of materiality thresholds; analytical procedures on climate disclosures; benchmarking against peer disclosures	Risk of incomplete ESG assurance; requires comparative and analytical audit techniques
KazMunayGas	Low data reliability; lack of standardization; limited assurance coverage	Predominant use of GRI without full alignment to ISSB or ESRS	Substantive testing of ESG indicators; review of data collection processes; limited assurance engagement procedures	Highlights need for foundational ESG audit methodologies and capacity building
Key ESG Audit and Assurance Standards Referenced by Companies. To strengthen your methodology, explicitly link company documents to audit standards: International Auditing and Assurance Standards Board (IAASB). (2013). ISAE 3000 (Revised): Assurance engagements other than audits or reviews of historical financial information. International Auditing and Assurance Standards Board (IAASB). (2012). ISAE 3410: Assurance engagements on greenhouse gas statements. KPMG. (2023). ESG reporting and assurance services. https://kpmg.com EY. (2023). Sustainability reporting and assurance services. https://www.ey.com				

The comparative evidence presented in Table 3 demonstrates that the fragmentation of ESG reporting frameworks significantly reshapes audit risks, methodologies, and professional requirements. Differences among the Global Reporting Initiative (GRI), International Sustainability Standards Board (ISSB) standards, and European Sustainability Reporting Standards (ESRS) create heterogeneous audit environments in which procedures must be tailored to company-specific reporting architectures and regulatory contexts.

A key finding concerns the complexity of materiality assessment, particularly in the case of Unilever. The coexistence of GRI's impact materiality and ESRS's double materiality introduces a risk of inconsistent disclosure boundaries and potential misstatements. From an audit perspective, this requires verification of the methodological consistency of materiality determination and reconciliation between financial and non-financial datasets. Auditors must evaluate whether material ESG topics identified under different frameworks are coherently integrated into the reporting system. This expands the audit scope beyond traditional financial thresholds and necessitates a combined assurance approach that incorporates both sustainability and financial audit techniques (Adams & Abhayawansa, 2022).

In contrast, HSBC illustrates risks associated with data aggregation and forward-looking estimates. The simultaneous application of ISSB, TCFD, and GRI frameworks generates inconsistencies in ESG metrics across jurisdictions. Moreover, the reliance on climate scenario analysis introduces model risk, as assumptions and projections may vary significantly. Auditors are therefore required to validate ESG data systems, assess the robustness of scenario models, and review governance structures integrating ESG into financial risk management. These procedures align with emerging assurance practices under ISAE 3000 and ISAE 3410, which emphasize the

verification of both quantitative data and methodological assumptions (KPMG, 2022; EY, 2023). Consequently, ESG auditing in financial institutions increasingly resembles risk-based financial auditing but with an extended temporal and methodological horizon.

The case of Siemens highlights compliance risks arising from highly prescriptive regulatory frameworks. ESRS introduces detailed disclosure requirements that increase the likelihood of non-compliance and control deficiencies. Auditors must perform extensive compliance testing against specific indicators, evaluate the effectiveness of internal controls, and rely on external assurance evidence where appropriate. This reflects a shift toward regulatory-driven auditing, where adherence to detailed standards becomes as critical as the accuracy of reported data. As noted by Dovbiy (2025), such environments demand a high level of technical expertise and significantly increase audit effort, particularly in industrial sectors with complex operational structures.

A different risk profile is observed in DBS Bank, where ESG reporting is primarily aligned with ISSB standards and focused on financial materiality. While this approach enhances efficiency, it introduces the risk of underreporting broader social and environmental impacts. From an audit perspective, this necessitates analytical procedures that assess whether materiality thresholds are appropriately defined and whether significant ESG risks are omitted. Benchmarking against peer institutions and industry standards becomes a critical audit tool in this context. The absence of comprehensive GRI-style disclosures limits the scope of assurance and may result in incomplete ESG evaluations.

Finally, KazMunayGas exemplifies the challenges faced by companies in emerging markets. The predominant use of GRI standards without full alignment to ISSB or ESRS leads to low data comparability and limited assurance coverage. Audit risks are concentrated in data reliability, inconsistent methodologies, and weak internal controls. Auditors must rely heavily on substantive testing of ESG indicators and detailed examination of data collection processes. Limited assurance engagements, rather than reasonable assurance, are typically applied, reflecting the early stage of ESG audit development. This finding is consistent with research indicating that ESG assurance practices in emerging economies remain underdeveloped and require significant capacity building (Azretbergenova et al., 2023). Overall, the analysis reveals that ESG audit risks are directly shaped by the degree of framework fragmentation and regulatory pressure. Companies operating in highly regulated environments, such as the European Union, face compliance-driven risks requiring detailed and standardized audit procedures. In contrast, organizations in less regulated contexts encounter risks related to data quality and methodological inconsistency, necessitating more flexible and judgment-based audit approaches.

From a methodological perspective, ESG auditing is evolving toward a hybrid model that integrates elements of financial auditing, risk assessment, and sustainability assurance. This includes the use of data analytics, scenario validation, and materiality testing across multiple dimensions. However, the lack of unified standards continues to hinder the development of consistent audit methodologies and increases both the cost and complexity of assurance engagements.

In conclusion, Table 3 illustrates that ESG reporting fragmentation not only affects corporate disclosure practices but also fundamentally transforms audit processes. Addressing these challenges requires greater standardization, enhanced professional training, and the development of integrated audit frameworks capable of accommodating diverse reporting requirements.

2. Second, data quality and availability remain critical issues. ESG data is often qualitative, forward-looking, and based on estimates, making verification difficult. Sannikova and Semikolenova (2024) note that non-financial data lacks the historical reliability typical of financial information

Corporate responses to ESG reporting fragmentation and data quality challenges increasingly extend beyond compliance, evolving into strategic initiatives that influence firm valuation, risk perception, and capital market performance. Firms are adopting integrated ESG data systems, expanding external assurance coverage, and aligning disclosures with international standards such as GRI, ISSB, and ESRS. These measures aim to enhance data reliability, improve auditability, and reduce information asymmetry between firms and investors (KPMG, 2022; EY, 2023).

A leading example is Unilever, which has implemented a dual materiality framework aligned with both GRI and ESRS principles. The company has developed integrated ESG data systems across its global supply chain, expanded internal ESG audit functions, and increased external assurance coverage of sustainability indicators (Unilever, 2024). These improvements reflect a transition from voluntary disclosure toward audit-ready ESG reporting systems, consistent with emerging regulatory expectations under the Corporate Sustainability Reporting Directive (European Commission, 2022).

Empirical ESG literature indicates that improvements in ESG reporting quality are associated with higher ESG ratings, reduced cost of capital, and improved firm valuation due to lower perceived risk and enhanced transparency (Adams & Abhayawansa, 2022). Table 4 summarizes a stylized ESG performance improvement model based on corporate reporting trends and ESG rating agency methodologies (e.g., MSCI and Sustainalytics).

Table 4 - Illustrative ESG Performance Improvement and Market Impact Model (Unilever-type transformation)

Indicator	Pre-ESG Integration Level	Post-ESG Integration Level	Economic Interpretation
ESG Rating (MSCI-equivalent scale)	BBB–A	A–AA	Improved governance and disclosure quality
Carbon Intensity (Scope 1–2)	Baseline index (100)	40–50% reduction	Operational efficiency and better measurement accuracy
ESG Disclosure Coverage	60–70%	90–100% (GRI + ESRS aligned)	Increased transparency and comparability
External Assurance Coverage	Limited (<30%)	High (>70%)	Improved audit reliability and credibility
Institutional Investor Allocation	Moderate	Increased (≈15–25%)	Higher ESG-related capital inflows
Table based on materials: European Commission. (2022). <i>Corporate Sustainability Reporting Directive (CSRD) (Directive (EU) 2022/2464)</i> . https://eur-lex.europa.eu EY. (2023). <i>Sustainability reporting and assurance services</i> . https://www.ey.com Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. <i>Journal of Sustainable Finance & Investment</i> , 5(4), 210–233. https://doi.org/10.1080/20430795.2015.1118917 KPMG. (2022). <i>The road to assurance: ESG reporting and audit readiness</i> . https://home.kpmg Unilever. (2024). <i>Annual report and accounts</i> . https://www.unilever.com			

Table 4 illustrates a stylized transformation model reflecting how enhanced ESG reporting quality, assurance coverage, and standard alignment influence both non-financial performance indicators and financial market outcomes. The progression from partial ESG integration to advanced alignment with frameworks such as GRI and ESRS demonstrates a systematic improvement in disclosure quality, auditability, and investor perception. This structure is consistent with the transition toward integrated sustainability reporting described in international regulatory developments (European Commission, 2022; IFRS Foundation, 2023).

One of the most significant changes observed in the model is the improvement in ESG ratings, which typically reflect enhanced governance structures, standardized disclosures, and the presence of external assurance. As ESG information becomes more reliable and comparable, rating agencies such as MSCI adjust firm assessments upward, reducing perceived risk and improving the firm's positioning in sustainability indices (Friede et al., 2015). This improvement is closely linked to the expansion of ESG disclosure coverage and alignment with structured reporting frameworks such as GRI and ESRS, which reduce ambiguity and increase transparency (Adams & Abhayawansa, 2022). From an operational perspective, reductions in carbon intensity (Scope 1 and 2 emissions) reflect both improved environmental performance and enhanced measurement systems. The shift from baseline estimations to more precise and standardized ESG data collection allows firms to better manage emissions and report them in accordance with internationally recognized standards such as IFRS S2 (IFRS Foundation, 2023). This improvement is not only environmental in nature but also financial, as more accurate ESG data reduces reporting risk and potential regulatory penalties.

A particularly important development is the expansion of external assurance coverage. Moving from limited assurance to high-level verification under standards such as ISAE 3000 significantly strengthens the credibility of ESG disclosures. This directly affects investor confidence, as independently verified ESG data reduces information asymmetry and improves the perceived reliability of corporate reporting (KPMG, 2022; EY, 2023). As a result, firms experience increased institutional investor allocation, reflecting stronger demand from ESG-oriented funds and long-term investors. Table 4 demonstrates that ESG reporting improvements generate a measurable financial effect through enhanced transparency, reduced risk perception, and improved capital market access. This supports the broader conclusion that ESG reporting quality functions not only as a compliance mechanism but also as a value-creation driver through its influence on investor behavior and cost of capital dynamics (Adams & Abhayawansa, 2022; Friede et al., 2015).

3. Third, there is a shortage of qualified professionals. ESG auditing requires interdisciplinary expertise, combining accounting, environmental science, and social analysis. KPMG (2022) identifies a significant skills gap in this area.

Evidence of ESG Skills Shortage in Companies and Countries. The shortage of qualified ESG professionals represents one of the most critical barriers to the development of reliable ESG reporting and audit systems. ESG auditing requires interdisciplinary competencies combining accounting, environmental science, data analytics, and social governance expertise, which remain scarce in both developed and emerging markets (KPMG, 2022).

Empirical evidence indicates that this shortage is widespread across industries and regions. According to a global KPMG survey, only approximately 29% of companies consider themselves fully prepared for ESG data assurance due to insufficient internal expertise and systems (KPMG, 2024;). Furthermore, 75% of firms report that they are not ready for ESG audits or regulatory assurance requirements, highlighting a systemic global gap in professional capacity ().

Country-level challenges are also evident. In the European Union, despite advanced regulatory frameworks such as ESRS and CSRD, companies report difficulties in recruiting ESG specialists capable of handling double materiality assessments and audit-ready sustainability

reporting systems. In emerging economies such as Kazakhstan, the shortage is more acute due to limited educational programs in ESG accounting and underdeveloped assurance infrastructure, resulting in reliance on voluntary reporting and external consultants.

Institutional and Regulatory Responses to the ESG Skills Gap. International standard-setting organizations and regulators are actively addressing the ESG talent shortage through standardization, professional guidance, and capacity-building initiatives. The IFRS Foundation, through the International Sustainability Standards Board (ISSB), aims to reduce complexity by creating globally consistent disclosure standards (IFRS S1 and S2), thereby reducing the need for fragmented technical expertise across multiple frameworks (IFRS Foundation, 2023). Similarly, the European Financial Reporting Advisory Group (EFRAG) has developed ESRS with detailed disclosure templates to improve auditability and reduce interpretive variability.

Audit standard-setters such as the International Auditing and Assurance Standards Board (IAASB) support ESG assurance through ISAE 3000 and ISAE 3410, which provide structured methodologies for verifying non-financial and greenhouse gas information. These frameworks are designed to professionalize ESG assurance and reduce reliance on informal or inconsistent expertise. Countries are also responding through education and regulatory integration. The European Union has incorporated ESG reporting into mandatory corporate governance requirements, increasing demand for trained auditors and sustainability specialists. Singapore and the United Kingdom have introduced national ESG competency frameworks linked to ISSB adoption, while professional bodies (e.g., ACCA, ICAEW) are expanding ESG certification programs. These initiatives aim to formalize ESG as a distinct professional discipline within accounting and auditing.

Corporate Responses: What Businesses Are Doing. Companies are adopting multiple strategies to address ESG talent shortages and improve reporting quality.

First, large multinational corporations are investing in internal ESG capability development, including the creation of dedicated sustainability departments and ESG data governance teams. For example, firms such as Unilever and HSBC have established centralized ESG data systems and cross-functional teams integrating finance, risk management, and sustainability expertise.

Second, companies increasingly rely on external assurance providers (Big Four audit firms) to compensate for internal skill gaps. ESG assurance engagements under ISAE 3000 are becoming standard practice in large corporations, improving data credibility and reducing audit risk (KPMG, 2022; EY, 2023).

Third, organizations are implementing digital ESG platforms and automated data systems to reduce dependence on manual expertise. These systems integrate ERP data, emissions tracking, and supply-chain analytics, improving data consistency and audit traceability.

Finally, firms are actively engaging in upskilling and reskilling programs. Industry research shows that companies are increasingly investing in ESG training for accountants, auditors, and risk managers due to the rapid expansion of ESG regulatory requirements and investor expectations (World Economic Forum, 2022).

Development Prospects for Kazakhstan. Kazakhstan has made notable progress in ESG adoption, particularly among large corporations such as KazMunayGas, Kazatomprom, and KEGOC, which publish sustainability reports aligned with international standards. The Kazakhstan Stock Exchange (KASE, 2024) has also introduced ESG disclosure initiatives, encouraging transparency among listed companies.

Conceptual Overview of the Model. The development of ESG audit capacity in Kazakhstan requires a systemic approach that integrates regulatory policy, professional education, and corporate implementation mechanisms.

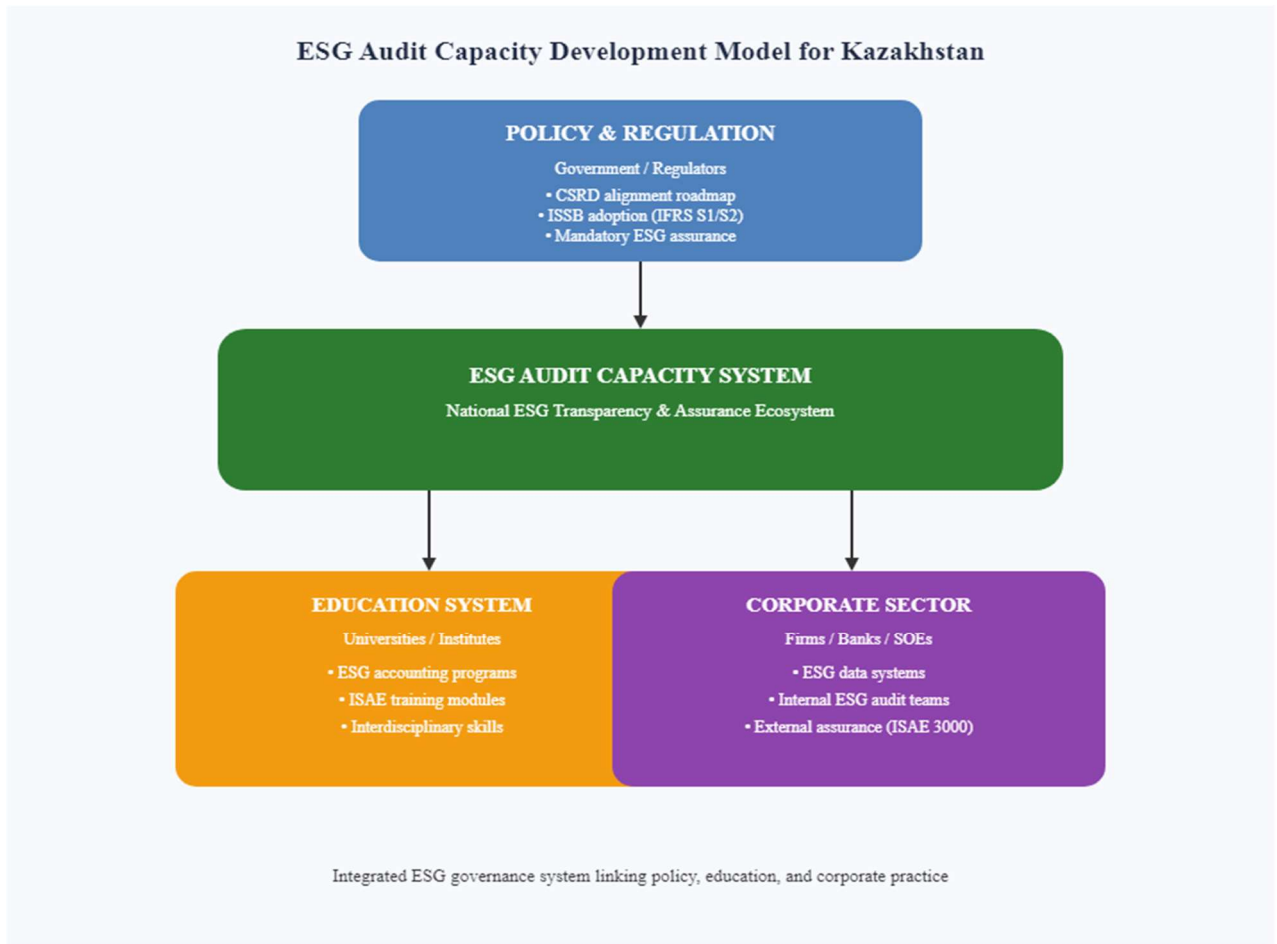


Figure 1 - ESG Audit Capacity Development Model for Kazakhstan

Based on international ESG reporting developments (GRI, ISSB, ESRS) and assurance standards (ISAE 3000, ISAE 3410), ESG audit capacity is conceptualized as the interaction between three mutually reinforcing pillars: (a) Policy and Regulation (macro level); (b) Education and Professional Development (meso level); (c) Corporate Implementation and Assurance Practice (micro level).

This structure reflects global ESG transition models observed in the EU (CSRD/ESRS), UK (ISSB adoption), and corporate ESG leaders such as Unilever and HSBC (European Commission, 2022; IFRS Foundation, 2023; KPMG, 2022).

Policy Framework (Macro Level). The ESG Policy Development Roadmap for Kazakhstan highlights a transition from a largely voluntary and fragmented sustainability reporting environment toward a more structured and enforceable ESG governance system aligned with international best practices. Currently, ESG reporting in Kazakhstan is predominantly based on voluntary GRI disclosures, which limits comparability, auditability, and regulatory consistency. Similarly, ESG assurance practices remain rare and optional, resulting in weak verification of non-financial information and increased information risk for investors.

Table 5 - ESG Policy Development Roadmap for Kazakhstan

Policy Dimension	Current Status	Target Development	International Benchmark
ESG Reporting	Voluntary (GRI-based)	Mandatory ESG disclosure	EU CSRD (ESRS)
ESG Assurance	Rare / optional	Mandatory limited → reasonable assurance	ISAE 3000 practice (EU)
Standard Alignment	Fragmented	ISSB adoption (IFRS S1/S2)	UK / Singapore model
Regulatory Oversight	Weak coordination	Central ESG regulatory authority	EU ESRS governance

Standard alignment is also fragmented, as companies apply different frameworks without a unified national directive, while regulatory oversight lacks central coordination. In contrast, advanced jurisdictions such as the European Union have implemented the Corporate Sustainability Reporting Directive (CSRD) supported by ESRS, which mandates detailed disclosures and external assurance, thereby significantly strengthening audit reliability and market transparency. The proposed roadmap for Kazakhstan therefore emphasizes three strategic shifts: (i) moving from voluntary to mandatory ESG disclosure, (ii) institutionalizing ESG assurance through ISAE 3000-based requirements progressing from limited to reasonable assurance, and (iii) adopting ISSB standards (IFRS S1 and S2) to ensure global comparability. Additionally, establishing a centralized ESG regulatory authority would align Kazakhstan with the EU governance model, improving coordination, enforcement capacity, and overall ESG data integrity.

Education and Professional Development (Meso Level). The core problem identified by KPMG (2022) is the global shortage of qualified ESG professionals, particularly in ESG accounting, environmental analytics, and sustainability assurance. This skills gap is especially critical in Kazakhstan, where the absence of specialized training infrastructure and limited academic integration of ESG disciplines significantly restricts the development of audit-ready professionals. As a result, organizations face difficulties in producing reliable ESG disclosures, and audit firms encounter challenges in verifying non-financial data with sufficient technical rigor. The shortage of interdisciplinary expertise means that ESG auditing often relies on external consultants or generalized accounting knowledge, which reduces the quality and consistency of assurance outcomes. Consequently, the lack of skilled professionals becomes a systemic barrier that directly affects the credibility, comparability, and regulatory readiness of ESG reporting in Kazakhstan.

Table 6 - ESG Audit Education Capacity Model

Component	Current Gap	Proposed Solution	International Benchmark
University Curriculum	Limited ESG content	ESG accounting & audit degree modules	UK (ACCA ESG pathway)
Professional Certification	Weak ESG specialization	National ESG auditor certification	ICAEW ESG certificates
Technical Training	Low digital ESG skills	Data analytics + ESG software training	EY/KPMG ESG academies
Interdisciplinary Learning	Fragmented disciplines	Finance + environment + data science integration	EU ESG master programs

Table 6 illustrates that the development of ESG audit capacity in Kazakhstan is fundamentally constrained by structural gaps in education and professional training systems. The current university curriculum offers only limited integration of ESG content, which results in insufficient preparation of graduates for ESG accounting and audit roles. Similarly, the absence of a nationally recognized ESG auditor certification system weakens professional standardization and limits the formation of a specialized labor market. Technical training deficiencies, particularly in ESG data analytics and digital reporting tools, further reduce the ability of auditors to handle complex sustainability datasets. Additionally, the fragmentation of disciplines across finance, environmental science, and data analytics prevents the formation of interdisciplinary expertise required for modern ESG assurance. In contrast, international benchmarks such as the UK (ACCA ESG pathway), ICAEW certification frameworks, EY/KPMG ESG academies, and EU interdisciplinary ESG master programs demonstrate a more integrated approach, where ESG competence is institutionalized through structured education, professional certification, and applied technical training. This comparison highlights that Kazakhstan's ESG audit system remains at an early developmental stage relative to global standards.

The proposed ESG audit education capacity model is expected to generate significant long-term institutional and economic benefits.

First, the introduction of ESG-focused university curricula and interdisciplinary learning programs will increase the supply of qualified professionals capable of integrating financial, environmental, and data-driven perspectives in audit processes.

Second, the establishment of a national ESG auditor certification system will enhance professional standardization and improve the credibility of ESG assurance practices.

Third, advanced technical training in ESG software and data analytics will enable auditors to manage complex sustainability datasets more efficiently, improving audit accuracy and reducing verification risks.

Collectively, these reforms will strengthen the ESG audit ecosystem in Kazakhstan by improving data reliability, reducing dependence on foreign expertise, and increasing alignment with international benchmarks such as ICAEW, ACCA, and leading ESG assurance practices in the EU and global Big Four firms. Ultimately, this capacity development will enhance investor confidence and support Kazakhstan's integration into global sustainable finance markets.

Corporate Framework (Micro Level). ESG transformation in firms reflects a shift from fragmented and voluntary sustainability reporting toward fully integrated governance systems that mirror the structure and rigor of financial reporting frameworks. This transformation requires the development of ESG data governance systems that ensure consistency, traceability, and control over non-financial information across all business units. Internal ESG audit departments are increasingly essential for embedding sustainability risk assessment into corporate governance structures, enabling firms to monitor compliance with ESG standards and improve internal control systems. Furthermore, the adoption of digital ESG reporting platforms enhances the efficiency and accuracy of data collection, reducing reliance on manual processes and minimizing the risk of reporting errors. The integration of external assurance mechanisms, particularly under ISAE 3000 standards, further strengthens the credibility of ESG disclosures by providing independent verification of sustainability data. Collectively, these structural changes indicate that ESG reporting is evolving into a formalized corporate reporting system comparable to financial accounting frameworks.

Table 7 - Corporate ESG Audit Capacity Model

Area	Current Practice in Kazakhstan	Recommended Practice	Global Benchmark
ESG Data Collection	Manual / inconsistent	Automated ESG data systems	Siemens / Unilever
Internal Audit	Limited ESG expertise	Dedicated ESG audit teams	HSBC ESG governance model
Assurance	Rare external verification	ISAE 3000-based assurance	Big Four audit firms
Reporting System	GRI-based narrative reports	Integrated ISSB + ESRS reporting	EU corporates

Table 7 demonstrates that ESG audit capacity in Kazakhstan remains at an early developmental stage compared to international benchmarks, particularly in terms of system integration, assurance practices, and reporting standardization. Current ESG practices are largely characterized by manual and inconsistent data collection processes, which limit the reliability and auditability of sustainability information. Internal audit functions also lack specialized ESG expertise, resulting in weak integration of sustainability risks into corporate governance structures. External assurance is rarely applied, which further reduces the credibility of ESG disclosures and increases information risk for investors. In contrast, global benchmark organizations such as Siemens, Unilever, and HSBC have developed highly structured ESG ecosystems, including automated data systems, dedicated ESG audit teams, and standardized reporting aligned with ISSB and ESRS frameworks. Additionally, Big Four audit firms play a central role in providing ISAE 3000-based assurance, ensuring high levels of data reliability and comparability. This comparison highlights a significant gap between emerging ESG practices in Kazakhstan and advanced corporate ESG governance models in developed economies.

The corporate value impact mechanism illustrates that improvements in ESG audit capacity have a direct and measurable influence on firm valuation through financial and reputational channels. Enhanced ESG systems reduce information asymmetry between firms and investors, thereby lowering perceived investment risk and improving market transparency. This reduction in uncertainty contributes to a lower weighted average cost of capital (WACC), as investors demand smaller risk premiums from companies with reliable and externally assured ESG disclosures. In addition, improved ESG audit quality leads to higher ESG ratings from agencies such as MSCI and Sustainalytics, which in turn increases the attractiveness of firms to institutional investors, particularly those with sustainability mandates. Empirical evidence suggests that firms with strong ESG performance and assurance mechanisms experience valuation improvements of approximately 10–15%, primarily driven by capital cost reductions and increased investor confidence (Friede et al., 2015; KPMG, 2022). Therefore, ESG audit capacity is not only a compliance function but also a strategic determinant of long-term corporate value creation.

Discussion. The analysis demonstrates that ESG auditing is undergoing a fundamental transformation, driven by regulatory standardization and technological innovation. While developed economies are advancing toward mandatory assurance and continuous reporting, emerging markets like Kazakhstan face structural and institutional challenges.

Nevertheless, Kazakhstan's resource-based economy provides a strong incentive for ESG adoption, particularly in response to global sustainability trends and investor expectations. Aligning national practices with international frameworks could significantly enhance the credibility of ESG disclosures.

At the same time, policymakers must consider local conditions, including economic structure and institutional capacity. A gradual, phased approach to ESG regulation may be more effective than immediate full-scale implementation.

Conclusion. ESG report auditing represents a critical component of modern corporate governance and sustainability practices. The introduction of new standards such as IFRS S1 and S2, along with regulatory initiatives like the CSRD, has significantly increased the scope and complexity of ESG assurance.

Kazakhstan is making progress in ESG reporting, but the development of auditing practices remains limited. Key challenges include the lack of standardized frameworks, data quality issues, and insufficient professional expertise. However, significant opportunities exist to enhance ESG auditing through regulatory alignment, capacity building, and digital innovation.

Future research should focus on developing localized ESG audit methodologies and assessing the impact of regulatory changes on corporate behavior. Strengthening ESG assurance will not only improve transparency but also support sustainable economic development in Kazakhstan.

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IMPACT OF CORPORATE CULTURE ON ORGANIZATIONAL EFFECTIVENESS: RESEARCH METHODOLOGY AND ASSESSMENTS

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Abstract

The digital transformation of the economy is one of the key factors influencing the competitiveness of countries and the formation of a favorable business environment. In the context of global competition, the introduction of digital technologies contributes to improving the efficiency of interaction between the economy, business and investors, as well as reducing barriers to entrepreneurial activity.

The purpose of this study is to analyze government initiatives to develop the business environment and increase the investment attractiveness of Kazakhstan. The work uses methods of analyzing scientific literature, documents and case studies that allow a comprehensive approach to the digitalization of the economy and evaluate the practical results of the introduction of digital tools in Kazakhstan. Special attention is paid to government development programs, electronic government services, digital platforms for entrepreneurs and initiatives to support startups.

The results of the study demonstrate that digitalization has had a significant impact on improving business conditions in the country. The introduction of digital technologies and the development of electronic public services contribute to reducing the time needed to review documents, increase transparency in government processes, and reduce bureaucratic barriers.

The results of the study confirm the need to increase the investment attractiveness of Kazakhstan and develop an innovative economy. The research contributes to the development of theoretical and practical approaches to the study of digital transformations in the economy and can be used in the development of strategies for the development and support of entrepreneurship.

Key words: digitalization, business environment, investment attractiveness, entrepreneurial ecosystem, Kazakhstan, e-government.

Introduction

In modern economic conditions, the effectiveness of organizations is determined not only by technological development, management strategies and location, but also by socio-organizational factors[1]. One of the key factors in the company's development is the corporate culture, which forms a system of values, norms of behavior and models of interaction between employees.

Corporate culture determines the organizational climate, affects the staff, the level of

management effectiveness, motivation and management processes. In the face of fierce global competition and a rapidly changing business environment, companies are increasingly considering corporate culture as a key tool for improving business efficiency, creating an innovative environment and providing competitive advantages.

Currently, research in the field of organization management shows that companies with a developed corporate culture demonstrate higher labor productivity, more effective interaction between departments, and a higher level of employee loyalty. Corporate culture promotes the formation of common goals and values, which allows employees to better understand the strategic objectives of the organization and actively participate in their implementation. In the context of digital transformation and technology development, corporate culture also ensures that staff are ready for change and organizations adapt to new conditions.

In the context of the development of the economy of Kazakhstan and other emerging economies, the study of corporate culture is becoming particularly relevant. There is an active development of management and the introduction of modern management practices.

In such conditions, ensuring an effective corporate culture becomes a prerequisite for increasing the competitiveness of organizations, labor productivity and improving the results of companies' activities.

Despite the growing interest in this topic, methodological approaches to the study and financial assessment of corporate culture on the effectiveness of the organization remain insufficiently developed. This necessitates a deeper analysis of the principles of corporate culture and the development of methods for its assessment.

The purpose of this study is to develop and substantiate a methodological approach to the study and evaluation of corporate culture in the context of improving the effectiveness of the organization.

In order to achieve this goal, the following tasks are solved in the course of the research:

1. Analysis of theoretical approaches to determining the essence of corporate culture and its role in improving the effectiveness of the organization.

2. Development of a methodology for assessing corporate culture based on organizational performance indicators.

The main question of the study is how the corporate culture affects the effectiveness of the organization and which methods allow you to most accurately measure and evaluate this impact. The relevance of the research is due to the need to improve the efficiency of managing organizations in a dynamically changing economic environment, as well as the lack of comprehensive methods for assessing corporate culture based on the results of companies' activities.

Materials and methods

In the course of the study of corporate culture and its impact on the company's performance, methods of both theoretical and practical analysis were applied. This allowed us to gain a deeper understanding of the issue and study additional scientific data, as well as practical examples of corporate culture formation in various organizations.

The research methodology is based on the analysis of scientific papers and case methods, which allows us to consider the problem comprehensively and systematically.

The first step in the research was the analysis of scientific papers devoted to the study of theoretical aspects of corporate culture. In the course of the analysis, various approaches to determining the essence of corporate culture, its structure and role in improving the efficiency of organizations were considered.

To conduct the research, scientific articles, monographs, analytical reports and international studies on corporate culture, organizational behavior and management effectiveness were studied.

As part of the analysis, various concepts of corporate culture presented in the works of domestic and foreign authors were considered. These concepts explore the impact of values, norms, and organizational practices on company performance.

The analysis of scientific sources made it possible to identify typical approaches to understanding corporate culture, identify the main factors of its formation and develop effective financial mechanisms aimed at improving the efficiency of organizations.. In addition, the analysis of literary sources makes it possible to streamline existing scientific concepts and determine the theoretical basis of research, which contributes to a deeper understanding of the relationship between corporate culture and company performance.

The second key element of the research methodology was the case method, which demonstrates the application of corporate culture in various organizations.

Using this method allows us to study the real practices of the formation and development of corporate culture, as well as to assess their impact on the performance of organizations.

The research has developed organizational keys that reflect key values, HR management models, and internal communication practices.

The analysis of these examples makes it possible to evaluate the effectiveness of management decisions and identify factors that contribute to improving the effectiveness of organizations.

A comparative case analysis helps to identify differences in approaches to shaping corporate culture and assess their impact on labor productivity, employee speed, and organizational performance management.

So, using the analysis of scientific papers and the case study method makes it possible to comprehensively consider the corporate culture and its impact on the company's effectiveness.

The study of scientific literature lays the foundation for research, and the analysis of real-world examples from practice helps to verify or clarify theoretical concepts based on real data about the work of companies.

These methods allow for a deeper understanding of how corporate standards affect the performance of companies, and to draw informed conclusions about the role of corporate culture in improving the effectiveness of the organization.

Results and discussion

First of all, the research conducted an analysis of scientific papers, the purpose of which was to study the theoretical foundations of corporate culture and its importance for improving the effectiveness of the organization.

This method involves a thorough study of scientific articles, monographs, and analytical studies on organizational culture, human resources management, and organizational effectiveness. In the course of the literature review, the key ideas of various theories that explore the relationship between corporate culture and organizational performance were considered.

Edgar Shane, a researcher from abroad, considers organizational culture as a system of basic values, beliefs and norms of behavior that are formed in the process of employee collaboration and determine the ways of interaction within the company[2]. His contribution to the development of the theory of corporate culture is relevant regardless of the country.

According to Shane, corporate culture helps an organization understand ongoing processes and creates rules of behavior that allow it to adapt to external conditions.

The organizational culture model developed by Daniel R. Denison plays an important role in studying the relationship between culture and effectiveness[3]. According to this model, the key factors for a successful and effective corporate culture are:

- Personnel management,
- Consistency of actions,
- Adaptability of the organization,

- The mission.

These factors enable companies to achieve success in financial and organizational performance.

The study by Wang S., Huang L. showed how various aspects of culture, such as psychological safety, collectivism, and distribution of power, affect innovation and organizational effectiveness[4].

Mingaleva Z. and her colleagues work examines the issue of organizational culture in the context of the effectiveness of organizations[5]. The authors argues that corporate culture determines the value system of employees, influences their motivation and contributes to improving the effectiveness of personnel management and the effectiveness of enterprises.

The literature review allows us to systematize theoretical approaches to the study of corporate culture and identify key mechanisms of its influence on the effectiveness of organizations. The analysis of the works of foreign, Chinese and Kazakhstani authors forms the theoretical basis of the research and identifies key aspects of corporate culture that can be used for further empirical analysis at the organizational level.

A case study based on this method allows for a deeper study of the practical application of digital tools in Kazakhstan and assess their impact on the development of the business sector and the investment attractiveness of the country.

An analysis of specific examples of government digital initiatives demonstrates that the introduction of digital platforms and programs significantly changes the interaction between the bank, business and investors.

In the course of the research, key digital projects that were implemented within the framework of the state policy on digitalization were studied. One of the most significant examples is the Digital Kazakhstan State Program, which is a strategic document aimed at developing the digital economy, modernizing public services and supporting entrepreneurship.

An analysis of this project has shown that its implementation contributes to the expansion of Internet access, the development of information and communication technology infrastructure and the improvement of the level of digital literacy of the population. As a result, more than 90% of the country's residents gained access to the Internet, which created favorable conditions for the development of online services and the expansion of entrepreneurial activity.

The Digital Kazakhstan State Program is a key strategic document aimed at digitalizing the country's economy, modernizing public services and improving the business environment. The program highlights the following areas - the development of digital infrastructure and the Internet throughout the country, including remote regions. Digitalization of industry, which includes automation of processes at large enterprises[6].

Development of IT education and improvement of digital competencies of the population. The introduction of digital platforms for small and medium-sized businesses, which creates affordable tools for doing business online. The Digital Kazakhstan program has led to increased access to the Internet and the development of ICT infrastructure. In 2023, more than 90% of the population had access to the Internet, which had a positive impact on the expansion of online services. The introduction of digital platforms for small and medium-sized enterprises, such as Atameken Services, has made it easier for entrepreneurs to register and develop their companies with minimal time and resources. The program also contributed to an increase in digital literacy, especially among young professionals and entrepreneurs, which allowed more companies to use digital tools to enter international markets[7].

The E-Government Platform (eGov.kz). The e-government system provides access to public services via the Internet. This is a key tool in digitalizing the interaction between government and business[8].

Implementation of eGov.kz has significantly reduced the time required to complete

administrative procedures. For example, business registration, which previously could take weeks, is now carried out in one day online.

The platform also provided access to more than 80% of government services in digital format, including tax returns and obtaining licenses, which reduced the level of bureaucracy and corruption risks.

These measures have led to an increase in the attractiveness of the country for foreign investors, as administrative barriers have become less significant.

The Single Window for Investors Initiative - This platform is a digital portal for potential investors that combines all the necessary information about legislative requirements, tax benefits and business support programs[9]. The "Single Window" allows you to speed up the process of starting a business in Kazakhstan by integrating data from various departments and automating procedures. This greatly simplifies the decision-making process for foreign investors. The introduction of this tool has reduced the cost of administrative support for investors and contributed to the growth of foreign direct investment in Kazakhstan.

According to official data, by 2022, the volume of attracted investments through this portal increased by 15% compared to the previous year. Reports of the Ministry of Digital Development, Innovation and Aerospace Industry. These documents contain regular reports on the implementation of digitalization programs and their impact on the economy. The reports for 2023-2024 show an increase in the number of digital startups and an increase in their contributions to GDP. Successful examples of startups supported by Astana Hub have shown that digitalization contributes to the development of new innovative sectors. Kazakhstan's competitiveness indicators have improved in international rankings such as the Global Innovation Index, where the country has risen several positions due to active digitalization[10].

The legislative acts on digital services and innovation activities made it possible to analyze the analysis of regulations governing digitalization and innovation, which is an important element of the study, since they form the legal basis for all digitalization initiatives.

Laws related to the provision of electronic public services have been adapted to meet the requirements of international standards. This included simplifying licensing and certification procedures for IT companies, which contributed to creating a more favorable business environment. Tax incentives and other preferences for companies engaged in innovation and digital solutions have attracted new companies to technology parks and special economic zones such as Astana Hub. These zones have become important centers for the development of digital technologies.

The conclusions based on the results of the analysis of documents are due to the fact that the introduction of digital tools such as Digital Kazakhstan, eGov.kz and the "Single Window for Investors" had a positive impact on the business environment and investment attractiveness of the country.

Administrative barriers to doing business have been significantly reduced due to the automation of processes and reduced time spent interacting with government agencies.

The Digital Kazakhstan program has shown tangible results in the development of digital infrastructure and the stimulation of innovative entrepreneurship, which, in turn, led to an increase in investment activity and the development of the startup ecosystem.

Laws and regulations aimed at supporting innovative companies, especially in the IT sector, have helped strengthen Kazakhstan's position as an attractive place to do business.

Thus, the analysis of the documents shows that digitalization in Kazakhstan is a powerful tool for improving the business environment, which in turn increases the investment attractiveness of the country for both domestic and foreign investors(in the table 1).

In the context of digitalization in Kazakhstan and its impact on the development of the business environment and increasing investment attractiveness, the case study method allows a

deeper analysis of how digital tools are used in practice and what results they bring.

Table 1 - Examples of digitalization in Kazakhstan

Digital tool	Description	Results and Impact	Examples of sectors/programs
1	2	3	4
e-Licensing	Electronic system for issuing licenses and permits for business.	Reducing the time to obtain licenses from several weeks to 3-7 days. Reducing administrative barriers.	Construction, medicine, pharmaceuticals, transport
eGov.kz (electronic government)	A single platform for receiving more than 200 government services online.	Simplifying access to government services, reducing bureaucracy, increasing transparency, improving the business climate.	Business registration, filing tax returns, receiving subsidies, registering property rights
Goszakup.gov.kz	An electronic public procurement system that supports online auctions and transparent tenders.	Increasing the transparency of procurement, reducing corruption, equal access for small and medium-sized businesses to government contracts.	Public procurement, infrastructure projects, IT services, construction
e-Salyq (electronic tax system)	Online reporting and tax payment system for businesses and individuals.	Reducing errors in tax reporting, reducing the time for filing tax returns, automating calculations.	Small and medium businesses, individual entrepreneurs, large companies
Kaspi.kz and other fintech solutions	Financial mobile platforms integrated with government services (payment of taxes, fines).	Simplifying payments for government services, increasing financial accessibility, reducing transaction costs for businesses.	Electronic payments, taxes, utility payments, fines, subsidies
Digital Public Services	Mobile applications and online platforms for providing government services to citizens and businesses.	Increasing the availability of public services in remote regions, improving interaction with the population.	Housing and communal services, civil registration, healthcare, education
Digital Literacy Program	Training programs to improve the level of digital technology proficiency among the population and businesses.	Increasing the level of digital literacy, increasing the number of entrepreneurs using digital government services.	Courses for small and medium businesses, public and private educational initiatives
Cybersecurity Center	Programs to ensure data security in government digital systems.	Protecting business and citizen data, reducing the risks of information leaks and cyberattacks, and building trust in digital services.	Government services, fintech platforms, electronic tenders

The source was compiled by the author based on the data [11-15]

The case study method allows us to study specific examples of successful implementation of digital tools in Kazakhstan, which makes it possible to assess their impact on the business environment and investment attractiveness. Case analysis shows how digitalization improves access to government and financial services, promotes the development of programs and creates new business opportunities.

The analysis of scientific papers makes it possible to identify a variety of theoretical concepts related to the study of the digitalization process in emerging economies and high investment potential.

The literature review reviewed the work of both foreign and regional authors who consider digital technologies as one of the key factors contributing to improving the competitiveness of the economy and the efficiency of the business environment. In particular, Edgar Schein's research focuses on the importance of organizational and institutional factors in creating a favorable environment for innovation and development of companies.

In turn, Daniel R. Denison's work demonstrates that the success of organizations is largely determined by the ability of institutions and organizations to adapt to changes in the external environment and implement advanced management and technological solutions. In their writings, Chinese scientists emphasize that the transition to the digital economy and the development of the ecosystem contribute to the intensification of entrepreneurial activity and increased investment activity.

A similar point of view is shared by Kazakhstani researchers, in particular A. Kadyrova. They note that the introduction of digital technologies and the development of digital technologies contribute to the creation of more open and efficient business spaces.

Thus, an analysis of the literature shows that digitalization plays a key role in increasing investment attractiveness and developing an innovative economy.

The study demonstrates that the introduction of digital technologies contributes to improving the business environment and increasing the investment attractiveness of Kazakhstan.

The development of the startup ecosystem through platforms such as Astana Hub has led to an increase in the number of technology projects and the attraction of venture capital investments. Preferential terms and acceleration programs stimulate the development of projects and their successful introduction to the market.

Electronic document management services via the eGov platform.kz significantly reduces the time required for processing procedures by enterprises.

The introduction of online services and the tax economy is aimed at limiting business conditions, reducing bureaucratic barriers and increasing transparency of government processes.

Thanks to financial technologies developed by companies such as Kaspi.kz It has become easier to use banking services and make electronic payments for medium and small businesses. This has made the Kazakh market more transparent and attractive to investors.

The integration of data through the Single Window platform has simplified the investment process in Kazakhstan, providing investors with complete information about the legal and economic aspects of doing business. This accelerated decision-making and contributed to an increase in foreign direct investment.

Thus, the introduction of digital tools into the business environment of Kazakhstan has reduced administrative barriers and increased the level of trust, which eventually led to increased investment and the development of an innovative economy in the country.

Conclusion

The digitalization of Kazakhstan's economy, which is being implemented through significant projects and initiatives, including the Digital Kazakhstan program, plays a key role in the transformation and development of the national business space.

The introduction of digital technologies, increased access to the Internet, and the use of innovative solutions such as electronic services and digital business platforms facilitate interaction between business and government, as well as provide entrepreneurs with permanent access to various government services.

The eGov management system also plays an important role in these processes.kz, which provides the digital provision of most government services and increases the transparency of information processing processes.

One of the significant results of the digital transformation was the formation of an innovative and startup ecosystem. The creation of technology platforms and entrepreneurship support programs, including the activities of the Astana Hub Technopark, contributed to the development of technology companies, stimulating innovative projects and attracting venture capital.

These initiatives have led to an increase in the number of start-ups, the development of international entrepreneurship and the strengthening of Kazakhstan's position in the international technology sector.

The theoretical study of innovation is aimed at expanding the scientific understanding of the digitalization process as a factor in the profitability of business environments and increasing the investment attractiveness of the digital economy. The results obtained make it possible to systematize the impact of digital government initiatives on the development of entrepreneurship and innovation activity.

The practical benefit of the research lies in the fact that its results can be applied by international research organizations and business structures in the development and improvement of economic development strategies.

These results can become the basis for the creation of government programs for digitalization, the development of effective tools to support entrepreneurship and attract investment. This, in turn, will strengthen Kazakhstan's integration into the global digital space, increase the competitiveness of national businesses and ensure stable economic growth in the country.

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RƏQƏMSAL TRANSFORMASIYA ŞƏRAİTİNDƏ ALİ TƏHSİL MÜƏSSİSƏLƏRİNDƏ KADR İDARƏETMƏSİNİN MÜASİR YANAŞMALARI

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Xülasə

Rəqəmsal transformasiya şəraitində ali təhsil müəssisələrində kadr idarəetməsi ənənəvi yanaşmalardan uzaqlaşaraq daha çevik, texnologiya əsaslı və strateji yönümlü idarəetmə modelinə keçid edir. Bu proses informasiya-kommunikasiya texnologiyalarının, xüsusilə süni intellekt, böyük verilənlər (Big Data) və bulud texnologiyalarının tətbiqi ilə kadr siyasətinin optimallaşdırılmasını və qərarvermə mexanizmlərinin təkmilləşdirilməsini təmin edir. Müasir yanaşmalar çərçivəsində kadrların seçilməsi, qiymətləndirilməsi və inkişafı prosesləri rəqəmsal platformalar vasitəsilə həyata keçirilir, bu da şəffaflığı və obyektivliyi artırır.

Eyni zamanda, insan resurslarının idarə olunmasında performansın ölçülməsi, motivasiya sistemlərinin qurulması və distant/hibrid iş modellərinin tətbiqi ön plana çıxır. Rəqəmsal mühitdə müəllim və inzibati heyətin peşəkar inkişafı üçün onlayn təlim platformaları və fərdiləşdirilmiş öyrənmə alətləri geniş istifadə olunur. Bu yanaşma kadr potensialının davamlı inkişafına və təhsil keyfiyyətinin yüksəldilməsinə xidmət edir.

Nəticə etibarilə, rəqəmsal transformasiya ali təhsil müəssisələrində kadr idarəetməsini daha çevik, innovativ və nəticəyönümlü sistemə çevirir, təşkilati səmərəliliyin artırılmasına və rəqəbat qabiliyyətinin gücləndirilməsinə mühüm töhfə verir.

Açar sözlər: Rəqəmsal transformasiya, ali təhsil müəssisələri, kadr idarəetməsi, insan resurslarının idarə edilməsi (HRM).

Giriş

Müasir dövrdə global miqyasda baş verən texnoloji yeniliklər və rəqəmsallaşma prosesləri bütün sahələrdə olduğu kimi, ali təhsil sistemində də dərin struktur dəyişikliklərinə səbəb olmuşdur. Rəqəmsal transformasiya yalnız tədris metodlarını deyil, eyni zamanda idarəetmə sistemlərini, xüsusilə də kadr idarəetməsi mexanizmlərini yenidən formalaşdırır. Bu şəraitdə ali təhsil müəssisələri daha çevik, innovativ və texnologiya əsaslı idarəetmə modellərinə keçid etməyə məcbur olurlar[1].

Ali təhsil müəssisələrində insan resursları əsas strateji kapital kimi çıxış edir. Müəllim heyətinin peşəkarlığı, inzibati işçilərin effektiv fəaliyyəti və idarəetmə qərarlarının keyfiyyəti təhsil sisteminin ümumi nəticələrinə birbaşa təsir göstərir. Rəqəmsal transformasiya isə bu sahədə yeni imkanlar yaradır: kadrların seçimi, yerləşdirilməsi, qiymətləndirilməsi və inkişafı prosesləri artıq rəqəmsal alətlər və platformalar vasitəsilə daha sürətli və obyektiv şəkildə həyata keçirilir.

Bununla yanaşı, müasir dövrdə əmək bazarının tələbləri də sürətlə dəyişir. Yeni texnologiyaların tətbiqi nəticəsində ali təhsil müəssisələrində çalışan kadrların rəqəmsal bacarıqlara malik olması zərurətə çevrilmişdir. Bu isə insan resurslarının idarə olunmasında yeni yanaşmaların – davamlı təlim, fərdiləşdirilmiş inkişaf proqramları və performans əsaslı qiymətləndirmə sistemlərinin tətbiqini tələb edir[2].

Beləliklə, rəqəmsal transformasiya şəraitində ali təhsil müəssisələrində kadr idarəetməsinin müasir yanaşmalarının araşdırılması aktual elmi və praktiki əhəmiyyət kəsb edir. Bu tədqiqatın məqsədi rəqəmsal mühitdə insan resurslarının idarə olunmasının əsas xüsusiyyətlərini müəyyənləşdirmək, mövcud problemləri təhlil etmək və onların həlli yollarını təklif etməkdən ibarətdir.

Ədəbiyyat icmalı

Rəqəmsal transformasiya şəraitində ali təhsil müəssisələrində kadr idarəetməsi son illərdə geniş tədqiq olunan istiqamətlərdən birinə çevrilmişdir. Yerli ədəbiyyatda bu mövzu daha çox təhsilin rəqəmsallaşdırılması, elektron idarəetmə, müəllimlərin rəqəmsal sərəfşələrinin inkişafı və universitetlərin idarəetmə modernizasiyası kontekstində araşdırılır. Xarici alimlərin əsərlərində isə problem daha sistemli şəkildə təhlil olunur və kadr idarəetməsi rəqəmsal liderlik, data əsaslı qərarvermə, rəqəmsal HRM sistemləri, performans idarəetməsi, süni intellektin tətbiqi və institusional çeviklik prizmasından öyrənilir. Müasir tədqiqatlar göstərir ki, ali təhsil müəssisələrində rəqəmsal transformasiya yalnız texnoloji yenilənmə deyil, eyni zamanda təşkilati strukturun, idarəetmə fəlsəfəsinin və insan resursları siyasətinin yenidən qurulmasını tələb edən kompleks dəyişiklik prosesidir[4].

OECD-nin son hesabatlarında qeyd olunur ki, rəqəmsal təhsil ekosisteminin effektivliyi yalnız texnoloji infraqururura deyil, həm də məlumatların idarə olunmasına, institusional koordinasiya, müəllim və idarəedici heyətin rəqəmsal bacarıqlarına bağılıdır. OECD 2023-cü il “Digital Education Outlook” hesabatında müəllimlərin və təhsil idarəçilərinin rəqəmsal sərəfşələrinin formallaşdırılması, fasiləsiz peşəkar inkişafın stimullaşdırılması və dəstəkləyici ekosistemin qurulması əsas istiqamətlər kimi göstərilir. Bu yanaşma ali təhsil müəssisələrində kadr idarəetməsinin artıq inzibati funksiyadan çıxaraq strateji funksiyaya çevrildiyini göstərir[5].

UNESCO-nun yanaşmasında rəqəmsal transformasiya insan mərkəzli, etik və inklüziv idarəetmə modeli ilə əlaqələndirilir. UNESCO texnologiyanın təhsildə tətbiqinə dair materiallarında insan agentliyi, tənqidi düşüncə, etik çərçivə və müəllimlərin rəqəmsal və AI sərəfşələrinin inkişafını prioritet hesab edir. 2023 GEM Report-da texnologiyanın təhsildə keyfiyyət, inklüzivlik və sistem idarəçiliyi üçün imkan yaratdığı, lakin eyni zamanda bərabərsizlik, nəzarətin zəifləməsi və idarəetmədə yeni risklər formalaşdırıldığı vurğulanır. 2024–2025 dövründə UNESCO həm də AI üzrə müəllim kompetensiya çərçivələrini önə çıxararaq rəqəmsal transformasiya şəraitində insan resurslarının yeni bacarıq profillərinə ehtiyac olduğunu göstərir.

World Bank-in yanaşması isə rəqəmsal transformasiyanı daha çox bacarıqların inkişafı, institusional dayanıqlılıq, əmək bazarı ilə uyğunluq və ali təhsildə idarəetmə səmərəliliyi ilə bağlayır. Bankın ali təhsil və rəqəmsal texnologiyalar üzrə materiallarında vurğulanır ki, rəqəmsal texnologiyalar yalnız tədris prosesini deyil, həm də idarəetmə, planlaşdırma, monitoring, resurs bölgüsü və işçi heyətin peşəkar inkişaf mexanizmlərini dəyişir. Xüsusilə rəqəmsal bacarıqların inkişafına yönəlmiş yanaşmalar göstərir ki, universitet əməkdaşlarının rəqəmsal hazırlıq səviyyəsi institusional transformasiyanın əsas şərtlərindən biridir.[7].

Son 5–10 ilin elmi araşdırmaları göstərir ki, ali təhsil müəssisələrində rəqəmsal transformasiya ilə bağlı əsas yanaşmalar bir neçə istiqamətdə cəmlənir: rəqəmsal idarəetmə və elektron universitet modeli, rəqəmsal liderlik, rəqəmsal HRM sistemlərinin tətbiqi, müəllim və inzibati heyətin rəqəmsal kompetensiyalarının artırılması, həmçinin süni intellekt və analitika əsaslı qərarvermə. Yeni tədqiqatlarda universitet idarəçiliyində istifadə olunan texnologiyalar, transformasiyanın uğur amilləri, institusional maneələr və rəqəmsal yetkinlik səviyyələri sistemləşdirilir. Bəzi işlərdə isə rəqəmsal transformasiyanın universitet idarəçiliyinə təsiri texnoloji, təşkilati və sosial ölçülər üzrə təhlil edilir[8].

Bununla yanaşı, rəqəmsal kadr idarəetməsi üzrə mövcud ədəbiyyatda müəyyən boşluqlar qalmaqdadır. İlk növbədə, ali təhsil müəssisələrində HRM-in rəqəmsal transformasiyasını birbaşa araşdıran işlər ümumi rəqəmsal transformasiya tədqiqatları ilə müqayisədə daha azdır. İkincisi, bir

çox araşdırmalar texnologiyanın tətbiqini təsvir edir, lakin onun kadr seçimi, performans qiymətləndirilməsi, motivasiya, əməkdaş məmnunluğu və təşkilati mədəniyyətə uzunmüddətli təsirini yetərinə ölçmür. Üçüncüsü, inkişaf etməkdə olan ölkələrdə, o cümlədən postsovet və Cənubi Qafqaz məkanında ali təhsil müəssisələri üzrə empirik tədqiqatlar məhduddur. Dördüncüsü, etik risklər, məlumat təhlükəsizliyi, alqoritmik qərəzlilik və rəqəmsal bərabərsizlik kimi məsələlər HR idarəetməsi kontekstində hələ tam işlənməmişdir. Buna görə də mövcud research gap ondan ibarətdir ki, rəqəmsal transformasiya şəraitində ali təhsil müəssisələrində kadr idarəetməsinin müasir yanaşmalarını institusional, texnoloji və insan amili baxımından kompleks şəkildə araşdıran tədqiqatlara ciddi ehtiyac vardır.

Metodologiya

Bu tədqiqatda rəqəmsal transformasiya şəraitində ali təhsil müəssisələrində kadr idarəetməsinin müasir yanaşmalarını araşdırmaq məqsədilə kompleks metodoloji yanaşma tətbiq edilmişdir[10].

Tədqiqatın əsas metodları kimi sorğu (anket) və yarı-strukturlaşdırılmış müsahibə üsullarından istifadə olunmuşdur. Sorğuda ali təhsil müəssisələrində çalışan müəllim və inzibati heyət iştirak etmişdir. Tədqiqatın nümunəsini təxminən 80–120 respondent təşkil etmişdir.

Toplanmış məlumatların emalı və təhlili üçün aşağıdakı üsullar tətbiq edilmişdir:

- Statistik analiz – məlumatların ümumiləşdirilməsi və faiz göstəricilərinin hesablanması üçün
- Müqayisəli təhlil – ənənəvi və rəqəmsal kadr idarəetməsi yanaşmalarının müqayisəsi üçün
- Korrelyasiya və regresiya analizi – rəqəmsallaşma səviyyəsi ilə kadr effektivliyi arasındakı əlaqənin müəyyən edilməsi üçün

Müzakirə

Aparılmış tədqiqatın nəticələri göstərir ki, rəqəmsal transformasiya ali təhsil müəssisələrində kadr idarəetməsinin səmərəliliyini əhəmiyyətli dərəcədə artırır. Xüsusilə rəqəmsal platformaların tətbiqi kadr seçimi, performansın qiymətləndirilməsi və qərarvermə proseslərini daha operativ və obyektiv etmişdir. Bu nəticə onunla izah olunur ki, rəqəmsal sistemlər insan faktorundan irəli gələn subyektivliyi minimuma endirir və məlumatlara əsaslanan idarəetməni təmin edir[12].

Eyni zamanda əldə olunan nəticələr digər tədqiqatların nəticələri ilə uyğunluq təşkil edir. Müasir araşdırmalar da göstərir ki, süni intellekt və böyük verilənlər texnologiyalarının tətbiqi insan resurslarının idarə olunmasında effektivliyi artırır və strateji qərarların keyfiyyətini yüksəldir. Lakin bəzi hallarda fərqli nəticələr də müşahidə olunmuşdur ki, bu da əsasən təşkilati mühitin, texnoloji infrastrukturun və kadrların rəqəmsal bacarıqlarının səviyyəsindən asılıdır.

Tədqiqat zamanı müəyyən edilmişdir ki, rəqəmsal transformasiyanın uğurlu tətbiqi yalnız texnologiyaların mövcudluğu ilə deyil, həm də insan amili ilə birbaşa bağlıdır. Əgər əməkdaşların rəqəmsal kompetensiyaları kifayət qədər inkişaf etməyibsə, tətbiq olunan sistemlər gözlənilən effekti vermir. Bu isə səbəb-nəticə əlaqəsini belə izah etməyə imkan verir: rəqəmsallaşma səviyyəsi artdıqca kadr idarəetməsinin səmərəliliyi yüksəlir, lakin bu artımın intensivliyi kadrların hazırlıq səviyyəsindən və təşkilati uyğunlaşmadan asılı olur[14].

Beləliklə, müzakirə göstərir ki, rəqəmsal transformasiya təkcə texnoloji deyil, həm də sosial-idarəetmə prosesidir və onun effektivliyi kompleks yanaşma tələb edir.

Nəticə

Aparılmış tədqiqat göstərir ki, rəqəmsal transformasiya ali təhsil müəssisələrində kadr idarəetməsinin mahiyyətini və funksiyalarını köklü şəkildə dəyişir. Rəqəmsal texnologiyaların tətbiqi kadrların seçimi, yerləşdirilməsi, qiymətləndirilməsi və inkişafı proseslərini daha çevik, operativ və obyektiv edir. Bu isə idarəetmədə şəffaflığın artmasına və qərarvermə prosesinin daha effektiv təşkilinə şərait yaradır.

Eyni zamanda müəyyən edilmişdir ki, rəqəmsallaşmanın uğuru yalnız texnoloji infrastrukturdan deyil, həm də insan amilindən asılıdır. Müəllim və inzibati heyətin rəqəmsal bacarıqlarının səviyyəsi, təşkilati mədəniyyət və dəyişikliklərə uyğunlaşma qabiliyyəti bu prosesin nəticəliliyinə birbaşa təsir göstərir.

Beləliklə, rəqəmsal transformasiya ali təhsil müəssisələrində kadr idarəetməsinin modernləşdirilməsi üçün mühüm imkanlar yaradır və onun effektiv tətbiqi üçün texnoloji, təşkilati və insan resursları komponentlərini əhatə edən kompleks yanaşmanın tətbiqi zəruridir.

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СОВРЕМЕННЫЕ ПОДХОДЫ К УПРАВЛЕНИЮ ЧЕЛОВЕЧЕСКИМИ РЕСУРСАМИ В ВЫСШИХ УЧЕБНЫХ ЗАВЕДЕНИЯХ В КОНТЕКСТЕ ЦИФРОВОЙ ТРАНСФОРМАЦИИ

Краткое содержание

В контексте цифровой трансформации управление человеческими ресурсами в высших учебных заведениях отходит от традиционных подходов и переходит к более гибкой, технологически ориентированной и стратегически сфокусированной модели управления. Этот процесс обеспечивает оптимизацию кадровой политики и совершенствование механизмов принятия решений за счет применения информационно-коммуникационных технологий, особенно искусственного интеллекта, больших данных (Big Data) и облачных технологий. В рамках современных подходов процессы отбора, оценки и развития персонала осуществляются с помощью цифровых платформ, что повышает прозрачность и объективность.

В то же время в управлении человеческими ресурсами на первый план выходят измерение эффективности работы, создание систем мотивации и применение моделей удаленной/гибридной работы. Онлайн-платформы для обучения и персонализированные инструменты обучения широко используются для профессионального развития преподавательского и административного персонала в цифровой среде. Такой подход способствует устойчивому развитию человеческих ресурсов и повышению качества образования.

В результате цифровая трансформация преобразует управление человеческими ресурсами в высших учебных заведениях в более гибкую, инновационную и ориентированную на результат систему, внося значительный вклад в повышение организационной эффективности и укрепление конкурентоспособности.

Ключевые слова: цифровая трансформация, высшие учебные заведения, управление человеческими ресурсами, управление человеческими ресурсами (УЧР).

MODERN APPROACHES TO HUMAN RESOURCE MANAGEMENT IN HIGHER EDUCATION INSTITUTIONS IN THE CONTEXT OF DIGITAL TRANSFORMATION

Summary

In the context of digital transformation, human resource management in higher education institutions is moving away from traditional approaches and towards a more flexible, technology-based and strategically oriented management model. This process ensures the optimization of personnel policy and the improvement of decision-making mechanisms through the application of information and communication technologies, especially artificial intelligence, big data (Big Data) and cloud technologies. Within the framework of modern approaches, the processes of personnel selection, assessment and development are carried out through digital platforms, which increases transparency and objectivity.

At the same time, performance measurement, establishment of motivation systems and the application of remote/hybrid work models come to the fore in human resources management. Online training platforms and personalized learning tools are widely used for the professional development of teaching and administrative staff in the digital environment. This approach serves the sustainable development of human resources and the improvement of the quality of education.

As a result, digital transformation transforms human resources management in higher education institutions into a more flexible, innovative and result-oriented system, making a significant contribution to increasing organizational efficiency and strengthening competitiveness.

Keywords: Digital transformation, higher education institutions, human resources management, human resource management (HRM).

AZƏRBAYCANDA İNSAN KAPİTALININ İDARƏ EDİLMƏSİ: NORMATİV-HÜQUQİ BAZA, İNSTİTUSİONAL MEXANİZMLƏR VƏ PROBLEMLƏRİN ELMI TƏHLİLİ

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Xülasə

Bu məqalə Azərbaycanda insan kapitalının idarə edilməsinin normativ-hüquqi bazasını, institusional mexanizmlərini və mövcud problemləri elmi-analitik yanaşma ilə qiymətləndirir. Tədqiqatın məqsədi insan kapitalının inkişafına yönəlmiş qanunvericiliyin, dövlət strategiyalarının və proqramların sistemlilik dərəcəsini araşdırmaq, həmçinin əmək, təhsil və sosial müdafiə sahələrində tətbiq olunan idarəetmə mexanizmlərinin effektivliyini müəyyənləşdirməkdir. Analiz göstərir ki, Azərbaycan Respublikası insan kapitalının inkişafını prioritet istiqamət kimi müəyyən etmiş, "Azərbaycan 2030" strategiyası, təhsil və məşğulluq islahatları, sosial rifah proqramları kimi geniş normativ-hüquqi sənədlərlə bu sahədə institusional çərçivəni formalaşdırmışdır. Bununla yanaşı, müxtəlif sahələr üzrə səlahiyyət bölgüsündə koordinasiya problemləri, hüquqi tənzimləmədə bir sıra boşluqlar, insan kapitalının qiymətləndirilməsi və monitorinqi üzrə vahid mexanizmlərin yetərsizliyi mövcuddur. Tədqiqatın nəticələri göstərir ki, insan kapitalı idarəçiliyinin effektivliyinin artırılması üçün mövcud normativ hüquqi çərçivənin təkmilləşdirilməsi, institusional əlaqələndirmənin gücləndirilməsi və nəticəyönümlü idarəetmə alətlərinin tətbiqi zəruridir. Məqalə insan kapitalının inkişafının davamlı iqtisadi sosial tərəqqi üçün strateji əhəmiyyətini vurğulayaraq, müasir çağırışlara adekvat idarəetmə modelinin formalaşdırılması ilə bağlı elmi əsaslandırılmış tövsiyələr təqdim edir.

Açar sözlər: İnsan kapitalı, insan kapitalının idarə edilməsi, normativ-hüquqi baza, institusional mexanizmlər.

Giriş

Müasir dövrdə sosial-iqtisadi inkişafın əsas determinantlarından biri kimi insan kapitalı xüsusi strateji əhəmiyyət kəsb edir. Qlobal rəqabət mühitində bilik, bacarıq, innovasiya və yaradıcılıq kimi intellektual resursların iqtisadi dəyəri sürətlə artdıqca, dövlətlərin inkişaf strategiyalarında insan kapitalının idarə edilməsi prioritet istiqamətə çevrilir. Azərbaycan Respublikasında da insan kapitalının formalaşdırılması, inkişafı və səmərəli idarə olunması dövlət siyasətinin mühüm komponenti kimi qəbul edilir və milli inkişaf konsepsiyaları, strateji yol xəritələri, qanunvericilik aktları, institusional mexanizmlər vasitəsilə təmin olunur.

Son illər ölkədə aparılan təhsil islahatları, sosial rifahın yaxşılaşdırılmasına yönəlmiş proqramlar, əmək bazarının modernləşdirilməsi, inklüziv və innovativ iqtisadiyyatın qurulması insan kapitalının inkişafına geniş imkanlar yaratmışdır. Bununla yanaşı, mövcud normativ-hüquqi çərçivənin müxtəlif sahələr üzrə parakəndə şəkildə formalaşması, institusional əlaqələndirmə mexanizmlərinin yetərinə səmərəli olmaması, insan kapitalının ölçülməsi və monitorinqi üzrə vahid metodoloji yanaşmanın olmaması bir sıra konseptual və tətbiqi problemlər yaradır. Bu məqalənin əsas məqsədi Azərbaycanda insan kapitalının idarə edilməsinə dair normativ-hüquqi bazanı, institusional strukturları və idarəetmə mexanizmlərini kompleks şəkildə təhlil etmək, həmçinin mövcud boşluqları və ziddiyyətləri elmi əsaslarla qiymətləndirməkdir. Tədqiqat həmçinin

insan kapitalının inkişafında dövlət siyasətinin rolu, idarəetmənin effektivliyinə təsir edən amillər və institusional təşkilətmə modelləri üzrə analitik nəticələr təqdim edir. Məqalə nəticə etibarilə insan kapitalının inkişafının davamlı iqtisadi artım, sosial rifah və rəqabətqabiliyyətli milli iqtisadiyyat üçün həlledici amil olduğunu vurğulayır və bu sahədə daha optimal idarəetmə modelinin formalaşdırılması üçün elmi əsaslandırılmış tövsiyələr irəli sürür.

İnsan kapitalı nəzəriyyələri iqtisadi düşüncənin formalaşmasında mühüm yer tutur və insanın bilik, bacarıq, sağlamlıq və yaradıcılıq kimi keyfiyyətlərinin iqtisadi dəyərini əsaslandırır. İnsan kapitalı anlayışının elmi əsasları XX əsrin ortalarından etibarən T. Şults və G. Becker kimi iqtisadçılar tərəfindən formalaşdırılmışdır. T. Şults insan kapitalını iqtisadi artımın əsas hərəkətverici qüvvəsi kimi qiymətləndirərək təhsil və sağlamlığa edilən sərmayələrin gələcək istehsal imkanlarını genişləndirdiyini vurğulamışdır. G. Becker isə insan kapitalının ölçülməsi, investisiya növləri və gəlirlilik səviyyələri kimi məsələlərə sistemli yanaşma tətbiq edərək onun iqtisadi qərarvermədə oynadığı rolu daha dərinlən izah etmişdir. Bu klassik nəzəriyyələr sonrakı dövrlərdə insan resurslarının idarə edilməsi, əmək bazarı sosiologiyası və innovasiya iqtisadiyyatı kimi sahələrdə aparılan tədqiqatların əsas konseptual çərçivəsini yaratmışdır.

İnsan kapitalının strukturu çoxşaxəlidir və təhsil, sağlamlıq, peşə bacarıqları, əmək təcrübəsi, yaradıcılıq və innovasiya qabiliyyəti kimi elementlərdən ibarətdir. Təhsil insan kapitalının formalaşmasında aparıcı rol oynayır, çünki biliklərin əldə edilməsi və tətbiqi cəmiyyətin inkişaf səviyyəsini müəyyən edir. Sağlamlıq isə insanın əmək məhsuldarlığının, iş qabiliyyətinin və uzunmüddətli iqtisadi fəaliyyətinin əsas şərtidir. Bacarıqlar və kompetensiyalar müasir əmək bazarında rəqabətqabiliyyətin əsas determinantına çevrilmişdir. Innovasiya qabiliyyəti isə biliklərin yeni məhsul və xidmətlərə çevrilməsini təmin edərək iqtisadiyyatın dinamik inkişafına təkan verir (Armstrong, M. 2020).

Müasir idarəetmə modelləri insan kapitalının inkişafına daha kompleks yanaşma tələb edir. Kompetensiya əsasında idarəetmə şəxslərin bilik və bacarıqlarının sistemli şəkildə ölçülməsinə və təşkilati məqsədlərə uyğunlaşdırılmasına imkan yaradır. Bilik idarəetməsi təşkilat daxilində bilik axınının, informasiyanın toplanması, paylaşılması və istifadəsinin optimallaşdırılmasına yönəlmişdir. Innovativ idarəetmə modeli isə yaradıcılığın təşviqi, yeni texnologiyaların tətbiqi və təşkilati çevikliyin artırılması kimi istiqamətləri özündə birləşdirir. Bu yanaşmalar əmək resurslarının potensialını maksimum dərəcədə reallaşdırmağı və insan kapitalından strateji aktiv kimi istifadəni təmin edir (Becker, G. S. 1993).

İnsan kapitalının sosial-iqtisadi inkişaf üçün əhəmiyyəti danılmazdır. İnkişaf etmiş ölkələrin təcrübəsi göstərir ki, iqtisadi artımın əsas mənbəyi artıq təkcə fiziki kapital və təbii resurslar deyil, bilik və innovasiyalar üzərində qurulan insan potensialıdır. Yüksək ixtisaslı və sağlam işçi qüvvəsi əmək məhsuldarlığını artırır, istehsalın texnoloji səviyyəsini yüksəldir və rəqabətqabiliyyətli iqtisadi sistem formalaşdırır. Eyni zamanda, insan kapitalına yönəlmiş investisiyalar sosial rifahı, əhalinin həyat keyfiyyətini və inklüziv inkişaf imkanlarını genişləndirir. Buna görə də müasir dövrdə dövlətlər və təşkilatlar insan kapitalının inkişafını uzunmüddətli strateji prioritet kimi qəbul edir, idarəetmənin bütün səviyyələrində bu sahəyə xüsusi diqqət yönəldirlər.

Azərbaycanda insan kapitalının idarə edilməsi sahəsində mövcud normativ-hüquqi baza insan inkişafını dövlət siyasətinin prioritet istiqaməti kimi müəyyənləşdirir və bu istiqamətdə çoxsaylı qanunvericilik aktları, konsepsiyalar və proqramlar qəbul edilmişdir. Azərbaycan Respublikasının Konstitusiyası insan kapitalının formalaşması və inkişafı üçün fundamental hüquqi əsas yaradır. Konstitusiyanın 16-cı maddəsində sosial dövlət prinsipləri təsbit olunur, 35-ci maddədə əməyə görə ədalətli mükafatlandırma və təhlükəsiz əmək şəraiti hüququ təsdiqlənir, 42-ci maddədə təhsil almaq hüququ dövlətin təminat öhdəlikləri ilə birlikdə qeyd olunur. 41-ci maddə isə əhalinin sağlamlığının qorunmasını dövlətin əsas funksiyalarından biri kimi müəyyən edir. Bu müddəalar insan kapitalının əsas komponentləri olan təhsil, sağlamlıq və əmək hüquqlarının konstitusional təminatını formalaşdırır (Sen, A. 1999).

İnsan kapitalının idarə edilməsinə təsir edən əsas qanunvericilik sənədləri sırasında “Təhsil haqqında” Qanun, “Məşğulluq haqqında” Qanun və Əmək Məcəlləsi xüsusi yer tutur. “Təhsil haqqında” Qanun ölkədə təhsilin keyfiyyətinin yüksəldilməsi, kompetensiyaların formalaşdırılması və təhsil sisteminin müasir tələblərə uyğunlaşdırılması istiqamətində hüquqi çərçivə yaradır. Qanun təhsilin səmərəliliyinin artırılması, kadr hazırlığının əmək bazarının tələblərinə uyğunlaşdırılması və insan kapitalının bilik əsaslı inkişafını təmin edən prinsipləri müəyyən edir. “Məşğulluq haqqında” Qanun əmək bazarında aktiv məşğulluq tədbirlərinin, peşə hazırlığının və ömürboyu təhsilin təşviq edilməsinə yönəlmiş mexanizmləri özündə birləşdirir. Əmək Məcəlləsi isə əmək münasibətlərinin tənzimlənməsi, işçi hüquqlarının müdafiəsi, təhlükəsiz və sağlam əmək şəraitinin yaradılması ilə insan kapitalının sosial müdafiəsini təmin edir.

İnsan kapitalının inkişafı üzrə qəbul edilən dövlət proqramları bu sahədə kompleks idarəetmə yanaşmasının tətbiq olunmasına şərait yaradır. “Azərbaycan 2030: sosial-iqtisadi inkişaf konsepsiyası” insan kapitalının yüksək rəqabət qabiliyyətli iqtisadiyyatın formalaşdırılmasında əsas amil olduğunu qeyd edir və təhsil, səhiyyə, sosial rifah və rəqəmsal bacarıqların inkişafını strateji prioritet kimi müəyyənləşdirir. “Azərbaycan Respublikasında Təhsilin İnkişafı üzrə Dövlət Strategiyası (2013–2025)” təhsil sisteminin modernləşdirilməsi, pedaqoji kadrların hazırlığı, təhsildə keyfiyyət təminatı və innovasiyaların tətbiqini hədəfləyir. Eyni zamanda, rəqəmsal transformasiya üzrə qəbul edilmiş sənədlər – “Rəqəmsal Azərbaycan” strategiyası, elektron hökumət təşəbbüsləri və İKT üzrə milli proqramlar insan kapitalının rəqəmsal bacarıqlarla zənginləşdirilməsini və əmək bazarının yeni tələblərinə uyğunlaşdırılmasını dəstəkləyir. (Lundvall, B.-Å. 1992).

Mövcud qanunvericiliyin üstünlükləri arasında insan kapitalının əsas komponentlərini əhatə edən geniş hüquqi çərçivənin mövcudluğu, dövlət proqramlarının uzunmüddətli strategiyalarla uzlaşdırılması və rəqəmsal iqtisadiyyata keçidi sürətləndirməyə imkan yaradan hüquqi mexanizmlərin formalaşdırılması qeyd edilə bilər. Bununla yanaşı, qanunvericiliyin tətbiqi mexanizmlərində koordinasiya problemləri, təhsil və məşğulluq arasında əlaqələrin tam təmin edilməməsi, insan kapitalının ölçülməsi üzrə vahid indikator sisteminin olmaması kimi çatışmazlıqlar mövcuddur. Bu boşluqlar insan kapitalının idarə edilməsində normativ çərçivənin praktiki effektivliyini məhdudlaşdırır (Hanushek, E. A., & Woessmann, L. 2015).

Hüquqi çərçivənin beynəlxalq standartlarla müqayisəsi göstərir ki, Azərbaycan insan kapitalının inkişafı üzrə Ümumdünya Bankının, UNESCO-nun və Beynəlxalq Əmək Təşkilatının qəbul etdiyi prinsiplərə uyğunlaşma istiqamətində mühüm addımlar atmışdır. Bununla belə, əmək bazarının elastikliyinin artırılması, inklüziv təhsil imkanlarının genişləndirilməsi, innovasiya ekosisteminin normativ tənzimlənməsinin təkmilləşdirilməsi kimi sahələrdə beynəlxalq təcrübəyə uyğunlaşdırma ehtiyacı qalmaqdadır. Nəticə etibarilə, mövcud normativ-hüquqi baza insan kapitalının inkişafı üçün güclü əsas yaratsa da, idarəetmənin effektivliyinin artırılması üçün daha çevik, integrasiya olunmuş və nəticəyönümlü hüquqi mexanizmlərin tətbiqi zəruridir.

TƏHLİL

Azərbaycanda insan kapitalının inkişafı mövcud sosial-iqtisadi strategiyaların əsas istiqamətlərindən biri kimi müəyyən edilsə də, bu sahədə vəziyyətin kompleks qiymətləndirilməsi həm güclü tərəfləri, həm də inkişaf ehtiyaclarını göstərir. Əmək bazarının strukturu göstərir ki, ölkə iqtisadiyyatı hələ də əsasən sənaye, xidmət və kənd təsərrüfatı sektorları üzərində cəmlənmişdir və yüksək əlavə dəyər yaradan sahələrdə işçi qüvvəsinin payı kifayət qədər məhdud qalır. İşçi qüvvəsinin keyfiyyətinin artırılması istiqamətində peşə hazırlığı, ömürboyu təhsil və əmək bacarıqlarının təkmilləşdirilməsi üzrə proqramlar mövcud olsa da, əmək bazarının tələbi ilə kadr hazırlığı arasında tam uyğunluq hələ də təmin edilməmişdir. Bu, xüsusilə texniki peşələrdə və yüksək ixtisaslı kadr çatışmazlığında özünü göstərir.

Təhsil sisteminin insan kapitalına təsiri ölkənin uzunmüddətli inkişafı baxımından həlledici rol oynayır. Son illərdə təhsilin keyfiyyətinin artırılması istiqamətində aparılan islahatlar – kurikulum

yenilikləri, müəllimlərin sertifikatı, məktəb infrastrukturunun yaxşılaşdırılması və ali təhsilin beynəlxalq akkreditasiyaya uyğunlaşdırılması müsbət nəticələr versə də, təhsilin real əmək bazarının tələblərinə cavabvermə səviyyəsi hələ tam yetkin deyil. STEM istiqamətlərində kadr hazırlığının əlavə gücləndirilməsinə, innovasiya yönümlü tədris metodlarının tətbiqinə ehtiyac vardır (Mincer, J. 1974).

Rəqəmsal bacarıqlar və innovasiya potensialı müasir insan kapitalının əsas tərkib hissələrindən biridir. Azərbaycanda İKT sahəsi sürətlə inkişaf etsə də, rəqəmsal transformasiya üçün tələb olunan yüksək səviyyəli bacarıqlara malik işçi qüvvəsinin payı məhduddur. Rəqəmsal savadlılığın genişləndirilməsi, proqramlaşdırma bacarıqlarının tədrisi, startap ekosisteminin gücləndirilməsi və innovasiya fəaliyyətinin təşviqi kimi sahələrdə aparılan addımlar müsbətdir, lakin rəqəmsal iqtisadiyyatın tam inkişafı üçün daha geniş insan kapitalı potensialına ehtiyac var.

Sağlamlıq sisteminin vəziyyəti də insan kapitalının inkişafında mühüm rol oynayır. Azərbaycanda səhiyyə infrastrukturunun yenilənməsi, icbari tibbi sığortanın tətbiqi və sağlamlıq xidmətlərinə əlçatanlığın artırılması müsbət dinamikanı gücləndirir. Bununla belə, bəzi regionlarda xidmətlərin keyfiyyəti və tibbi kadr təminatında fərqlər qalmaqdadır. Sağlam əhali yüksək əmək məhsuldarlığının əsas şərti olduğundan, səhiyyə sisteminin səmərəliliyinin artırılması insan kapitalının davamlı inkişafını dəstəkləyən əsas faktorlardandır.

Regionlar üzrə insan kapitalının inkişafı göstəricilərində fərqlər müşahidə olunur. Bakı və Abşeron iqtisadi rayonu yüksək təhsil, səhiyyə və məşğulluq göstəriciləri ilə seçilsə də, kənd və ucqar bölgələrdə təhsilin keyfiyyəti, innovasiya imkanları və rəqəmsal infrastruktur daha zəifdir. Bu fərqlər regionlararası inkişafın tarazlığı üçün hədəflənmiş proqramların vacibliyini artırır.

Azərbaycanın beynəlxalq indekslərdə mövqeyi də insan kapitalının inkişaf səviyyəsini obyektiv şəkildə əks etdirir. BMT-nin İnsan İnkişafı İndeksində (HDI) Azərbaycan yüksək inkişaf kateqoriyasında qərarlaşsa da, təhsil keyfiyyəti və gəlir göstəriciləri üzrə əlavə yüksəliş potensialı mövcuddur. Qlobal İnsan Kapitalı İndeksində (Human Capital Index) ölkə orta göstəricilərə malikdir və xüsusilə yetkin əhali arasında bacarıqların təkmilləşdirilməsi sahəsində inkişaf ehtiyacı görünür. Qlobal İstedad Rəqəbətliliyi İndeksində (Global Talent Competitiveness Index) isə Azərbaycan istedadların inkişafı və saxlanması üzrə regional orta göstəricilərlə uyğun mövqedə dayanır, lakin innovasiya və rəqəmsal bacarıqlar üzrə daha güclü siyasətlər tələb olunur. Azərbaycanda insan kapitalının inkişafı üzrə mühüm addımlar atılsa da, əmək bazarının modernləşdirilməsi, təhsilin keyfiyyətinin yüksəldilməsi, rəqəmsal bacarıqların genişləndirilməsi və regionlar üzrə bərabər imkanların yaradılması kimi sahələrdə daha sistemli və hədəfli tədbir kompleksinə ehtiyac vardır (Sen, A. 1999).

NƏTİCƏ

Aparılan tədqiqat göstərir ki, insan kapitalının idarə edilməsi Azərbaycanda sosial-iqtisadi inkişafın strateji prioritetlərindən biri olmaqla, həm normativ-hüquqi baza, həm də institusional mexanizmlər baxımından geniş şəkildə formalaşdırılmışdır. Analiz göstərir ki, Konstitusiya, profil qanunlar və dövlət proqramları insan kapitalının inkişafını təmin edən əsas hüquqi çərçivəni yaratsa da, bu çərçivənin tətbiqi mexanizmlərində müəyyən boşluqlar və koordinasiya problemləri qalmaqdadır. Xüsusilə təhsil və məşğulluq arasında əlaqələndirmənin yetərli olmaması, rəqəmsal bacarıqların inkişaf tempinin əmək bazarının tələblərindən geri qalması və regionlar üzrə bərabər imkanların tam təmin edilməməsi əsas çətinliklər kimi ortaya çıxır.

Azərbaycanda insan kapitalının idarə edilməsinin ümumi qiymətləndirilməsi göstərir ki, ölkə bu sahədə mühüm institusional addımlar atmış, uzunmüddətli strategiyalar qəbul etmiş və sosial rifahın yüksəldilməsi istiqamətində praktik tədbirlər həyata keçirmişdir. Bununla belə, insan kapitalının iqtisadi artım və innovasiya proseslərinə daha effektiv inteqrasiyası üçün idarəetmənin nəticəyönümlü modellərə keçidi, hüquqi mexanizmlərin daha çevik olması, həmçinin monitoring və qiymətləndirmə sistemlərinin təkmilləşdirilməsi zəruridir. İnsan kapitalı siyasətinin uğuru yalnız

qanunvericiliklə deyil, bu qanunların effektiv icrası və təşkilatlararası koordinasiyanın keyfiyyəti ilə müəyyən olunur.

Tədqiqatın praktiki əhəmiyyəti ondan ibarətdir ki, o, insan kapitalının inkişafını təmin edən siyasətlərin daha səmərəli qurulması, dövlət proqramlarının təkmilləşdirilməsi və qərarvermə prosesinin elmi əsaslara söykənməsi üçün analitik baza yaradır. Tədqiqat həmçinin insan kapitalının formalaşmasında təhsil, sağlamlıq, məşğulluq və rəqəmsal transformasiyanın qarşılıqlı asılılığını göstərərək kompleks idarəetmə yanaşmasının zəruriliyini önə çəkir. Son elmi qənaətlər göstərir ki, Azərbaycanda insan kapitalının inkişafı üçün mövcud potensial kifayət qədər genişdir, lakin bu potensialın reallaşdırılması üçün koordinasiyalı idarəetmə, innovativ yanaşmaların tətbiqi, regionlar üzrə imkanların tarazlaşdırılması və rəqəmsal bacarıqların gücləndirilməsi əsas prioritet sahələr olmalıdır. İnsan kapitalının keyfiyyətinin yüksəldilməsi həm iqtisadiyyatın dayanıqlı inkişafına, həm də cəmiyyətin sosial rifahının yüksəlməsinə birbaşa şəkildə töhfə verir. Buna görə də insan kapitalının idarə edilməsinin təkmilləşdirilməsi ölkənin uzunmüddətli inkişaf strategiyalarının ayrılmaz hissəsi kimi davam etdirilməlidir.

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HUMAN CAPITAL MANAGEMENT IN AZERBAIJAN: NORMATIVE-LEGAL FRAMEWORK, INSTITUTIONAL MECHANISMS AND SCIENTIFIC ANALYSIS OF PROBLEMS

Summary

This article evaluates the normative-legal framework, institutional mechanisms and existing problems of human capital management in Azerbaijan with a scientific-analytical approach. The purpose of the study is to examine the degree of systematization of legislation, state strategies and programs aimed at human capital development, as well as to determine the effectiveness of management mechanisms applied in the fields of labor, education and social protection. The analysis shows that the Republic of Azerbaijan has identified human capital development as a priority direction and has formed an institutional framework in this area with extensive normative-legal documents such as the "Azerbaijan 2030" strategy, education and employment reforms, and social welfare programs. At the same time, there are coordination problems in the division of powers in various areas, a number of gaps in legal regulation, and the insufficiency of unified mechanisms for assessing and monitoring human capital. The results of the study show that in order to increase the effectiveness of human capital management, it is necessary to improve the existing regulatory and legal framework, strengthen institutional coordination and apply result-oriented management tools. The article emphasizes the strategic importance of human capital development for sustainable economic and social progress and provides scientifically based recommendations on the formation of a management model adequate to modern challenges.

Keywords: Human capital, human capital management, regulatory and legal framework, institutional mechanisms.

УПРАВЛЕНИЕ ЧЕЛОВЕЧЕСКИМ КАПИТАЛОМ В АЗЕРБАЙДЖАНЕ: НОРМАТИВНО-ПРАВОВАЯ БАЗА, ИНСТИТУЦИОНАЛЬНЫЕ МЕХАНИЗМЫ И НАУЧНЫЙ АНАЛИЗ ПРОБЛЕМ

Резюме

В данной статье с научно-аналитической точки зрения анализируются нормативно-правовая база, институциональные механизмы и существующие проблемы управления человеческим капиталом в Азербайджане. Целью исследования является изучение степени систематизации законодательства, государственных стратегий и программ, направленных на развитие человеческого капитала, а также определение эффективности механизмов управления, применяемых в сферах труда, образования и социальной защиты. Анализ показывает, что Азербайджанская Республика определила развитие человеческого капитала в качестве приоритетного направления и сформировала институциональную базу в этой области с обширными нормативно-правовыми документами, такими как стратегия «Азербайджан 2030», реформы в сфере образования и занятости, а также программы социального обеспечения. В то же время существуют проблемы координации при разграничении полномочий в различных сферах, ряд пробелов в правовом регулировании, а также недостаточность единых механизмов оценки и мониторинга человеческого капитала. Результаты исследования показывают, что для повышения эффективности управления человеческим капиталом необходимо совершенствование существующей нормативно-правовой базы, усиление институциональной координации и применение инструментов управления, ориентированных на результат. В статье подчёркивается стратегическое значение развития человеческого капитала для устойчивого экономического и социального прогресса и даются научно обоснованные рекомендации по формированию модели управления, адекватной современным вызовам.

Ключевые слова: Человеческий капитал, управление человеческим капиталом, нормативно-правовая база, институциональные механизмы.

Political Studies

ГОД ЦИФРОВИЗАЦИИ И ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В КАЗАХСТАНЕ: ПОЛИТИКО- ИНСТИТУЦИОНАЛЬНЫЙ АНАЛИЗ СТРАТЕГИЧЕСКОЙ ИНИЦИАТИВЫ ПРЕЗИДЕНТА К.-Ж.К. ТОКАЕВА

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Аннотация. В статье анализируется объявление 2026 года Годом цифровизации и искусственного интеллекта в Республике Казахстан через призму теории институционального изоморфизма и концепции перформативной политики национальных ИИ-стратегий. Рассматриваются нормативные, институциональные и программные меры, принятые в рамках этой инициативы, и проводится их сравнительный анализ с подходами Узбекистана и Кыргызстана. Показывается, что казахстанская модель сочетает элементы миметического изоморфизма (заимствование институциональных форм у ОАЭ и Эстонии) с попыткой выстроить собственную регуляторную архитектуру. Делается вывод о необходимости различать декларативный и реальный уровни цифровой трансформации и о сохраняющемся разрыве между амбициозностью нормативных целей и институциональными возможностями их реализации.

Ключевые слова: Год цифровизации и искусственного интеллекта, Казахстан, институциональный изоморфизм, перформативная политика, цифровая трансформация, Центральная Азия, Закон об искусственном интеллекте.

Введение. 6 января 2026 года Президент Республики Казахстан К.-Ж.К. Токаев подписал Указ «Об объявлении Года цифровизации и искусственного интеллекта» [1]. Это событие стало кульминацией серии нормативных и институциональных решений, принятых во второй половине 2025 года: Послания народу Казахстана «Казахстан в эпоху искусственного интеллекта» (8 сентября 2025) [2], Закона «Об искусственном интеллекте» (17 ноября 2025) [3], Цифрового кодекса (9 января 2026) [4] и создания Министерства искусственного интеллекта и цифрового развития (сентябрь 2025) [5]. Совокупность этих мер позиционирует Казахстан как первое государство Центральной Азии, предпринявшее попытку системной, а не фрагментарной интеграции искусственного интеллекта в архитектуру государственного управления.

Вместе с тем масштабность заявленных целей – от охвата 99 % населения высокоскоростным интернетом до перевода 50 государственных услуг на платформу ИИ [6] – ставит вопрос о природе этой инициативы: является ли она реальным стратегическим поворотом или представляет собой перформативный политический жест, характерный для национальных ИИ-стратегий во всём мире? Как показали Дж. Барайс и К. Катценбах, национальные ИИ-стратегии используют поразительно схожие нарративные конструкции – от провозглашения неизбежности технологической революции до обещания национального лидерства – и создают «перформативный замок» (performative lock-in), при котором государства наделяют символические декларации реальными ресурсами вне зависимости от институциональной готовности к их освоению [7].

Цель настоящей статьи – проанализировать политико-институциональное содержание казахстанской инициативы, используя теоретическую рамку институционального изоморфизма и концепцию перформативной политики ИИ-стратегий, а также провести сравнительный анализ с подходами Узбекистана и Кыргызстана для выявления общих и специфических черт цифровой трансформации в Центральной Азии.

Теоретическая рамка. Анализ казахстанской инициативы требует теоретической оптики, позволяющей объяснить, почему государства с различными экономическими и институциональными условиями формируют поразительно похожие ИИ-стратегии, и в какой мере заимствованные институциональные формы наполняются реальным содержанием.

Первым аналитическим инструментом выступает теория институционального изоморфизма П. ДиМаджио и У. Пауэлла [8]. Авторы выделяют три механизма, посредством которых организации в одном институциональном поле становятся структурно подобными: принудительный изоморфизм (coercive), возникающий под давлением регуляторных требований и зависимости от ресурсов; миметический изоморфизм (mimetic), при котором организации копируют модели, воспринимаемые как успешные, в условиях неопределённости; и нормативный изоморфизм (normative), порождаемый профессиональными сообществами, экспертными сетями и образовательными стандартами. Применительно к государственной политике в области ИИ все три механизма действуют одновременно: рекомендации ОЭСР и ЮНЕСКО создают принудительное давление [9; 10], успех «цифровых наций» (Эстония, Сингапур, ОАЭ) порождает миметическое заимствование, а глобальные экспертные сети – от Stanford HAI до OpenAI Academy – транслируют нормативные стандарты.

Вторым инструментом служит концепция перформативной политики национальных ИИ-стратегий, предложенная Барайсом и Катценбахом [7]. Авторы показали на материале стратегий США, Китая, Франции и Германии, что несмотря на содержательные различия, все эти документы воспроизводят единую нарративную структуру: конструирование ИИ как неизбежной и «разрушительной» силы, апелляция к международной конкуренции, провозглашение государственного вмешательства и артикуляция «национального пути». Этот нарратив не просто описывает реальность – он её создаёт, канализируя ресурсы и внимание в определённом направлении. Для анализа казахстанского случая данная концепция важна тем, что позволяет разграничить символический и операциональный уровни инициативы и задать вопрос: в какой мере «Год цифровизации и ИИ» представляет собой реальную трансформацию, а в какой – перформативное воспроизводство глобального ИИ-нарратива?

Третьей теоретической линией выступает концепция policy transfer (трансфера политик), развитая Д. Долловицем и Д. Маршем [11]. В отличие от изоморфизма, акцентирующего структурное подобие, policy transfer фокусируется на процессе: что именно заимствуется (цели, инструменты, институты, идеологии), у кого, и в какой степени – от полного копирования до избирательной адаптации. Казахстанский случай представляет

собой комбинированный трансфер: институциональная форма (специализированное министерство ИИ) заимствована у ОАЭ, регуляторная модель (риск-ориентированный закон об ИИ) – у Европейского Союза, а образовательные программы строятся на нормативном импорте от американских исследовательских центров.

Нормативная база: между заимствованием и адаптацией. Ядро нормативной базы Года цифровизации и ИИ образуют два акта: Закон «Об искусственном интеллекте» и Цифровой кодекс. Их анализ позволяет проиллюстрировать как сильные стороны казахстанского подхода, так и его проблемные зоны.

Закон Республики Казахстан от 17 ноября 2025 года № 230-VIII «Об искусственном интеллекте» [3], вступивший в силу 18 января 2026 года, стал одним из первых комплексных законодательных актов в области ИИ на постсоветском пространстве. Закон закрепляет приоритет прав человека, вводит классификацию систем ИИ по уровню риска, определяет требования к прозрачности алгоритмических решений и устанавливает перечень запрещённых практик: манипулятивное воздействие, социальная и биометрическая дискриминация, определение эмоций без согласия [3]. Концептуально закон следует логике Регламента ЕС об искусственном интеллекте (AI Act, 2024) [12] – классический случай policy transfer в терминологии Долловица и Марша. Однако, как отмечают М. Вил и Ф. Зюйдервеен Боргесиус, даже в условиях развитых правовых систем ЕС разрыв между нормативными декларациями и практикой правоприменения в сфере ИИ остаётся системным [13]. Для Казахстана этот разрыв потенциально ещё глубже: закон предполагает институт аудита алгоритмов и механизмы обжалования автоматизированных решений, но создание независимых надзорных органов с реальными полномочиями – задача, решение которой зависит от факторов, выходящих за рамки технического регулирования.

Здесь уместна критическая перспектива Ф. Паскуале, описавшего режим «общества чёрного ящика», в котором алгоритмические решения, затрагивающие миллионы людей, остаются недоступными для независимой проверки [14]. В условиях Казахстана, где автоматизированные решения всё активнее применяются в сфере назначения социальных пособий, налогового администрирования и оценки кредитоспособности, проблема алгоритмической непрозрачности приобретает не только техническое, но и политическое измерение: она затрагивает базовые вопросы подотчётности власти перед гражданами. Дж. Данаэр обозначает эту тенденцию термином «алгократия» – сценарий, при котором демократические процедуры вытесняются из сфер, переходящих под управление автоматизированных систем [15]. Вопрос о том, насколько Закон об ИИ способен предотвратить подобный сценарий в условиях ограниченной независимости судебной системы и гражданского общества, остаётся открытым.

Цифровой кодекс, подписанный 9 января 2026 года [4], систематизирует ранее действовавшее законодательство – Закон «Об информатизации» (2015) и Закон «О персональных данных и их защите» (2013) – и закрепляет правовой статус данных как объекта прав. Для развития ИИ это принципиально: данные являются ключевым ресурсом обучения алгоритмических систем, и правовой режим их оборота определяет возможности и пределы применения ИИ в государственном и частном секторах. Вместе с тем кодификация сама по себе не решает ключевого противоречия между интересами государства в агрегации данных для целей управления и правом граждан на приватность – противоречия, которое С. Зубофф описала как структурную основу «надзорного капитализма» [16]. В казахстанском контексте, где государство одновременно выступает крупнейшим оператором данных и регулятором их оборота, это противоречие приобретает особую остроту.

Институциональные преобразования: изоморфизм и контекст. Создание в сентябре 2025 года Министерства искусственного интеллекта и цифрового развития [5] – решение, не имеющее аналогов на постсоветском пространстве. В терминологии ДиМаджио и Пауэлла [8] оно представляет собой случай миметического изоморфизма: ближайшим прецедентом является назначение в ОАЭ Государственного министра по искусственному интеллекту в 2017 году [17]. Казахстан воспроизводит институциональную форму страны, занимающей позицию глобального лидера в символической политике ИИ, однако институциональный контекст двух государств принципиально различен: ОАЭ опираются на компактную экономику с высоким ВВП на душу населения и развитой частной ИТ-инфраструктурой, тогда как Казахстан – обширная территория с выраженным цифровым неравенством между городскими и сельскими регионами [18].

Глава нового министерства наделён статусом заместителя Премьер-министра, что обеспечивает межведомственную координацию. Подобная архитектура отражает понимание ИИ как сквозной технологии, требующей координации между всеми секторами управления. Однако централизация управления цифровой трансформацией в едином ведомстве несёт и риски: она может подавить горизонтальные инициативы и создать бюрократическое «бутылочное горлышко», через которое должны проходить все проекты. Исследования цифрового государственного управления показывают, что наиболее успешные модели – эстонская X-Road, британская GDS – строились не на централизации, а на создании открытых платформ и стандартов, позволяющих ведомствам действовать автономно в рамках общей архитектуры [19; 20]. П. Данливи и Х. Маргеттс описывают этот принцип как ключевой элемент «цифрового государственного управления» второй волны: успешная цифровизация предполагает не вертикальную централизацию, а создание интероперабельной инфраструктуры, на которой ведомства выстраивают собственные сервисы [20].

План мероприятий: амбиции и институциональные ограничения. Постановлением Правительства от 31 января 2026 года утверждён План мероприятий по проведению Года цифровизации и ИИ [6]. План включает 8 тематических блоков и 100 мероприятий, охватывающих стратегическое планирование, нормативное регулирование, GovTech-трансформацию, кибербезопасность, отраслевую цифровизацию, «умные города» и формирование цифровой экономики. Целевые показатели амбициозны: интернет для 99 % населения, 5G в 20 городах, 50 госуслуг на ИИ, 80 % госслужащих на цифровых рабочих местах Gov Workspace, миграция 30 % государственных информационных систем на платформу QazTech, охват 450 000 обучающихся программами цифровых навыков [6].

Информативность этих цифр бесспорна; вопрос – в их реалистичности. Концепция перформативной политики [7] предупреждает, что масштабные количественные цели могут функционировать как элемент символического производства легитимности, а не как операциональные ориентиры. Предшествующий опыт Казахстана даёт основания и для оптимизма, и для скепсиса. С одной стороны, Государственная программа «Цифровой Казахстан» (2017–2022) действительно обеспечила перевод более 90 % массовых госуслуг в электронный формат и вхождение страны в тридцатку мировых лидеров индекса электронного правительства ООН [21; 22]. С другой стороны, количественные показатели оцифровки услуг не тождественны качественной трансформации: как отмечается в аналитическом докладе Департамента ООН по экономическим и социальным вопросам, между политическими декларациями, провозглашающими гражданское участие приоритетом, и реальной готовностью государственных институтов к содержательному учёту мнения граждан сохраняется устойчивый разрыв, варьирующийся по странам и во времени [23].

Образовательная программа AI Leaders 2026, запущенная в партнёрстве со Stanford HAI, OpenAI Academy и Silkroad Innovation Hub [24], представляет собой характерный пример нормативного изоморфизма: через партнёрство с глобальными экспертными центрами транслируются профессиональные стандарты, модели компетенций и технологические подходы. Программа ориентирована на руководителей высшего звена и строится на трёхступенчатой модели: академический фундамент (Stanford HAI), практические инструменты (OpenAI Academy), прикладные проекты. Её геополитическое значение – позиционирование Казахстана как участника глобальной технологической экосистемы – не менее важно, чем образовательное содержание. Однако программа для элитных управленцев не решает проблемы массовой подготовки ИИ-специалистов: для этого необходимы исследовательские школы, лаборатории и – что критически важно – условия для удержания талантов в стране [25].

Центральноазиатский контекст: сравнительный анализ. Казахстанская инициатива не существует в региональном вакууме. Сравнительный анализ с подходами Узбекистана и Кыргызстана позволяет выявить как общие паттерны, объясняемые теорией изоморфизма, так и существенные различия, обусловленные спецификой институциональных контекстов.

Узбекистан в октябре 2024 года принял Стратегию развития технологий искусственного интеллекта до 2030 года [26] с амбициозными целями: вхождение в топ-50 государств по Индексу готовности к ИИ, подготовка 1 миллиона специалистов, доведение объёма ИИ-продуктов до 1,5 млрд долларов. На развитие инфраструктуры выделено 50 млн долларов, приобретены 16 суперкомпьютеров. По итогам 2024 года Узбекистан поднялся на 17 позиций в международном Индексе готовности к ИИ [26]. Если Казахстан делает ставку на институциональную архитектуру (отдельное министерство, кодифицированное законодательство), то узбекская модель акцентирует инфраструктурные инвестиции и количественные показатели подготовки кадров. Обе стратегии, однако, воспроизводят глобальный нарратив технологической гонки и национального лидерства [7], адаптируя его к внутриполитическому контексту.

Кыргызстан находится на более ранней стадии: национальная Стратегия по искусственному интеллекту находится в процессе подготовки, создан Национальный совет по ИИ, в 2026 году планируется начать строительство Национального центра искусственного интеллекта [27; 28]. На форуме «Digital Almaty 2025» Кыргызстан выдвинул инициативу создания Регионального хаба ИИ в рамках ЕАЭС. Кыргызский случай демонстрирует иную модель: меньший масштаб амбиций, но потенциально более реалистичное соотношение целей и институциональных ресурсов. Как отмечают аналитики Всемирного банка, Кыргызстан переживает «тихую трансформацию» в области ИИ, где при ограниченных государственных ресурсах основным двигателем выступает частный сектор и сообщество разработчиков [28]. Вместе с тем зависимость от внешней экспертизы ставит вопрос о суверенности цифровой трансформации.

Сравнение трёх стран показывает, что Центральная Азия переживает синхронный, но неравномерный процесс формулирования ИИ-политик. Все три государства подвержены одним и тем же изоморфным давлениям – рекомендациям международных организаций, примеру «цифровых наций», влиянию глобальных экспертных сетей – но отвечают на них различными институциональными конфигурациями. Казахстан идёт по пути максимальной институционализации; Узбекистан – инфраструктурных инвестиций; Кыргызстан – осторожного выстраивания базовых институтов. Какая из этих стратегий окажется более продуктивной, покажет сравнительный анализ результатов их реализации.

Дискуссия: перформативность vs. трансформация. Наиболее существенный вопрос, который теоретическая рамка позволяет поставить к казахстанской инициативе, касается соотношения перформативного и трансформативного измерений.

С одной стороны, инициатива обладает чертами реальной трансформации: принят закон, создано министерство, утверждён план с измеримыми показателями, запущены международные образовательные программы. Предшествующий опыт «Цифрового Казахстана» подтверждает способность государства реализовывать масштабные цифровые проекты. Сама идея «тематического года» в казахстанской политической практике не нова и в ряде случаев действительно служила катализатором реформ, концентрируя ресурсы и политическое внимание.

С другой стороны, несколько факторов указывают на значительную перформативную составляющую. Во-первых, нарративная структура казахстанской инициативы точно воспроизводит глобальный шаблон, описанный Барайсом и Катценбахом [7]: конструирование ИИ как неизбежности, апелляция к международной конкуренции, провозглашение национального пути. Во-вторых, скорость принятия нормативных актов (от Послания до закона – менее трёх месяцев) вызывает вопрос о глубине проработки и качестве общественной дискуссии. В-третьих, институциональная форма (министерство ИИ) заимствована у государства с принципиально иным экономическим и институциональным профилем, что создаёт риск того, что Дж. Мейер и Б. Роуэн называли «церемониальным соответствием» – формальным принятием институциональных структур без их реального встраивания в организационную практику [29].

Отдельного внимания заслуживает вопрос о роли ИИ-технологий в контексте гибридных политических режимов. Исследования последних лет показывают, что искусственный интеллект может использоваться как инструмент расширения государственного контроля: от систем видеонаблюдения с распознаванием лиц до алгоритмического профилирования граждан [30; 31]. Институт Карнеги отмечает, что технологии ИИ «экспоненциально усиливают возможности государства по мониторингу населения, подавлению несогласия и упреждению сопротивления» [30]. Казахский Закон об ИИ содержит ограничения на манипулятивное применение систем ИИ, однако эффективность этих ограничений зависит от независимости институтов надзора – вопрос, который в условиях казахстанской политической системы не имеет однозначного ответа. Для политической науки этот аспект представляет ключевой исследовательский интерес: каким образом цифровая трансформация влияет на баланс между эффективностью управления и гражданскими свободами?

Наконец, проблема цифрового неравенства остаётся структурным ограничением всей инициативы. По данным Бюро национальной статистики, доступ к интернету и уровень цифровой грамотности существенно различаются между городским и сельским населением, а также между возрастными группами [18]. Ускоренная цифровизация в этих условиях может обернуться не расширением, а сужением доступа к государственным услугам для наиболее уязвимых групп. Риск технологической зависимости – использование зарубежных платформ и моделей ИИ при отсутствии собственных крупных языковых моделей – дополнительно ставит вопрос о суверенитете данных и устойчивости инфраструктуры.

Заключение. Объявление 2026 года Годом цифровизации и искусственного интеллекта в Республике Казахстан представляет собой масштабную политическую инициативу, которая заслуживает серьёзного аналитического внимания – и как случай реальной институциональной трансформации, и как случай перформативной политики.

Теоретический анализ через призму институционального изоморфизма показывает, что казахстанская модель формируется под воздействием всех трёх механизмов – принудительного (международные стандарты), миметического (заимствование у ОАЭ и Эстонии) и нормативного (глобальные экспертные сети). Концепция перформативной политики позволяет объяснить, почему при существенных различиях в институциональных

условиях страны воспроизводят схожие нарративные конструкции и организационные формы.

Сравнительный анализ с Узбекистаном и Кыргызстаном демонстрирует, что Центральная Азия переживает синхронный, но неравномерный процесс формирования ИИ-политик, причём Казахстан избирает путь максимальной институционализации – со всеми вытекающими преимуществами (системность, координация) и рисками (бюрократизация, церемониальное соответствие).

Ключевой вопрос для дальнейших исследований состоит не в том, удастся ли Казахстану выполнить 100 мероприятий Плана, а в том, приведёт ли институциональная активность к реальному изменению качества взаимодействия государства и общества: к повышению прозрачности алгоритмических решений, расширению гражданского участия в выработке политики в области ИИ и преодолению цифрового неравенства. Именно по этим критериям – а не по количеству принятых актов и проведённых мероприятий – следует оценивать успех Года цифровизации и искусственного интеллекта.

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Philological Sciences

ОСОБЕННОСТИ ПРОЗАИЧЕСКОГО ТВОРЧЕСТВА Б. КАНАПЬЯНОВА

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Институт литературы и искусства им. М.О. Ауэзова, ведущий научный сотрудник, кандидат филологических наук, г. Алматы, Республика Казахстан

Творчество члена Союза писателей Казахстана, Заслуженного деятеля Казахстана, лауреата Государственной премии Республики Казахстан в области литературы и искусства Бахытжана Канапьянова – яркое явление современной казахстанской литературы. Ему свойственно счастливое сочетание в одном лице таланта поэта и прозаика. Его поэзия имеет в своей основе личные переживания. Пейзажные описания выступают в роли призм, через которую читатели ощущают единство человека с природой. Создано множество стихотворений, посвященных родным, друзьям и соратникам по перу.

Основной особенностью прозаического творчества Б. Канапьянова является обращение к жанру малой прозы, которая представлена интересными темами Рассказы и повести Б. Канапьянова обращены и в прошлое, и в настоящее, преобладает реалистическое восприятие действительности. Интерес автора вызывает личность с ее внутренним духовным миром.

Б. Канапьянов является сценаристом и режиссером ряда кино- и видеофильмов. Он известен и как переводчик. Им переведены поэтические произведения известных казахских авторов Абая Кунанбаева, Жамбыла Жабаева, Шакарима Кудайбердиева, Махамбета Утемисова и многих других. В 2009 году Б. Канапьянов был инициатором проведения Первого республиканского конкурса переводчиков (г. Астана). В 2010 году по Программе Министерства связи и информации Республики Казахстан в издательстве «Аударма» вышла в свет книга «Жумабаев Магжан. Пророк. Стихи, поэмы, рассказ», составителем, автором комментариев и одним из переводчиков которой является Б. Канапьянов.

Б. Канапьянов вносит большой вклад в развитие малой прозы Казахстана. Его рассказы и повести публикуются в журналах «Нива», «Простор», «Книголюб», в альманахе «Литературная Алма-Ата», а также выходят в свет отдельными книгами. Например, в 2010 году в Алматы изданы книги «Куранты небес. Рассказы, повести» [1] и «Тамга Иссык-Куля».

Тематика прозаических произведений Б. Канапьянова разнообразна. В результате отбора литературного материала в качестве объекта исследования определены рассказы Б. Канапьянова «Почтовый холст», «Прогулка перед вечностью» и повесть «Последняя осень поэта» из книги «Куранты небес».

Рассказ «Почтовый холст» посвящен художнику Мендыбаю Алину – члену Союза художников СССР, одному из авторов дизайна казахстанских тенге. Писатель показывает взросление художника через восприятие мальчика: от первых рисунков и сказок – к глубоким философским размышлениям через искусство.

Мальчик с детства любил природу, особенно степь. Зимой он видел в белом снеге целую гамму оттенков. Его восприятие природы было очень тонким: он различал цвета снега в разное время суток, вглядывался в звезды, иней, узоры на школьных окнах. Всё это вдохновляло его на рисунки, хотя поначалу ему было трудно передать на бумаге белизну и блеск снега. Он постепенно учился изображать детали – следы птиц, деревья, сани, лошадей. Весной природа оживает: талая вода, подснежники, капель, птицы. Мальчик

наблюдает за таянием снега, весенними звуками, светом фонаря в каплях сосулек. Летом он проводит время в ауле с дедушкой и бабушкой, пасёт лошадей, изучает природу Наурзымского заповедника. Его впечатляют фауна, степные травы, перелётные птицы. Он внимательно наблюдает за животными, рисует бабочек, стрекоз, пейзажи.

Мальчик рисует с детства. Даже когда ему дают задание по литературе пересказать сказку, он вместо этого иллюстрирует её, потому что так лучше выражает чувства и образы. Его рисунки становятся всё более выразительными. Он изображает сказочных персонажей, которых ассоциирует с реальными людьми, например, с кузнецом Хасеном, сварливой соседкой и другими. Его талант замечают в школе и районе: он оформляет стенгазеты, афиши для киносеансов. Наградой служит бесплатный вход в кино. Его дядя Шайсултан, чемпион Москвы по борьбе, приезжает летом в аул и, увидев работы мальчика, увозит их в Москву. Позже присылает посылку – настоящий мольберт, масляные краски, кисти, книгу-пособие. Мальчик учится подготавливать холст, читая пособие. Не имея профессионального холста, он использует мешковину из посылки. Так рождается первый «почтовый» холст. Он осваивает работу с маслом, понимает, как передать глубину, свет, воздух на картине. Его картины становятся всё более живыми. Мальчику постоянно нужны холсты. Он находит решение: договаривается с почтой и получает мешковину от посылок, превращая их в основу для картин. С этого момента «почтовый холст» становится символом его творчества.

Б. Канапьянов использует поэтичную прозу с метафорами, эпитетами и сравнениями. Эти средства подчеркивают эмоциональность и художественное зрение героя. Стиль писателя – мягкий, созерцательный, с тонким чувством природы и времени. Текст насыщен символикой. Так, масляные краски являются символом взросления художника, перехода на «высокий уровень». Почтовый штемпель – знак принадлежности к родной земле, связь с истоком. Образы природы (луна, звезды, иней, лошади) – живые архетипы, влияющие на внутренний мир героя. Автор мастерски вплетены народные сказки, мифология (Тенгри, святые), реальные бытовые детали (учёба, аул, посылка). Б. Канапьянов использует казахскую культурную и духовную традицию как органичную часть мира героя. История мальчика-художника – одновременно и простой рассказ о детстве, и глубокое размышление о природе искусства, памяти и бессмертии.

Рассказ «Прогулка перед вечностью» – это философская и автобиографическая проза о жизни, памяти, верности, науке, литературе и одиночестве в конце пути. Главный герой – пожилой академик, ученый и писатель – отправляется на утреннюю прогулку со своим псом Досом. Эти прогулки стали частью его жизни после инфаркта. Он вспоминает свою жизнь: детство в казахском ауле Баганаты, голод и переселение в Сибирь, учебу, первые шаги в литературе, и как мечта стать писателем уступила научной карьере. Герой добился успехов в металлургии, стал доктором наук, академиком, ректором университета. Он старался совмещать научную деятельность с писательской.

Воспоминания переплетаются с болью: старость, предательство коллег, забвение со стороны учеников, несправедливое снятие с поста ректора. Он думает об одиночестве, долге писателя, страхе быть забытым, о роли памяти и души. Рассказ наполнен размышлениями о великих людях – Чокане Валиханове, Абае Кунанбаеве, Шакариме Кудайбердиеве, Каныше Сатпаеве. Б. Канапьянов цитирует Абая, размышляет о переведённом стихотворении Шакарима, о бессмертии души.

В снежной метели, возвращаясь с прогулки, главный герой ощущает приближение смерти. Его сердце останавливается у подъезда родного дома. Верный пёс Дос не пускает врачей к умирающему хозяину, защищая его до конца. Финал наполнен трагизмом и символизмом – смерть героя на фоне белого снега как переход в вечность.

В рассказе переплетаются мемуарные фрагменты, художественное повествование, лирические размышления, публицистика и очерк. Стиль автора – созерцательный,

интеллектуальный, местами ироничный и трагически-ироничный. Произведение построено как внутренний монолог героя во время его утренней прогулки. Оно разделено на двенадцать фрагментов, каждый из которых представляет собой отдельный пласт воспоминаний и размышлений. Б. Канапьянов раскрывает такие проблемы, как карьеризм в науке и литературе, показывает судьбу творческой личности в условиях политических интриг. Важным символическим образом является пес Дос. Он олицетворяет верность, искренность, преданность. Дос становится последним спутником героя перед смертью.

Главный герой – литературно замаскированный автопортрет ученого, писателя и общественного деятеля, несомненно, имеющего черты самого Б. Канапьянова. Это одаренный человек, совмещающий науку и литературу, обладающий душевной чуткостью, честностью и преданностью делу. В рассказе «Прогулка перед вечностью» выражена авторская философия жизни: быть верным себе, служить народу, сохранять память и не предавать слово. Это произведение объединяет научную доблесть, духовный поиск, национальную идентичность и универсальные человеческие ценности.

Повесть Б. Канапьянова «Последняя осень поэта» посвящена последним дням жизни казахского поэта, философа и мыслителя Шакарима Кудайбердиева. Автор мастерски соединяет поэтические размышления героя с жестокой исторической реальностью Казахстана 1930-х годов, ставя перед зрителем и читателем ряд моральных и философских вопросов.

Центральным образом произведения становится фигура Шакарима – мудреца, духовного наставника народа, человека высокой нравственности и внутренней свободы. В его монологах – размышления о смысле жизни, справедливости, роли человека в обществе. Поэт отказывается от крайностей: религиозного фанатизма, утопической веры в науку, насильственного равенства. Он предлагает путь доброты, честного труда и разума как единственно возможный способ улучшения жизни людей.

В повести представлен один из самых мрачных периодов в истории Казахстана – начало 1930-х годов, время насильственной коллективизации, массового голода и разрухи. Хроника событий, документальные кадры, архивные данные – всё это органично встроено в повествование. Б. Канапьянов с поразительной точностью и художественной силой показывает, как репрессивная политика центра, непонимание специфики кочевого образа жизни, и произвол местных властей привели к разрушению человеческих судеб. Особое впечатление производят сцены голодающих аулов, беженцев, погибших детей, матерей, доведённых до безумия.

Ключевым конфликтом в повести является столкновение личности, обладающей духовной силой и моральным авторитетом, с механизмом тоталитарной власти. Шакарим, в отличие от представителей власти, не подчинён идеологии. Его оружие – мысль, слово и пример личной честности. Именно этим он опасен для системы. Его не могут сломить угрозами. Он открыто заявляет о гибели людей от голода, критикует грубые методы коллективизации. Он противостоит государственному механизму, разрушающему устои традиционного уклада жизни казахского народа.

Б. Канапьянов включает в сюжет реальные исторические документы, хронику, письма, а также литературные цитаты, создавая сложную систему смыслов и перекличек между эпохами. Это придаёт произведению не только документальную достоверность, но и универсальность – судьба Шакарима становится образом судьбы любого свободомыслящего человека, попавшего в жернова тоталитарного времени.

Произведение отличает богатый поэтический язык. Важную роль играют символы: лошадь – как образ свободы и степной жизни, костёр – как символ тепла, памяти и угасающей надежды, пепел – как итог прошедшей жизни, и, конечно, луна и вода – как знаки вечности и очищения. Пламя, воск, тени на стенах – всё в произведении наполнено

философским подтекстом. Постоянные отсылки к зеркалу, к отражениям, к прошлому, подчеркивают философский характер произведения. Сон, в котором Шакарим видит своё детство, семью, юность, – это путь внутрь себя, к истокам, к утрате. Цикличность природы – осень, первый снег, замерзание реки – становится фоном трагедии. Последняя осень в названии – не только сезон, но и последний этап жизни поэта, его личной и творческой судьбы. В этом природном круговороте чувствуется неотвратимость, но также и надежда на очищение и возрождение.

Художественное пространство повести пронизано трагизмом, оно несёт в себе ощущение надвигающейся гибели. Однако автор не лишает своего героя достоинства. Шакарим, отказываясь покинуть родной край, сохраняет верность себе, своим убеждениям и народу. Его молчаливое сопротивление, философская стойкость и человечность контрастируют с образами служителей власти, движимых страхом, карьеризмом или жестокостью.

Финальные сцены особенно трагичны. Арест Шакарима, уничтожение его стихов, попытка присвоения его наследия – это свидетельство того, как власть пыталась стереть из памяти народа всё, что связано с достоинством, духовной независимостью и правдой. Однако Б. Канапьянов противопоставляет этой попытке мощного свидетеля – самого народного поэта, чьё слово, даже будучи запрещённым, продолжает жить.

Повествование завершает образ луны, пробивающейся сквозь решётку – символ надежды, вечного света знаний и творчества, которое не может быть заключено в тюрьму. Голос Шакарима звучит сдержанно, но проникает глубоко: «Ну что же, кажется я исполнил завет Толстого... Проник вовнутрь последней страницы жизни своей» [1, с.224].

«Последняя осень поэта» – не просто художественное переосмысление судьбы Шакарима, но и литературно-философское полотно, создающее образ народа, пережившего страшную трагедию и не утратившего веры в человеческое достоинство. Это произведение – важнейшее звено в восстановлении исторической справедливости, напоминание о цене свободы и глубине духа, который невозможно сломить.

Итак, в данной статье, посвященной прозе Б. Канапьянова, проанализированы его два рассказа и одна повесть. Несмотря на интерес к творчеству Б. Канапьянова со стороны отечественных ученых-литературоведов, рассмотренные нами рассказы «Почтовый холст», «Прогулка перед вечностью» и повесть «Последняя осень поэта» не были объектом их исследования. Следует отметить, что большинство казахстанских научных исследований посвящено в основном поэзии Б. Канапьянова.

Осмысление творчества известных деятелей современной литературы Казахстана имеет большое значение для отечественного литературоведения, так как способствует поиску путей для сохранения высокого уровня художественно-эстетических традиций казахской литературы. Важным является стремление рассматривать художественный процесс не изолированно, а в его возрастающей взаимосвязи с такими социально-идеологическими и мировоззренческими явлениями, как углубление национального самосознания, укрепление государственного международного авторитета, формирование патриотизма.

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THEORETICAL PRINCIPLES OF FRENCH ROMANCE

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Abstract: In the «Oriental romanticism Victor Hugo» are regarded as the "autumn" theme in V. Gyugo's creativity. The personality of the great French master will be analyzed in the context of the specificity of the East in the works of V. Gyugo. The main directions of French romanticism Summary Victor Hugo is the most popular writer in the world literature. The Culture of West - East has the most important position in its works. Revolutionary processes that occurred in France are described in their works. He has an exceptional role in the drama. The creativity of Victor Hugo takes a special place in the history of French romance. The name and creativity of this remarkable vocabulary master became a symbol of the triumph of the romantic movement in France in a very short time. In his face romance is primarily based on a number of specific principles. One of the most important of these is the fact that advanced writers defend the idea of identity with the objective universe and confrontation with the socios. This means that personality is, first of all, understood as the sole shelter of morality. At the same time, human beings are the center of the universe and, therefore, are considered as a unique source of change in the world of romance. Just as a result of such adherence to the principle of spirituality, it is easy to accept logical religious thought systems of romantic thought. These systems, as a rule, aspire to the realization of the principle of "world of intentionality" that is consistent with the romantic "two world" structural principle.

Keywords: V. Hugo, romance, the East, the sea, the sky

V. Hugo was an instructor and witness to the great events of the 19th century in France. He understood that the idea of personal liberty was limited to involvement of an individual, primarily in the mass movement. This was perhaps the next romance in the French romantic literature, and perhaps for the writer itself, perhaps the leading romantic principle. Here, the focus was not on the general political situation for the idea of sovereignty and identity, in particular the artistic, as well as the idea of the greatness of personality. Undoubtedly, the idea of the personality in the active French romanticism, which, undoubtedly, is a brilliant representative of Hugo, is neutralized with the idea of "fate" and the inevitable failure. By the way, this idea had a solid foundation: it was primarily due to the lesson of Napoleon's fate - from the "half of the world" to the exile life on the island of St. Helens. Thus, French "romanticism", which was in the process of forming and forming, came out of the modern era. In the first decades of the 19th century, the attention of active French romanticism, including V. Hugo, was drawn to the suffering of the delicate heart, which was always in direct contact with reality.

On the other hand, for the correct analysis of V. Hugo's creative work, in our opinion, the clear and honest understanding of the French romance is extremely important. We have such a fact that the French Revolution was a specific cataclysm, and in modern languages even apocalypse. In addition to inspiring active romance, he also increased his clarity. The difference between the reality and the expectation was quite large and the origin of bourgeois utopia originated from here. Bourgeois was criticized by French romantics and, first of all, was interpreted in a public-moral aspect. In the minds of the French intellectuals, the denial of the bourgeoisie began to activate mainly in the first two decades of the 19th century. The proximity of the distance

played a crucial role in this process: the hurricane of history was devastating, as well as the events that were not only frightening, but also hoped that the romantic historical thoughts were a proof of it.

But what is the position of V. Hugo in France, and in a broader sense, in Europe? Since 1848, there has been a special activity in its public position. He has traced a romantic outlook on all of Hugo's next creations, including the Origins of his poems and dramas. The embodiment of the theoretical principles of European romance has been found in humanism in the subsequent and productive development.

Let us note that such a position was entirely in line with the general political situation that dominated the history of France. The attention of the French romantic heroes was drawn to real human suffering; however, the titanic and genius, which seemed to be the only exception in the common backgrounds, joined them only during the great romanticism (the 20th). For the most important issues of the day, these interests preserve the French romance for the next decades, and in the 30s of the 19th century, romance is becoming more actual. The most active romantic is Victor Hugo. His creativity is completely integrated into the world literature space with his theoretical principles.

The next principle is that the previous literature is indissolubly connected with Classeism and Enlightenment, ie loyalty to the past traditions of the past. The artistic experience of the Golden Age has always been harmonious with the consciousness of H. Hugo, and he adhered to the seemingly rising trends of the romantic century as a whole. V. Hugo's argument with rationalist logic. From the theoretical point of view, Hugo's romance is purely rational, and consequently, his lyrical, epic and all the contradictions in his dramatic works are fairly straightforward and organized. It is important to emphasize one more aspect that V. Hugo's desire to build the romance of the world is not to deny the world, but to understand it. What does it mean? Being impressed by the work of Pierre Cornell and Nicola Buteo, he attempts to test the capabilities of a refreshed and advanced romantic poet. At the same time, the gradual formation of a population that is convinced of the possibility of romantic writers, unfortunately, to establish their own culture without tradition is gradually beginning in Europe and France. Initially, these French-born romants refused to follow the main stages of the ancient tragedy, and then they were subjected to criticism and even destruction of the humane ideals of the Renaissance. Hugo went on to defend the best traditions of European classical literature and wanted to write the next principle of his romantic outlook in the most varied genres. For example, the rooms were mainly added to balladas written on fascinating motifs on Medieval subjects. At that time, the novels featured "gothic" and romantic anger in the most acute forms, and the poetics of "local color" played a major role. The "East Motives" used by Hugo in different genre works was also a manifestation of such a "local color". We support such an idea that no theoretical provision, which is not tested by artistic practice, has the right to exist independently. From this point of view, in our opinion, the literary creativity of V. Hugo is remarkable. In general, the interest in the Muslim East was characteristic of Western European romance. But this interest was not new and had its ancient roots. The West and the East are phenomena that differ in many different philosophical and religious characteristics. At the same time, not every region has ever been isolated and developed. On the contrary, Western Europe and the Eastern countries had a close relationship. The history of this rapprochement is directly related to the Great Silk Walk. Generally speaking, Oriental motifs in medieval literature were fairly stylish, and prominent writers of various literary trends resorted to these motives. An example of this is that, for example, Ramon wrote Baldém tragedy during the Classisian era, and Volter's famous "Zair", "Mohammed" tragedies during the enlightenment period, and finally Montesky's "Persian Letters." But for East Hugo, who is "purely" romantic, the "East" color is not a tradition of artistic work. The "East" fund has helped solve the problem of "two worlds" - a completely characteristic and natural problem for romantic creativity. The problem of doubling of

worlds, as Shakespeare's personality in the Hamlet tragedy has yet to become, has become the theoretical principle that has been embodied in the work of V.Hugo's creativity as well as in his works. Thus, a romantic hero, who can not use his opportunities in the Western civilization, first of all goes to the East - his lifestyle is more appropriate to his inner world and meets his essential needs. But from this point of view, V. Hugo attributes the specific character of the "East" to his character. More precisely, despite the overall romantic background, the choice of space in the Orient's motives is remarkable. They do not even give preference to mysticism or fantasy, nor do they ever live in underground caves, ancient churches, barracks, or stone quarries, as they are accepted in European romanticism during the history of the heroes. For comparison: there are many such scenes in the novel "The Paris Notre Dame", where eastern motifs are very fragile and all content is based on typical "european" material. Or, let's take a look at the little Kozetta or Gavrosh scenes in the novel The Suspenders. The Eastern fund is almost in the same degree, and therefore, it is not so common to have Hugo's approach to the "miserable" and hungry "lifeless" survivors in the basements and ravines. In the works of William Hugo, "Eastern spirit", we do not encounter anything like them. The issue is not in the spatial location of any minor heroes. In the works created on the basis of the East motives of the truth, neither lonely elderly nor "noble" pirates are encountered. In addition, there is no child or teenage image in medieval churches or caves in his magnificent artistic heritage. Accordingly, romantic enthusiasm is also moderate. This is due to the fact that when applying to eastern subjects in different genres, the French writer is always referring to the most ordinary everyday life that goes beyond normal life norms. For example, in the preface of the collection of poems called "Eastern Motives", Hugo makes the following comment: this fantasy, which gives rise to the "Eastern motives" is not unusual. For a thousand reasons ... now we are more interested in the East. During the reign of XIV Ludovic, we were a feller, and now we are orientalists. The brain, which has never been so large, has never experienced this endless stream called Asia. Now our scientists have penetrated all the dialects of the East ". It is clear that the thought or the image of the East is based on the mind and mind of all, and the author (Hugo) is no exception. It has also had a "eastern" euphoria all around. However, it does not seem to be of interest to her. From this point of view, the writer follows the following theoretical principle: there is no exotics for the literature for literature, but exotica itself (then the word "art for art"), but exotic for true romantic creativity. Hugo's approach to the East, however, differs from the "east" by the most innovative ones. The Oriental color is all about her own dreams, all of her dreams, almost entirely European, Greek, Turkish, Persian, Arabic and even Spanish (Spain is also East, half Africa) itself is also half Asia). The author of these poems, as a poet, always admired the eastern world, thought there was a high poetry shining. Hugo himself admitted that soon the East would play a remarkable role in the West, both for the empire and for the literature. Thus, it is clear from the foregoing that as a typical active romanticist, Victor Hugo guided by a number of theoretical principles, producing works with high artistic value. At the same time, we are witnessing the special interest of the artist to the East. But this did not stem from elemental observance of fashion or innovation tradition, which was not new in France. On the contrary, he emphasizes the interest of the East in its vivid and deep poetry, expresses its high regard for the history of Eastern culture and its role in the future development of Europe. The following are some of the great facts:

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THE EFFECTIVENESS OF TASK-BASED LANGUAGE TEACHING IN DEVELOPING COMMUNICATIVE COMPETENCE: A BIBLIOMETRIC ANALYSIS

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Abstract

This study provides a comprehensive bibliometric analysis of research on Task-Based Language Teaching and its effectiveness in developing communicative competence. The analysis is based on publications indexed in Scopus, retrieved using a structured search strategy limited to peer-reviewed journal articles in English. A total of 125 studies were selected following the PRISMA framework. The study aims to identify major research trends, influential publications, leading countries, and thematic developments within the field. Bibliometric tools, including VOSviewer and bibliometrix (RStudio), were used to conduct citation analysis, co-authorship mapping, and keyword co-occurrence analysis. The results reveal a growing number of publications, particularly after 2019, indicating increasing academic interest in TBLT. The findings show that highly cited studies emphasize learner-related variables such as willingness to communicate and self-efficacy, as well as the integration of technology in language learning. Geographical analysis highlights a concentration of research output in countries such as the United States, China, and Canada, while many regions remain underrepresented. Thematic mapping identifies communicative competence and TBLT as core research areas, alongside emerging interdisciplinary themes related to digital learning and psychological factors. The study concludes that although TBLT demonstrates strong potential for enhancing communicative competence, the field remains fragmented and requires further methodological and geographical diversification. The results contribute to a better understanding of the intellectual structure of TBLT research and provide directions for future studies.

Keywords: Task-Based Language Teaching; Communicative Competence; Bibliometric Analysis; Second Language Acquisition; Language Education; Scopus; VOSviewer; bibliometrix; EFL; Technology-Enhanced Learning

Introduction

Relevance of the study. In the context of accelerating globalization, digital transformation, and the growing demand for multilingual communication, the development of communicative competence has become a central objective of modern language education. Traditional teacher-centered approaches are increasingly criticized for their limited ability to foster authentic interaction and real-life language use. Against this background, Task-Based Language Teaching (TBLT) has emerged as a prominent pedagogical paradigm that emphasizes meaningful communication, learner autonomy, and the use of language as a tool for achieving specific goals. Grounded in principles of communicative language teaching and supported by influential scholars

such as Rod Ellis and Jane Willis, TBLT has gained substantial attention in both theoretical and empirical research. Despite the increasing number of studies examining the effectiveness of TBLT in developing communicative competence, the existing body of literature remains fragmented across contexts, educational levels, and methodological designs. There is a lack of systematic and comprehensive synthesis that would allow researchers to identify dominant trends, research gaps, influential publications, and collaboration networks within this field. In particular, the rapid growth of publications indexed in databases such as Scopus necessitates the use of advanced analytical approaches capable of mapping the intellectual structure of the research domain. In this regard, bibliometric analysis provides a robust methodological framework for quantitatively evaluating the development of scientific knowledge, revealing citation patterns, thematic evolution, and the global distribution of research output. Conducting a bibliometric analysis of studies on TBLT and communicative competence will not only systematize existing knowledge but also contribute to identifying underexplored areas, emerging research directions, and methodological tendencies. Therefore, the present study is highly relevant as it bridges the gap between pedagogical theory and research synthesis, offering evidence-based insights for both scholars and practitioners in the field of language education.

Research problem. Despite the widespread recognition of Task-Based Language Teaching as an effective approach for fostering communicative competence, there remains a persistent lack of consensus regarding its actual impact across diverse educational contexts. While TBLT is theoretically grounded in communicative and interactionist frameworks, emphasizing meaningful language use and learner engagement, empirical findings on its effectiveness are often inconsistent and context-dependent. Some studies report significant improvements in learners' fluency and interactional skills, whereas others highlight challenges related to implementation, assessment, and contextual constraints (Ellis, 2017; Long, 2015). One of the central problems lies in the variability of how communicative competence itself is conceptualized and operationalized in research. Drawing on the foundational model of communicative competence proposed by Dell Hymes and further developed by Michael Canale and Merrill Swain, contemporary studies adopt differing frameworks, making it difficult to compare results across studies (Savignon, 2018). This conceptual ambiguity complicates the evaluation of TBLT outcomes and limits the generalizability of findings. Additionally, methodological inconsistencies across studies present another significant challenge. Research on TBLT employs a wide range of designs, including experimental, quasi-experimental, and qualitative approaches, often with small sample sizes and limited longitudinal data. As a result, there is insufficient cumulative evidence to draw definitive conclusions about the long-term effectiveness of TBLT in developing communicative competence (González-Lloret & Ortega, 2014). Furthermore, variations in task design, teacher expertise, and classroom environments introduce additional variables that are rarely controlled systematically.

Another critical issue concerns the uneven geographical distribution of research. A substantial proportion of studies are concentrated in specific regions, particularly in East Asia and Europe, which raises questions about the applicability of findings to other linguistic and cultural contexts (Butler, 2011). This imbalance highlights the need for a broader, more inclusive perspective on TBLT research. Given these challenges, there is a clear need for a systematic and quantitative synthesis of the existing literature. A bibliometric approach allows for the identification of research trends, influential authors, collaboration networks, and thematic clusters within the field. However, to date, such comprehensive analyses remain limited, particularly in relation to the intersection of TBLT and communicative competence. Therefore, the research problem can be defined as the lack of a structured and integrative understanding of how TBLT contributes to the development of communicative competence, as reflected in the global scientific literature.

The aim of this study is to conduct a comprehensive bibliometric analysis of scientific publications on Task-Based Language Teaching in relation to the development of communicative competence, in order to identify the main research trends, influential authors, leading journals, thematic clusters, and the intellectual structure of the field. The study seeks to systematize existing knowledge and provide an evidence-based overview of how TBLT has been explored and evaluated in the international academic discourse.

The study is guided by the following overarching research question: *What are the main trends, patterns, and research directions in the scientific literature on Task-Based Language Teaching and its effectiveness in developing communicative competence?*

Significance of the study. The significance of this study lies in its theoretical, methodological, and practical contributions. From a theoretical perspective, the research provides a structured synthesis of knowledge on the relationship between TBLT and communicative competence, helping to clarify the intellectual landscape of the field. By integrating findings across a large body of literature indexed in Scopus, the study contributes to a deeper understanding of how key concepts and approaches have evolved over time. From a methodological standpoint, the use of bibliometric analysis offers a systematic and objective approach to evaluating scientific production. It enables the identification of citation patterns, collaboration networks, and thematic developments that are not easily observable through traditional literature reviews. This enhances the rigor and transparency of research synthesis in applied linguistics. From a practical perspective, the findings of the study are valuable for educators, curriculum designers, and policymakers. By highlighting the effectiveness and limitations of TBLT, as well as identifying underexplored areas, the study supports evidence-based decision-making in language education. Furthermore, it provides guidance for future research by revealing gaps and emerging trends, thereby facilitating the advancement of more context-sensitive and impactful pedagogical practices. Overall, the study bridges the gap between fragmented empirical findings and the need for a comprehensive understanding of the role of TBLT in developing communicative competence, reinforcing its relevance in contemporary language education research.

Literature Review

The concept of TBLT has emerged as a central paradigm within communicative approaches to second language acquisition, emphasizing the use of authentic tasks to promote meaningful interaction and language use. Rooted in interactionist and sociocultural theories, TBLT prioritizes the development of communicative competence through real-world language activities rather than the explicit teaching of linguistic forms. Foundational contributions by scholars such as Michael Long and Rod Ellis have shaped the theoretical and pedagogical underpinnings of TBLT, highlighting the importance of input, interaction, and task design in facilitating language acquisition (Ellis, 2003; Long, 2015). Communicative competence, initially conceptualized by Dell Hymes, extends beyond grammatical knowledge to include sociolinguistic, discourse, and strategic competencies. This multidimensional framework was further elaborated by Michael Canale and Merrill Swain, providing a basis for evaluating language learners' ability to use language effectively in context (Canale & Swain, 1980). Within this framework, TBLT is considered particularly effective, as it creates opportunities for learners to engage in authentic communication and negotiate meaning.

A substantial body of empirical research has investigated the effectiveness of TBLT in developing communicative competence. Studies have shown that task-based instruction can enhance learners' fluency, interactional competence, and pragmatic awareness (Bygate, 2016; Ellis, 2017). For instance, task repetition and planning have been found to improve both accuracy and complexity in learners' language production (Ahmadian & Tavakoli, 2011). Similarly, research indicates that TBLT fosters greater learner engagement and promotes deeper cognitive processing compared to traditional form-focused instruction (Robinson, 2011). However, the literature also

reveals several challenges and limitations associated with the implementation of TBLT. One major issue concerns the difficulty of balancing fluency and accuracy, as task-based approaches may prioritize communication at the expense of grammatical precision (Skehan, 2014). Additionally, teachers often face constraints related to curriculum requirements, assessment practices, and insufficient training in task design, which can hinder effective implementation (Butler, 2011). These challenges are particularly evident in contexts where examination-oriented systems dominate language education. Another important strand of research focuses on the role of technology in enhancing TBLT. The integration of digital tools and online platforms has expanded the possibilities for task design and interaction, enabling learners to engage in multimodal and collaborative activities (González-Lloret & Ortega, 2014). Technology-mediated TBLT has been shown to support communicative competence by providing authentic communication environments and facilitating interaction beyond the classroom. Despite the growing volume of research, the field remains fragmented, with studies varying widely in terms of context, methodology, and theoretical orientation. There is a lack of comprehensive synthesis that systematically maps the development of research on TBLT and communicative competence. In this regard, bibliometric analysis offers a valuable approach to identifying trends, influential works, and research gaps within the literature. By examining publications indexed in databases such as Scopus, researchers can gain insights into the evolution and structure of the field, thereby contributing to a more integrated understanding of TBLT effectiveness.

Research Methods

This study employs a quantitative bibliometric approach to systematically analyze the scientific literature on Task-Based Language Teaching and communicative competence. Bibliometric analysis is widely used to evaluate the structure, development, and impact of research fields through statistical and visualization techniques applied to large datasets of academic publications. The data for this study were retrieved from the Scopus database, which is recognized as one of the most comprehensive sources of peer-reviewed literature. The search was conducted using the following query:

TITLE-ABS-KEY ("Task-Based Language Teaching" AND "Communicative Competence") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))

The study follows a structured and transparent bibliometric methodology, incorporating elements of the PRISMA (Figure 1) framework to ensure rigor in the identification, screening, and

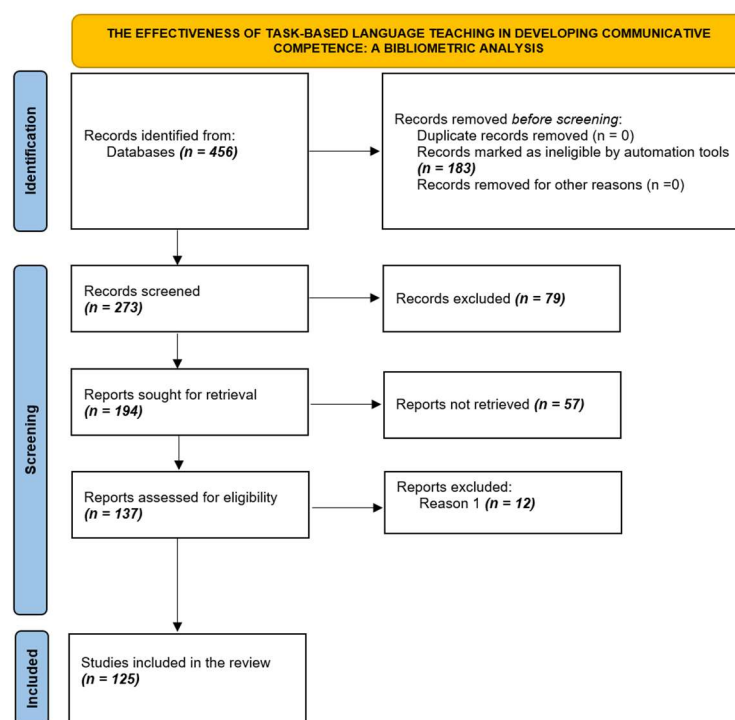


Figure 1. PRISMA flow diagram of the study selection process for bibliometric analysis

inclusion of relevant studies.

The initial dataset was obtained from the Scopus database using a predefined search query focused on Task-Based Language Teaching and communicative competence. A total of 456 records were identified at the identification stage. Prior to screening, duplicate records were removed, and irrelevant studies were excluded using automated filtering tools, resulting in the removal of 183 records. The remaining 273 articles were subjected to a screening process based on titles and abstracts, during which 79 records were excluded due to lack of relevance to the research topic. Subsequently, 194 full-text reports were sought for retrieval; however, 57 reports were not accessible. This resulted in 137 studies being assessed for eligibility through full-text review. During the eligibility phase, studies were evaluated against the inclusion criteria, focusing on their direct relevance to both Task-Based Language Teaching and communicative competence, as well as their empirical or theoretical contribution to the field. As a result, 12 studies were excluded due to insufficient alignment with the research objectives. Ultimately, a final sample of 125 articles was included in the bibliometric analysis. The selected dataset was then processed using specialized bibliometric tools, including VOSviewer and RStudio (bibliometrix package), to conduct quantitative and network-based analyses. The study examined publication trends, citation structures, co-authorship networks, and keyword co-occurrence patterns. In addition, thematic mapping techniques were applied to identify core research clusters and emerging topics within the field. The integration of the PRISMA approach enhances the transparency and reproducibility of the study selection process, while the use of bibliometric tools ensures a comprehensive and systematic exploration of the scientific literature. This combined methodology enables a robust analysis of the evolution, structure, and research dynamics of studies on Task-Based Language Teaching and communicative competence.

Results

To identify the most influential contributions within the field of TBLT and communicative competence, a citation analysis was conducted on the selected dataset. Citation metrics serve as a key indicator of scientific impact, enabling the identification of widely recognized studies that have significantly shaped the development of the research domain. In bibliometric research, highly cited publications often reflect theoretical advancements, methodological innovations, or emerging trends that influence subsequent studies. Therefore, examining the most cited articles provides insight into the intellectual structure and evolution of the field. The results of this analysis are presented in Table 1, which lists the 10 most-cited studies based on the number of citations indexed in Scopus.

Table 1. Top 10 Most Cited Studies on the Effectiveness of Task-Based Language Teaching in Developing Communicative Competence

No	Document Title	Authors	Source	Year	Citations
1	Willingness to Communicate, Speaking Self-Efficacy, and Perceived Communicative Competence as Predictors of Second Language Spoken Task Production	Leeming, P.; Vitta, J.P.; Hiver, P.; McLean, S.; Nicklin, C.	<i>Language Learning</i>	2024	31
2	Enhancing multimodal interaction and communicative competence through task-based language teaching (TBLT) in synchronous computer-mediated communication (SCMC)	Belda-Medina, J.	<i>Education Sciences</i>	2021	30
3	Task-based language teaching and theme-based role-play: Developing EFL learners' communicative competence	Waluyo, B.	<i>Electronic Journal of Foreign Language Teaching</i>	2019	27
4	Revisiting functional adequacy and task-based language teaching in the GBA: insights from translanguaging	Bui, G.; Tai, K.W.H.	<i>Asian Pacific Journal of Second and Foreign Language Education</i>	2022	26
5	Implementing computer-assisted task-based language teaching in the Korean secondary EFL context	Park, M.	<i>Task-Based Language Teaching</i>	2012	23
6	What do second language speakers really need for real-world interaction? A needs analysis of L2 Chinese interactional competence	Dai, D.W.	<i>Language Teaching Research</i>	2026	21

7	Implementing task-based language teaching in Vietnamese secondary schools: What hinders EFL teachers?	Duong, T.M.; Nguyen, H.T.T.	<i>TESL-EJ</i>	2021	19
8	Language teaching and task based approach	Rozati, S.M.	<i>Theory and Practice in Language Studies</i>	2014	6
9	Improving Students' Speaking Skills in Engineering Colleges Through Task-Based Language Teaching	Basireddi, R.; Dasam, S.; Anumula, V.S.S.; Bolleddu, S.N.; Suvarna, L.K.	<i>Theory and Practice in Language Studies</i>	2025	3
10	The effectiveness of task-based language teaching in improving communicative competence	Chunliu, X.; Guangsheng, L.	<i>International Journal of Advanced and Applied Sciences</i>	2025	3

As shown in Table 1, the most cited publications demonstrate a strong emphasis on the relationship between TBLT and key components of communicative competence, including speaking performance, interactional ability, and learner-related variables. The leading study by Leeming et al. (2024) highlights the predictive role of psychological constructs such as willingness to communicate and self-efficacy, indicating a growing research interest in the affective dimension of language learning. Another important trend evident in Table 1 is the increasing integration of technology into TBLT research. For instance, Belda-Medina (2021) explores the effectiveness of synchronous computer-mediated communication, reflecting the shift toward digital and multimodal learning environments. Similarly, several studies focus on pedagogical innovations such as role-play, translanguaging, and computer-assisted instruction, demonstrating the adaptability of TBLT across different instructional contexts. Furthermore, Table 1 reveals that the majority of highly cited studies have been published in recent years, particularly after 2019, which suggests that the field is rapidly expanding and gaining scholarly attention. At the same time, earlier works, such as Park (2012), continue to receive citations, highlighting their foundational role in the development of TBLT research.

To provide a more nuanced understanding of the geographical distribution of research on TBLT and communicative competence, the country-level data were visualized using RStudio with bibliometric mapping techniques. A choropleth world map was generated to illustrate the intensity of scientific output across countries, complemented by a categorical classification of publication activity. The results reveal a highly uneven global distribution of research output. The United States leads significantly with 33 publications, confirming its dominant role in shaping research trends and theoretical developments in TBLT. It is followed by China (21 documents) and Canada (16 documents), indicating strong contributions from both North America and East Asia. A second cluster of productive countries includes India (14), Japan (13), Thailand (13), and Australia (13). This suggests that Asia-Pacific regions play a central role in advancing empirical research on communicative competence, particularly in EFL contexts. The strong presence of countries such as Japan and Thailand reflects the educational importance of communicative approaches in these regions. European contribution appears more moderate, with Spain (9 documents) as the primary contributor, while other countries such as Portugal and the Russian Federation show minimal output. Similarly, representation from regions such as Africa (Morocco) and Latin America (Colombia) remains very limited, highlighting a significant geographical imbalance in the literature. Of particular relevance is the presence of emerging contributors such as Kazakhstan (3 documents) and South Korea (3 documents), indicating a gradual expansion of

research activity into new academic contexts. However, many countries including Iraq, Kyrgyzstan, Indonesia, and Trinidad and Tobago are represented by only a single publication, suggesting underdeveloped research engagement in these regions. Overall, the global distribution demonstrates that research on TBLT and communicative competence is concentrated in a relatively small number of countries, with a clear dominance of developed and education-intensive regions. This imbalance points to a critical research gap and underscores the need for broader geographical representation in future studies.

The temporal analysis of authors' productivity provides important insights into the evolution and dynamics of research activity within the field of Task-Based Language Teaching and communicative competence. As illustrated in Figure 2, the distribution of publications over time demonstrates both continuity and emerging scholarly engagement across different periods.

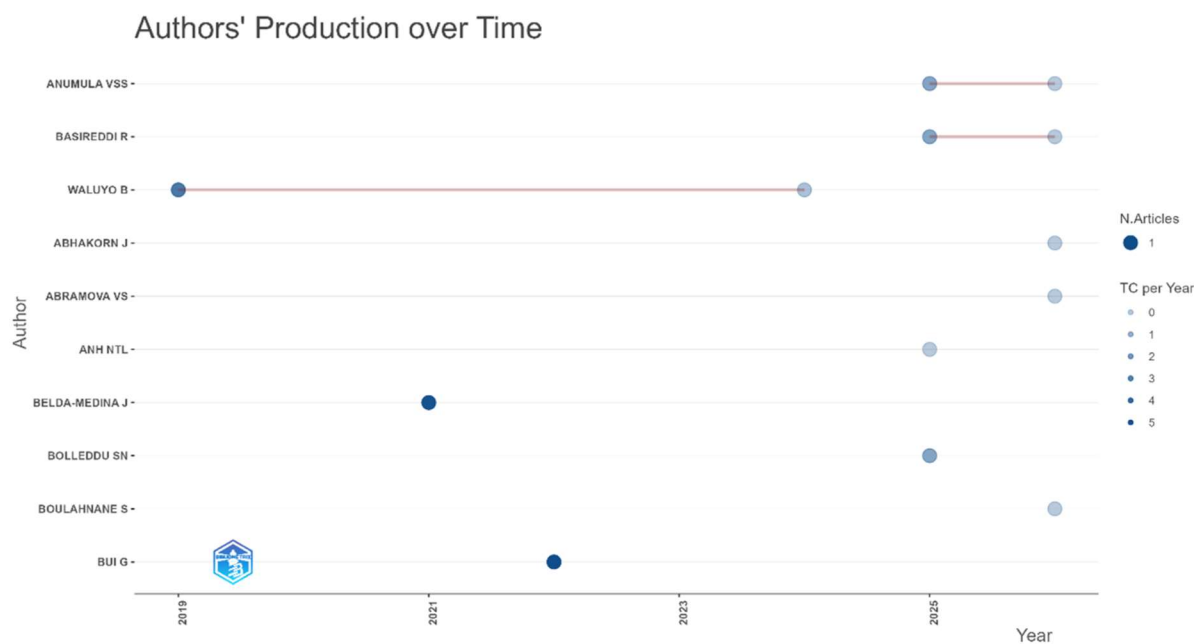


Figure 2. Authors' scientific production over time in TBLT and communicative competence research

The figure reveals that earlier contributions, such as those by Waluyo (2019), represent foundational research that has maintained relevance over time, as indicated by continued citation presence in later years. This suggests that initial empirical studies played a significant role in establishing the research direction of TBLT-focused communicative competence. A noticeable increase in author productivity can be observed from 2021 onwards. For instance, Belda-Medina (2021) marks the beginning of a more active phase characterized by the integration of digital and multimodal approaches. This aligns with broader trends in language education, where technology-enhanced learning environments have become increasingly important. The most intensive research activity appears in the period between 2024 and 2026, where multiple authors including Basireddi, Anumula, and Bolleddu demonstrate concurrent publication outputs. This clustering effect indicates a growing academic interest and possibly the formation of research groups or collaborative networks focusing on TBLT applications in specific contexts such as engineering education and EFL environments. Another important observation is the relatively limited number of publications per author, as most contributors appear with a single publication. This suggests that the field is still developing and is characterized by a dispersed authorship structure rather than a small group of highly prolific researchers. Such a pattern is typical of emerging research domains where scholarly participation is expanding but has not yet reached consolidation.

The thematic map presented in Figure 3 illustrates the conceptual structure of research in the field of Task-Based Language Teaching and communicative competence, based on the co-occurrence of keywords. The map is divided into four quadrants according to two dimensions: centrality (relevance degree) and density (development degree), which together indicate the importance and maturity of research themes.

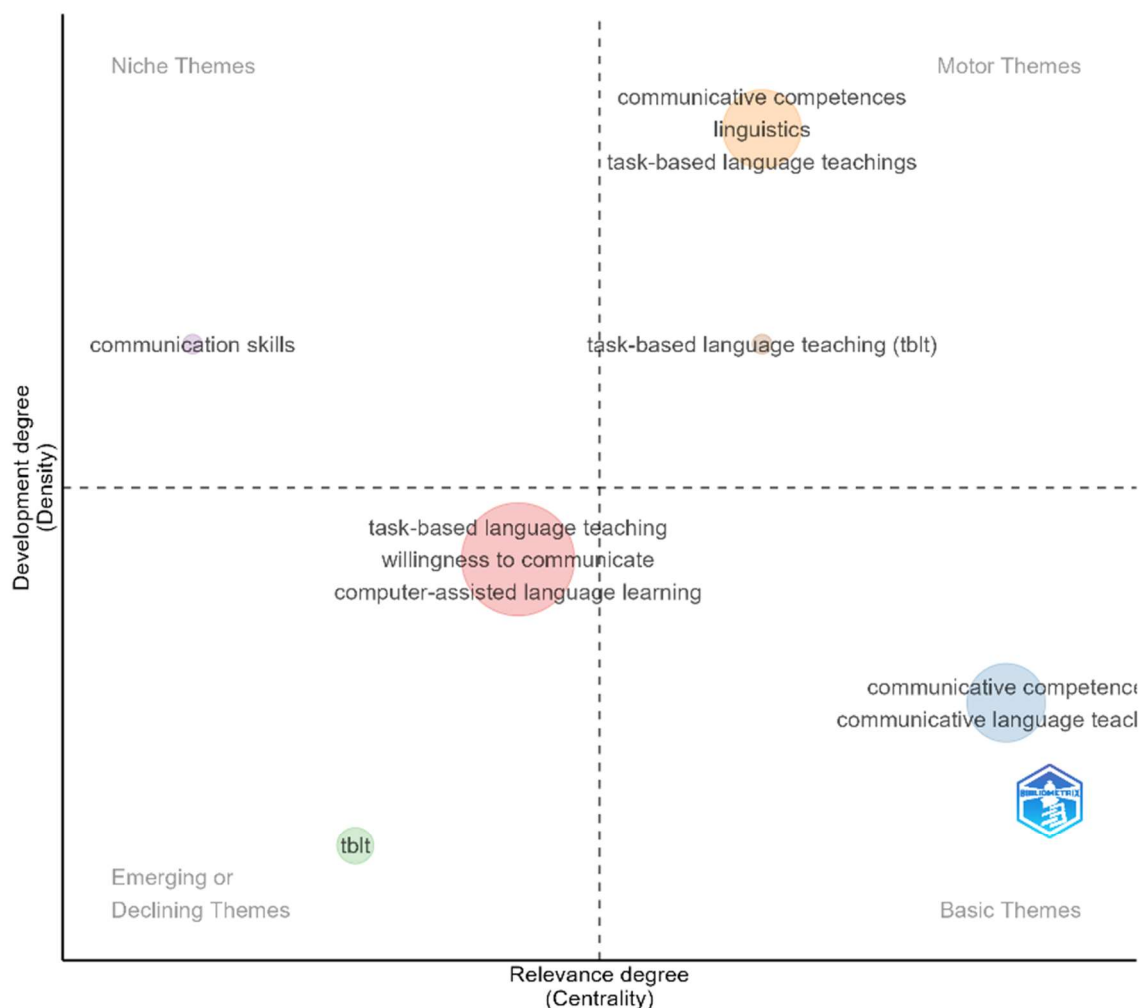


Figure 3. Thematic map of research on task-based language teaching and communicative competence

The **motor themes** (upper-right quadrant) represent well-developed and highly relevant topics that drive the field forward. In this study, key themes such as *communicative competence*, *linguistics*, and *task-based language teaching* are located in this quadrant. Their position indicates that these topics are both conceptually strong and central to the research domain, forming the theoretical and empirical core of current studies.

The **basic themes** (lower-right quadrant) include *communicative competence* and *communicative language teaching*, which are highly relevant but less developed in terms of internal cohesion. These themes serve as foundational concepts that underpin the field but require further theoretical refinement and empirical expansion.

In the **niche themes** quadrant (upper-left), topics such as *communication skills* appear. These themes are well-developed internally but have limited connections to the broader research field. This suggests that while these areas are specialized and mature, they remain somewhat isolated from mainstream TBLT research.

The **emerging or declining themes** (lower-left quadrant), such as *TBLT* as an isolated keyword, indicate areas that are either newly developing or losing relevance. Their low centrality and density suggest that these topics are not yet fully integrated into the core research structure or may represent shifting terminologies within the field.

A particularly notable cluster appears near the center of the map, including *task-based language teaching*, *willingness to communicate*, and *computer-assisted language learning*. This cluster reflects an intersection of pedagogical, psychological, and technological dimensions, indicating an emerging interdisciplinary direction in recent research.

Discussion

The findings of this bibliometric analysis provide important insights into the development, structure, and current directions of research on TBLT and communicative competence. Overall, the results confirm that the field is dynamic but still in the process of consolidation, which is consistent with the research problem identified earlier. First, the citation analysis demonstrates that the most influential studies increasingly focus on the integration of psychological and learner-related variables, such as willingness to communicate and self-efficacy. This aligns with earlier theoretical perspectives emphasizing the role of interaction and learner engagement in language acquisition (Ellis, 2017; Long, 2015). The prominence of such variables suggests a shift from purely structural approaches toward more holistic models of communicative competence, supporting the multidimensional framework proposed by Canale and Swain (1980). At the same time, this trend reflects Robinson's (2011) cognitive perspective, which highlights the importance of task complexity and learner processing in language performance. Second, the growing presence of technology-oriented studies particularly those involving computer-mediated communication confirms the increasing relevance of digital environments in TBLT research. This finding is consistent with previous studies emphasizing the role of technology in enhancing interaction, authenticity, and learner autonomy (González-Lloret & Ortega, 2014). The emergence of clusters combining TBLT, willingness to communicate, and computer-assisted language learning (Figure 3) indicates a clear interdisciplinary shift, where pedagogical, psychological, and technological dimensions intersect. This development extends earlier work by Bygate (2016), who noted the expansion of TBLT into new domains and modalities. Third, the geographical analysis reveals a strong concentration of research output in a limited number of countries, particularly the United States, China, and several Asia-Pacific regions. This supports Butler's (2011) observation that TBLT implementation and research are often shaped by regional educational priorities and policy frameworks. However, the limited representation of developing regions highlights a significant gap in the literature. The presence of emerging contributors such as Kazakhstan suggests a gradual diversification of research contexts, yet the overall imbalance raises concerns about the generalizability of findings across different sociocultural environments.

Furthermore, the analysis of authors' productivity indicates that the field is characterized by dispersed authorship, with most researchers contributing only a small number of publications. This pattern suggests that TBLT research has not yet reached a stage of full academic maturity, where a stable core of highly prolific scholars dominates the field. Instead, the increasing number of contributors in recent years reflects expanding interest and growing accessibility of the research area. The thematic analysis further supports these conclusions by revealing a well-defined conceptual core alongside emerging and peripheral themes. The positioning of communicative competence and TBLT as motor themes confirms their central role in the field, consistent with the foundational theories of Hymes and later developments by Savignon (2018). At the same time, the presence of niche and emerging themes such as communication skills and isolated TBLT-related terms indicates ongoing conceptual diversification and possible shifts in research focus. Notably, the identification of emerging themes related to technology and learner psychology suggests that future research is likely to move toward more integrated and interdisciplinary frameworks.

However, the findings also highlight several persistent challenges. The variability in conceptualizations of communicative competence and the diversity of research methodologies continue to limit comparability across studies, as previously noted in the literature (Ellis, 2017; Skehan, 2014). Additionally, the relatively moderate citation counts of even the most influential studies indicate that the field is still developing and has not yet achieved a high level of theoretical or empirical consolidation.

In summary, the results of this study both support and extend existing research. They confirm the effectiveness of TBLT as a communicative approach while also revealing significant gaps related to geographical representation, methodological consistency, and thematic integration. These findings underscore the need for more longitudinal, context-sensitive, and interdisciplinary studies to advance the field and strengthen the evidence base for TBLT in developing communicative competence.

Conclusion

This study set out to provide a comprehensive bibliometric analysis of research on TBLT and its effectiveness in developing communicative competence. By examining publications indexed in Scopus, the study identified key trends, influential works, geographical distribution patterns, and thematic structures that characterize the current state of the field. The findings demonstrate that research on TBLT and communicative competence has experienced noticeable growth, particularly in recent years, indicating increasing scholarly interest and relevance. Citation analysis revealed that contemporary studies are increasingly oriented toward learner-centered variables, including psychological factors such as willingness to communicate and self-efficacy, as well as the integration of digital and multimodal learning environments. These trends reflect a shift toward more holistic and interdisciplinary approaches to language teaching. At the same time, the study identified significant imbalances in the geographical distribution of research, with a concentration of publications in a limited number of countries. This highlights the need for broader international representation to ensure the generalizability and contextual relevance of findings. Furthermore, the analysis of authorship patterns suggests that the field is still in a stage of development, characterized by a dispersed research community rather than a consolidated group of leading scholars. The thematic analysis confirmed the central role of TBLT and communicative competence as core research areas while also revealing emerging themes related to technology integration and learner psychology. However, the presence of fragmented and less-developed themes indicates that further conceptual and methodological refinement is required. The study contributes to the field by providing a systematic and evidence-based overview of the scientific landscape of TBLT research. It highlights both the strengths and limitations of existing studies and offers directions for future research. In particular, there is a need for more longitudinal studies, greater methodological consistency, and increased attention to underrepresented regions and contexts. In conclusion, while TBLT continues to demonstrate strong potential as an effective approach for developing communicative competence, its full impact can only be understood through more integrated, diverse, and context-sensitive research efforts.

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ELISION OF CONSONANT PHONEMES IN ENGLISH

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Abstract. Words that are pronounced in isolation differ from the pronunciation of those same words in a sentence depending on speech rate, whether they are used in stressed or unstressed positions, the degree to which they undergo reduction, and even on who is speaking. It should be noted that when words are pronounced outside a phonetic context, they are heard in an ideal form in accordance with phonetic transcription; however, in the flow of connected speech we can hear altered and reduced pronunciation variants. To a certain extent, sounds influence one another during the speech process. In this regard, the influence of vowel phonemes on consonants, consonants on vowels, and consonants on one another gives rise to a number of phonetic processes in speech. These processes include elision, assimilation, accommodation, and reduction.

Key words: elision, consonants, plosives, reduction, pronunciation

Annotation. When studying the pronunciation features of English, which has a complex phonetic structure, it is important to learn not only the vocabulary and grammar of the language, but also its phonetic aspects, in other words, the phonetic peculiarities of pronunciation and sound changes. When pronouncing words consisting of more than one sound, sounds undergo changes according to certain phonetic rules. These rules may be the same or different across languages, and some rules may be characteristic of particular languages.

Introduction. It is important to understand the mechanism by which sounds interact with one another. Language used in everyday communication is realized in connected speech in words, phrases, and sentences. The differences between the pronunciation of words in isolation and their pronunciation within a sentence become evident in this context. A number of sound changes manifest themselves both within a word and at word boundaries. Consonant and vowel sounds influence one another during the speech process. In this position a number of phonetic processes occur in connected speech. These processes include elision, assimilation, accommodation, reduction etc.

Elision is one of the phonetic phenomena which is widely used by native speakers. For example, some suffixes used in English, although belonging to different parts of speech, are pronounced with the same sounds. Their abbreviated written forms make it difficult to determine which suffix is being used. Especially when different words are represented by the same phonemes, words with different meanings may turn into words *has*, *is*, and *does*. It is also the pronunciation of the plural suffix of nouns and the suffix taken by verbs in the third person singular.

At first glance, the semantic load carried by a single sound is quite large. However, ambiguity and uncertainty are rarely observed. In this case, the semantic function of the words involved comes to our aid, and context provides clarification. For example, when we hear the sentence:

/ɪz 'nɪk kʌmɪŋ/ we naturally understand it as “Is Nick coming?”

Or: “The boy has done it” – /ðə 'bɔɪ həz dʌnɪt/ may be perceived as /ðə 'bɔɪ z dʌnɪt/, meaning “the boys did it” instead of “the boy did it.”

When speaking about the semantic significance of a word, it should be noted that the presence of elision directly depends on the meaning the word carries - in other words, whether it

is a content word or a function word. This factor is more important than others, because elision occurs more frequently and is more commonly used in function words than in content words.

The more frequent use of elision in function words can be explained by the fact that such elements do not carry essential information and therefore do not damage the meaning of speech; their omission does not lead to a change in sentence meaning. These function words include articles, conjunctions, prepositions, particles, various types of pronouns, auxiliary and modal verbs, and so on. In sentences, they are usually unstressed and only faintly audible. Since such elements do not convey core meaning and serve primarily grammatical functions, they are unstressed and during speech, are easily weakened, reduced, and may even be omitted.

By contrast, content words-nouns, adjectives, numerals, pronouns, adverbs, and verbs are stressed and have clear pronunciation, as they serve to convey the main idea. In content words, the loss of certain sounds may occur only when the words used are well known to the listener and when the omission of these sounds does not cause any difficulty in communication.

Thus, sound changes do not serve only certain articulatory conditions; they also contribute to changes in the semantic sphere of morphemes and words, to grammatical changes at various levels, and to mutual intelligibility between languages and dialects. The reasons for these changes should not be sought solely in articulatory mechanisms, but rather in the historical conditions of a language's development, as well as at the grammatical and semantic levels. The change or loss of segments as a result of elision does not cause difficulty in individual words. However, within a sentence, it may create difficulties and misunderstandings that can disrupt communication. For example:

And that's not all that's the matter. /ænd 'ðæts 'nɒt 'ɔ:l ðæts ðə 'mætə//
may be pronounced as /næs 'nɒt 'ɔ:l əts ə 'mætə/.

As a rule, native speakers do not experience problems understanding such changes. Even if they come from different English-speaking countries or speak different dialects, this shortened and modified speech remains clear to them. Native speakers usually perceive such speech easily and can even infer similar or reduced words from context. For example, despite their phonetic similarity, they can distinguish between:

sport /spɔ:t/ "sport" and *support* /sə'pɔ:t/ "to support."

They identify words depending on the situation with the help of certain expressions. In addition, both linguistic and extralinguistic factors assist them in understanding information. However, pronunciation norms modified at the segmental level are difficult to perceive for learners of English as a foreign language.

The phonetic phenomenon opposite to elision is epenthesis. This occurs in the form of adding extra sounds in order to facilitate pronunciation. Elision cannot be understood as the loss of whole words within a sentence; rather, it involves only the loss or modification of sounds.

If a language user is not a native speaker and is not preparing to teach the language, there is no need to recall linguistic terminology. Such speakers may also avoid using words affected by elision. Elision is not an essential phenomenon in speech: a person can express their thoughts slowly, fluently, and clearly without it.

The use of elision is individual and may vary depending on circumstances. Nevertheless, learning these changes, improving auditory perception during pronunciation, recognizing modified sounds, and better understanding English speech are important and necessary. In other words, understanding these changes is a crucial factor in comprehending natural spoken language. Knowing words that have been modified under the influence of elision facilitates the perception of speech structure. From this, it can be concluded that when perceiving spoken language, it is essential to learn not only lexical and grammatical knowledge, but also the phonetic aspects of the language and sound changes.

During communication with native speakers, a number of phonemes that are expected to be heard are lost and not pronounced. This can lead to confusion and misunderstanding in the language being learned. Linda Shockey notes that everyone who speaks the national varieties of English uses elision, but they rarely acknowledge it, because it occurs automatically and unconsciously. When this phenomenon is pointed out or demonstrated to them, they admit-often reluctantly and out of necessity, that they do use it. She further concludes that a close study of spontaneous spoken discourse shows that elision exists in an unusual and even excessive degree [17, p. 234].

Other scholars, E. A. Buraya and U. E. Galochkina argue that foreign language learners must study the interaction and mutual influence of sounds specific to the target language and follow these patterns in their own speech. Avoiding such interactions leads to the emergence of different accents and creates difficulties in understanding the speaker, which in turn complicates communication [3, p. 93].

In spontaneous spoken discourse, we rarely pronounce words in their full form, with all phonetic features preserved and all phonetic rules strictly observed. During communication, words follow one another in sequence, so they are not pronounced in isolation with each sound articulated precisely. Instead, the sequence of words flows like a melody. E. A. Buraya notes that pronouncing words in sentence form while preserving all their phonetic features would be unnatural in spontaneous connected speech, because in the communicative process we pronounce not individual words but sequences of sounds and their combinations [3, p. 88]. From this, it can be concluded that in connected speech words are pronounced differently from their dictionary forms.

Word forms affected by elision are not reflected in pronunciation dictionaries, as they require special symbols and additional explanatory commentary. In the *Cambridge English Pronouncing Dictionary*, D. Jones presents the most widespread and salient cases of elision, marking the sounds that are lost or omitted in parentheses. For example, the plosive /d/ following the apical alveolar nasal /n/ is not pronounced. This change is represented in the dictionary as follows:

landscape /'læn(d)skeɪp/

friendship /'fren(d)ʃɪp/

As Linda Shockey emphasizes, when learning a language it is important not only to see with one's eyes, but also to hear with one's own ears [17, p. 230].

In English, the elision of consonants is related to assimilatory factors, whereas the elision of vowels is associated with the nature of dynamic stress. Zeynalov F. H. and Mammadova Ə. O. define elision as the loss of a sound in a phonetic environment or the replacement of a phoneme with its zero variant. According to the authors, English words and word combinations are characterized by a wide range of consonant clusters: within a single word or at the junction of two words, three, four, five, or even six consonants may occur consecutively [18, p. 130].

For example: *simpletons* /'sɪmpltɪnz/

Therefore, when three plosive consonants or a combination of two plosives and one sonorant occur within a word or at a word boundary, there is a strong tendency for the medial plosive to be elided. Elision at word boundaries is more characteristic of informal or free style speech.

The elision of the consonants /t, d/ at word boundaries is conditioned by the pronunciation of the *-ed* ending as /t/ or /d/ in word-final position and the presence of a consonant at the beginning of the following word. Consonant elision at word boundaries closely resembles the phenomenon of loss of plosion, but these two processes should not be equated. In loss of plosion, the third phase of the consonant merges into the first phase of the following consonant, whereas in elision none of the phases of the sound are realized in pronunciation. For example:

next day /neks deɪ/ ; *listen* /'lɪsn/ (elision)

asked /ɑːskt/ ; *blackboard* /'blækbɔːd/ (loss of plosion)

Within consonant clusters that occur inside a single word, the omission of medial /t, d/ sounds (unlike /t, d/ elision at word boundaries) has become an orthoepic pronunciation norm.

In English, the phoneme /h/ tends to undergo elision when it occurs in the middle of a sentence in an unstressed position and is often dropped in rapid speech. For example: *tell him* /tel hɪm/ → /tel ɪm/

However, the omission of /h/ at the beginning of a sentence or in a stressed position is excluded. The most important factor causing vowel elision in English is stress. Vowel elision can occur both within words and within sentences. Within a word, vowel loss is observed in all three positions: word-initial (anlaut), word-medial (inlaut), and word-final (auslaut).

In word-final position (auslaut), the loss of a vowel between two consonants has, to a certain extent, become an orthoepic pronunciation norm. Thus, double pronunciation variants of such words are considered acceptable.

Word-initial (anlaut) vowel elision is characteristic of informal or free style speech and is not regarded as a norm. In the unstressed initial syllables of certain words, the elision of the vowel /ə/ allows sonorant consonants to become syllabic. For example:

fanatic /fə'nætɪk/ → /f'nætɪk/ ; *tomato* /tə'mɑ:təʊ/ → /t'mɑ:təʊ/

Vowel elision in word-medial (inlaut) position also occurs in informal speech and is considered acceptable. For example: *similar* /'sɪmɪlə/ → /'sɪmlə/

Within sentences, vowel elision most frequently occurs in statements, typically in unstressed auxiliary and modal verbs, as well as in the unstressed pronunciation of the negative particle *not* when it is attached to auxiliary or modal verbs. Elision is also observed in poetry. In this case, vowels are sometimes omitted to maintain an equal number of syllables within poetic lines. Graphically, vowel omission is marked by an apostrophe ('). For example:

'tis instead of *it is*; *e'en* instead of *even*.

The fact that vowels and sonorants are only rarely subject to elision is directly related to the dominance of voice and resonance in their articulation, as well as to their syllable-forming properties. Studying elision is important for learners of a foreign language. First, they must recognize sounds that have undergone elision, often referred to in English as "silent letters." For example:

sign /saɪn/ ; *comb* /kəʊm/ ; *knee* /ni:/
write /raɪt/ ; *hour* /'aʊə/ ; *honour* /'ɒnə/

Second, learners should understand that in native speakers' speech certain sounds are not pronounced and are therefore lost, and they should take this into account during communication. The omission of certain sounds in speech continues only up to a certain point. In other words, if the conveyed information becomes unclear or distorted and the listener has difficulty understanding the idea, communication breaks down. At this point, the process of elision automatically ceases. In such situations, elided meanings become clear from the context, and certain expressive forms help clarify the message.

When learning English, it is not essential to pronounce the modified forms of words, since they may not always be present in speech. Words can be pronounced more clearly, precisely, and slowly. However, learning to recognize these forms and becoming accustomed to them is crucial for understanding naturally sounding speech.

Knowing the modified forms that arise from the interaction of sounds and being able to understand changes caused by various phonetic phenomena facilitate communication.

Conclusion. From the above, we may conclude that in order to understand spoken language, it is not sufficient to possess only lexical and grammatical knowledge. Along with these, learning the phonetic difficulties of pronunciation and the modified forms of speech is a fundamental condition for achieving mutual understanding and successful communication in a foreign language.

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Philological Sciences

APPLYING ARTIFICIAL INTELLIGENCE TECHNOLOGIES TO ENHANCE THE INFORMATION AND COMMUNICATION COMPETENCE OF PRE-SERVICE ENGLISH TEACHERS: A BIBLIOMETRIC ANALYSIS

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Abstract

The rapid advancement of artificial intelligence technologies has significantly transformed educational environments, creating new demands for the development of information and communication competence among pre-service teachers. This study aims to conduct a comprehensive bibliometric analysis of scientific publications on the application of AI technologies in enhancing the ICC of pre-service English teachers. The data were retrieved from the Scopus database using a structured search strategy, and the study selection followed the PRISMA framework. A total of 95 peer-reviewed articles published between 2017 and 2025 were included in the analysis. The study employs bibliometric methods, including publication trend analysis, citation analysis, geographical distribution analysis, and keyword co-occurrence analysis, to identify major research trends, influential contributions, and thematic structures in the field. The results indicate a rapid increase in research output since 2018, reflecting the growing importance of AI in education. The findings reveal a shift from traditional digital competence toward more advanced AI-related competencies, including generative AI, prompt engineering, and AI literacy. The geographical analysis demonstrates a concentration of research in developed countries, particularly the United States, Canada, and European nations, while developing regions remain underrepresented. The keyword analysis highlights artificial intelligence as the central concept connecting multiple research themes, including teacher education, higher education, and educational technology. Despite the expanding body of literature, the study identifies a significant research gap in the specific context of pre-service English teacher education. The findings underscore the need for integrating AI competencies into teacher education programs and developing more comprehensive theoretical frameworks that incorporate technological, pedagogical, and ethical dimensions.

Keywords: artificial intelligence; digital competence; information and communication competence; pre-service English teachers; teacher education; bibliometric analysis.

Introduction

Relevance of the study. The rapid digital transformation of education in the 21st century has significantly increased the importance of integrating emerging technologies, particularly artificial intelligence (AI), into teaching and learning processes. AI is widely recognized as a transformative force capable of enhancing educational quality, supporting personalized learning, and enabling data-driven pedagogical decision-making. Recent studies emphasize that AI technologies are reshaping teachers' professional roles and competency frameworks, requiring educators to develop not only digital literacy but also advanced information and communication competence (ICC) to effectively operate in technology-rich environments (Zawacki-Richter et al., 2019; Holmes et al., 2019). In this context, the preparation of pre-service English teachers is particularly important, as language education is inherently linked to communication, digital interaction, and the use of technological tools. Research demonstrates that the successful integration of AI in education largely depends on teachers' technological readiness, pedagogical flexibility, and their ability to critically engage with digital tools and AI-driven systems (Zhai et al., 2021; Chiu et al., 2023). However, empirical findings indicate that many pre-service teachers lack sufficient knowledge and practical experience related to AI applications, which limits their capacity to integrate these technologies effectively into their future professional practice (Ng et al., 2021; Scherer et al., 2021). At the same time, the development of ICT competence remains a fundamental component of teacher professionalism in the digital age. Despite the growing body of research on digital competence, studies reveal that pre-service teachers often demonstrate a fragmented understanding of technology integration, focusing predominantly on technical skills rather than pedagogically meaningful applications (Tondeur et al., 2017; Instefjord & Munthe, 2017). The emergence of AI further complicates this issue, as it requires the integration of technological, pedagogical, and ethical dimensions of competence. Moreover, the increasing volume of scholarly publications highlights the growing academic interest in AI in education. Bibliometric and systematic reviews indicate a rapid expansion of research in this field since 2018, with key themes including AI literacy, adaptive learning systems, and teacher professional development (Zawacki-Richter et al., 2019; Chen et al., 2020). Nevertheless, there remains a lack of focused bibliometric studies that specifically examine the role of AI technologies in enhancing the information and communication competence of pre-service English teachers, particularly using large-scale international databases such as Scopus. The relevance of this study lies in the need to systematically map the scientific landscape, identify key research trends, and reveal existing gaps in the field of AI applications for the development of information and communication competence among pre-service English teachers. Conducting a bibliometric analysis using Scopus data will deepen understanding of the evolution of this research domain and provide a solid foundation for future theoretical and empirical investigations.

Research gap. Although the integration of artificial intelligence (AI) in education has been extensively explored in recent years, the existing body of literature reveals several critical gaps. First, most studies focus on general applications of AI in education or higher education contexts, with limited attention to the specific domain of pre-service English teacher education. Second, while information and communication competence (ICC) has been widely studied, there is insufficient conceptual and empirical integration of AI technologies within this competence framework. Third, existing research is often fragmented, lacking a systematic synthesis of global scientific output. In particular, there is a scarcity of comprehensive bibliometric studies that map the intellectual structure, research trends, and thematic evolution of AI applications in developing ICC among pre-service English teachers using large-scale international databases such as Scopus.

The aim of this study is to conduct a comprehensive bibliometric analysis of scientific publications on the application of artificial intelligence technologies in enhancing the information and communication competence of pre-service English teachers.

The study is guided by the following research questions: *What are the main publication trends in research on AI and ICC in pre-service English teacher education?*

The novelty of this study lies in its comprehensive, systematic approach to analyzing the role of AI technologies in the development of ICC among pre-service English teachers. Unlike previous studies, this research:

- focuses specifically on pre-service English teacher education;
- integrates the concepts of AI and ICC within a unified analytical framework;
- employs bibliometric methods to map the global research landscape;
- utilizes data from Scopus to ensure a high level of scientific reliability and coverage.

Significance of the study. This study makes several important contributions to the field of educational research. Theoretically, it provides a systematic understanding of the intersection between artificial intelligence and information and communication competence in teacher education. Methodologically, it demonstrates the value of bibliometric analysis as a tool for mapping scientific knowledge and identifying research trends. Practically, the findings can inform curriculum design, teacher training programs, and policy development aimed at integrating AI technologies into pre-service English teacher education.

Literature Review

The integration of artificial intelligence into education has emerged as a rapidly expanding field of research, attracting significant scholarly attention over the past decade. AI technologies are increasingly recognized for their potential to transform teaching and learning processes by enabling adaptive learning environments, intelligent tutoring systems, and data-driven educational decision-making. Systematic reviews indicate that AI applications in education primarily focus on profiling and prediction, assessment and evaluation, adaptive systems, and personalization, highlighting the multidimensional impact of AI on educational practices (Zawacki-Richter et al., 2019). Furthermore, empirical studies demonstrate that AI can significantly enhance learning outcomes, improve efficiency, and support personalized instruction, thereby contributing to the overall quality of education (Zhang et al., 2021; Wang et al., 2024). At the same time, the growing body of literature emphasizes that the successful implementation of AI in education depends heavily on teachers' competencies and their readiness to integrate these technologies into pedagogical practice. Researchers argue that despite the increasing availability of AI tools, educators often lack sufficient understanding of how to effectively apply them in teaching and learning contexts. In particular, studies highlight a limited connection between technological innovations and pedagogical frameworks, as well as a недостаточное участие педагогов в разработке и внедрении AI-решений (Zawacki-Richter et al., 2019). This indicates a critical need for strengthening teacher education programs to ensure that future educators are equipped with the necessary competencies to work in AI-enhanced environments.

In this regard, the concept of information and communication competence (ICC) has become a central component of teacher professionalism in the digital age. ICC encompasses not only technical skills but also the ability to critically evaluate, select, and pedagogically integrate digital tools into teaching practice. Previous studies have shown that pre-service teachers often demonstrate uneven levels of digital competence, with a tendency to focus on operational skills rather than pedagogical integration (Tondeur et al., 2017; Instefjord & Munthe, 2017). The emergence of AI further expands this competence framework by introducing new dimensions such as data literacy, algorithmic thinking, and ethical awareness, which are essential for responsible and effective use of AI in education. Recent research also highlights the importance of AI literacy as a key component of modern teacher competence. AI literacy involves understanding how AI systems function, their potential applications in education, and the ethical implications associated with their use. Studies suggest that both pre-service and in-service teachers often report low levels of preparedness for working with AI technologies, emphasizing the need for systematic integration

of AI-related content into teacher education curricula (Ng et al., 2021; Chiu et al., 2023). In addition, educators express concerns regarding issues such as data privacy, ethical use of AI, and the potential over-reliance on automated systems, which further complicates the process of AI adoption in educational settings (Garzón et al., 2025).

Another important strand of research focuses on the dynamics and trends of AI-related studies in education. Bibliometric and systematic reviews reveal a sharp increase in the number of publications since 2018, indicating the growing relevance of AI in educational research (Chen et al., 2020; Garzón et al., 2025). These studies also demonstrate that research on AI in education is highly interdisciplinary, combining insights from computer science, education, psychology, and data science. However, despite the expanding volume of research, scholars note a lack of coherence and theoretical grounding in many studies, as well as the fragmentation of research topics across different domains (Zawacki-Richter et al., 2019). While numerous studies examine the general application of AI in education, there is a limited number of works specifically addressing the role of AI in the development of information and communication competence among pre-service English teachers. Language education presents unique challenges and opportunities for AI integration, including the use of natural language processing, automated feedback systems, and personalized language learning environments. Despite these promising applications, the literature lacks a systematic synthesis of research findings in this specific domain, particularly from a bibliometric perspective. The existing literature confirms the transformative potential of AI in education while simultaneously revealing significant gaps related to teacher preparedness, competence development, and the systematic analysis of research trends. These gaps highlight the need for a comprehensive bibliometric analysis using Scopus data to map the scientific landscape and identify future directions in the field of AI-enhanced development of information and communication competence among pre-service English teachers.

In addition to the growing emphasis on AI literacy, recent studies have increasingly focused on integrating artificial intelligence into established pedagogical frameworks, particularly the Technological Pedagogical Content Knowledge model and digital competence frameworks such as DigCompEdu. Scholars argue that effective use of AI in education requires not only technical proficiency but also the ability to align AI tools with pedagogical objectives and subject-specific content (Mishra & Koehler, 2006; Redecker, 2017). In this context, AI is not viewed merely as a technological enhancement but as a transformative element that reshapes teaching strategies, assessment practices, and learner engagement. However, empirical evidence suggests that pre-service teachers often struggle to integrate AI meaningfully into instructional design due to insufficient training and lack of exposure to real-world applications of AI technologies in educational settings. Furthermore, an emerging body of research highlights the ethical and socio-cultural implications of AI in education, which are becoming an integral component of teacher competence. Issues such as algorithmic bias, data privacy, transparency, and the role of human agency in AI-supported learning environments are increasingly discussed in the literature (Holmes et al., 2019; Zhai et al., 2021). These concerns underscore the necessity of developing a holistic approach to AI competence that combines technical skills with critical thinking and ethical awareness. In the context of pre-service English teacher education, this is particularly relevant, as language learning involves nuanced human interaction, cultural sensitivity, and communication dynamics that cannot be fully automated. Therefore, the integration of AI into teacher education must balance technological innovation with the preservation of human-centered pedagogical values.

Methodology

This study employs a bibliometric research design to systematically analyze the scientific literature on the application of artificial intelligence technologies in enhancing the information and communication competence of pre-service English teachers. Bibliometric analysis is widely

used to map research trends, identify influential contributors, and examine the intellectual structure of a given field. The data for this study were retrieved from the Scopus database, which is recognized as one of the largest and most comprehensive sources. The search was conducted using a combination of keywords related to artificial intelligence, information and communication competence, and pre-service teacher education. Boolean operators (AND, OR) were applied to refine the search query and ensure relevance. Combination of keywords:

TITLE-ABS-KEY ("AI " AND "digital competence") AND PUBYEAR > 2016 AND PUBYEAR < 2026 AND (LIMIT-TO (EXACTKEYWORD , "E-learning") OR LIMIT-TO (EXACTKEYWORD , "Teachers") OR LIMIT-TO (EXACTKEYWORD , "Teaching") OR LIMIT-TO (EXACTKEYWORD , "Students") OR LIMIT-TO (EXACTKEYWORD , "Higher Education") OR LIMIT-TO (EXACTKEYWORD , "Education Computing") OR LIMIT-TO (EXACTKEYWORD , "Learning Systems") OR LIMIT-TO (EXACTKEYWORD , "Educational Technology") OR LIMIT-TO (EXACTKEYWORD , "Education") OR LIMIT-TO (EXACTKEYWORD , "Teacher Training")) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))

The study selection followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure transparency and replicability. The process is illustrated in Figure 1. Initially, 316 records were identified from the database. After removing duplicates and records flagged as ineligible by automated tools (n = 183), 133 records remained for screening. During the screening stage, 9 records were excluded based on title and abstract review. Subsequently, 124 reports were sought for full-text retrieval, of which 17 reports were not accessible. A total of 107 reports were assessed for eligibility, and 12 studies were excluded due to not meeting the inclusion criteria. As a result, 95 studies were included in the final bibliometric analysis. The inclusion criteria comprised studies focusing on artificial intelligence in education, research addressing information and communication competence or related constructs, studies involving pre-service teachers or teacher education contexts, and empirical or review articles published in peer-reviewed journals.

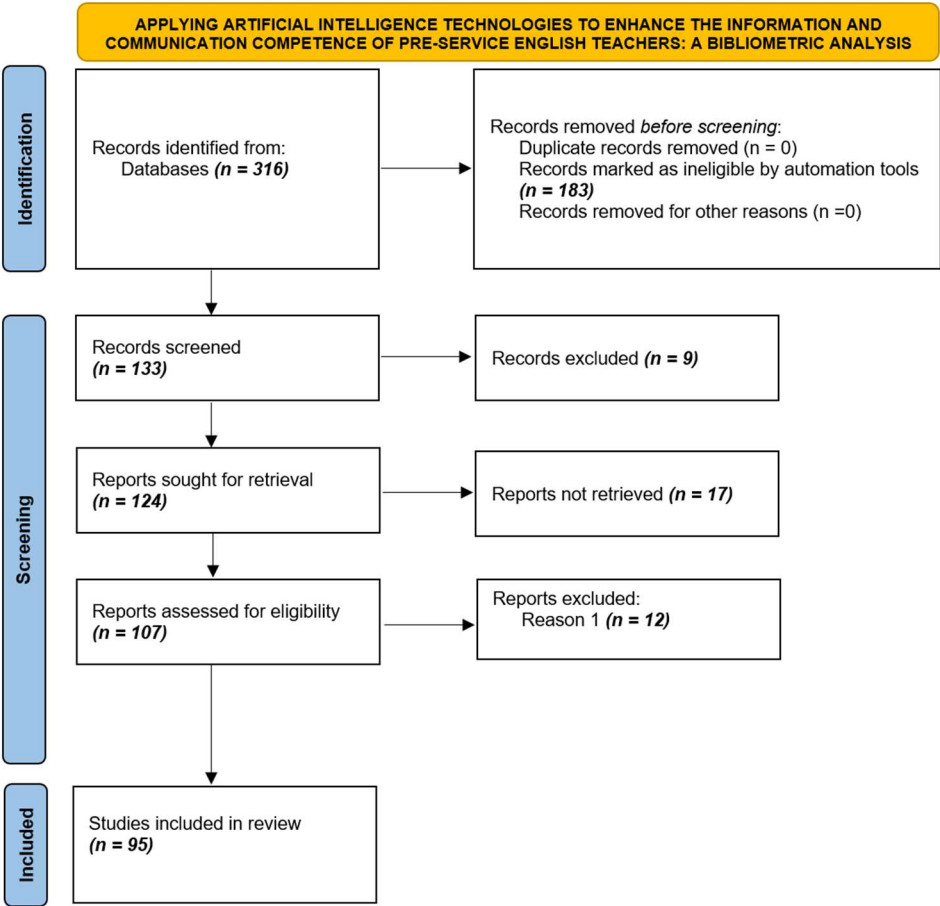


Figure 1. PRISMA flow diagram of the study selection process for bibliometric analysis

In contrast, the exclusion criteria encompassed conference papers, book chapters, and other non-peer-reviewed sources; studies not directly related to artificial intelligence or teacher competence; and publications lacking sufficient bibliographic information. The selected publications were analyzed using a range of bibliometric techniques. These included publication trend analysis to examine the growth and development of research over time, citation analysis to identify influential studies and leading authors, co-authorship analysis to explore patterns of scientific collaboration, and keyword co-occurrence analysis to determine dominant research themes and emerging trends. Visualization and mapping of bibliometric networks were conducted using specialized software tools, such as VOSviewer enabling the identification of clusters, thematic structures, and relationships within the dataset.

Results

To identify the most influential contributions in the field, a citation analysis was conducted on the selected publications. Citation counts serve as an indicator of the academic impact and relevance of studies within the research domain. Table 1 presents the top 10 most cited articles related to artificial intelligence and information and communication competence in teacher education.

Table 1. Top 10 Most Cited Studies on AI and Digital Competence in Education

No	Document Title	Authors	Source	Year	Citations
1	Artificial intelligence prompt engineering as a new digital competence: Analysis of generative AI technologies such as ChatGPT	Korzynski, P.; Mazurek, G.; Krzypkowska, P.; Kurasinski, A.	Entrepreneurial Business and Economics Review, 11(3), 25–37	2023	174
2	A self-determination theory approach to teacher digital competence development	Chiu, T.K.F.; Falloon, G.; Song, Y.; Zhao, L.; Ismailov, M.	Computers and Education, 214, 105017	2024	91
3	Relationship between teachers' digital competence and attitudes towards artificial intelligence in education	Galindo-Domínguez, H.; Delgado, N.; Campo, L.; Losada, D.	International Journal of Educational Research, 126, 102381	2024	87
4	Needs and performance analysis for changes in higher education and implementation of artificial intelligence, machine learning, and extended reality	Ilić, M.P.; Păun, D.; Šević, N.P.; Hadžić, A.; Jianu, A.	Education Sciences, 11(10), 568	2021	73
5	Development and validation of teacher artificial intelligence (AI) competence self-efficacy (TAICS) scale	Chiu, T.K.F.; Ahmad, Z.; Çoban, M.	Education and Information Technologies, 30(5), 6667–6685	2025	64
6	Mapping the use of artificial intelligence in medical education: a scoping review	Rincón, E.H.H.; Jimenez, D.; Aguilar, L.A.C.; Tapia, Á.E.R.; Peñuela, C.L.J.	BMC Medical Education, 25(1), 526	2025	51
7	The interplay between teachers' trust in artificial intelligence and digital competence	Lucas, M.; Zhang, Y.; Bem-haja, P.; Vicente, P.N.	Education and Information Technologies, 29(17), 22991–23010	2024	30
8	Accounting students' technology readiness, perceptions, and digital competence toward artificial intelligence adoption in accounting curricula	Abdo-Salloum, A.M.; Al-Mousawi, H.Y.	Journal of Accounting Education, 70, 100951	2025	24

9	Digital assessment: A survey of Romanian higher education teachers' practices and needs	Grosseck, G.; Bran, R.A.; Țîru, L.G.	Education Sciences, 14(1), 32	2024	24
10	Analysis of artificial intelligence chatbots and satisfaction for learning in mathematics education	Moral-Sánchez, S.N.; Rey, F.J.R.; Cebrián-De-la-serna, M.	International Journal of Educational Research and Innovation, 20	2023	24

The citation analysis presented in Table 1 highlights the most influential publications shaping the research field at the intersection of artificial intelligence (AI) and digital competence in education. The most cited study by Korzynski et al. (2023), with 174 citations, reflects the rapid emergence of generative AI particularly tools such as ChatGPT as a new dimension of digital competence, emphasizing prompt engineering as a critical skill for modern educators. This finding indicates a shift from traditional ICT competence toward more advanced, AI-oriented capabilities. Similarly, highly cited works by Chiu et al. (2024, 2025) demonstrate a strong research focus on conceptualizing and measuring AI-related competencies among teachers, including the development of validated instruments such as the TAICS scale. A notable trend in the dataset is the increasing number of highly cited studies published in 2023–2025, confirming the accelerated growth of AI research in education. Several studies (Galindo-Domínguez et al., 2024; Lucas et al., 2024) emphasize the relationship between teachers' digital competence and their attitudes toward AI, suggesting that the development of competence is closely linked to psychological factors such as trust, acceptance, and readiness to adopt new technologies. In addition, interdisciplinary applications of AI are evident, as illustrated by studies in medical education (Rincón et al., 2025) and accounting education (Abdo-Salloum & Al-Mousawi, 2025), indicating that AI competence is becoming a cross-sectoral requirement rather than a domain-specific skill. Furthermore, the presence of studies addressing institutional transformation and digital assessment (Ilić et al., 2021; Grosseck et al., 2024) highlights the systemic impact of AI on higher education. Research on AI chatbots in mathematics education (Moral-Sánchez et al., 2023) also demonstrates the growing interest in AI-driven learning tools and their influence on student engagement and satisfaction. Overall, the analysis suggests that the field is evolving from general discussions of digital competence toward more specialized investigations of AI competence, its measurement, and its pedagogical implications. However, despite the breadth of research, there remains a limited number of highly cited studies specifically focused on pre-service English teachers, confirming the relevance and necessity of the present bibliometric study.

Following the identification of the most influential studies, it is essential to examine the geographical distribution of research output in order to understand global patterns of scientific productivity and leadership in the field.

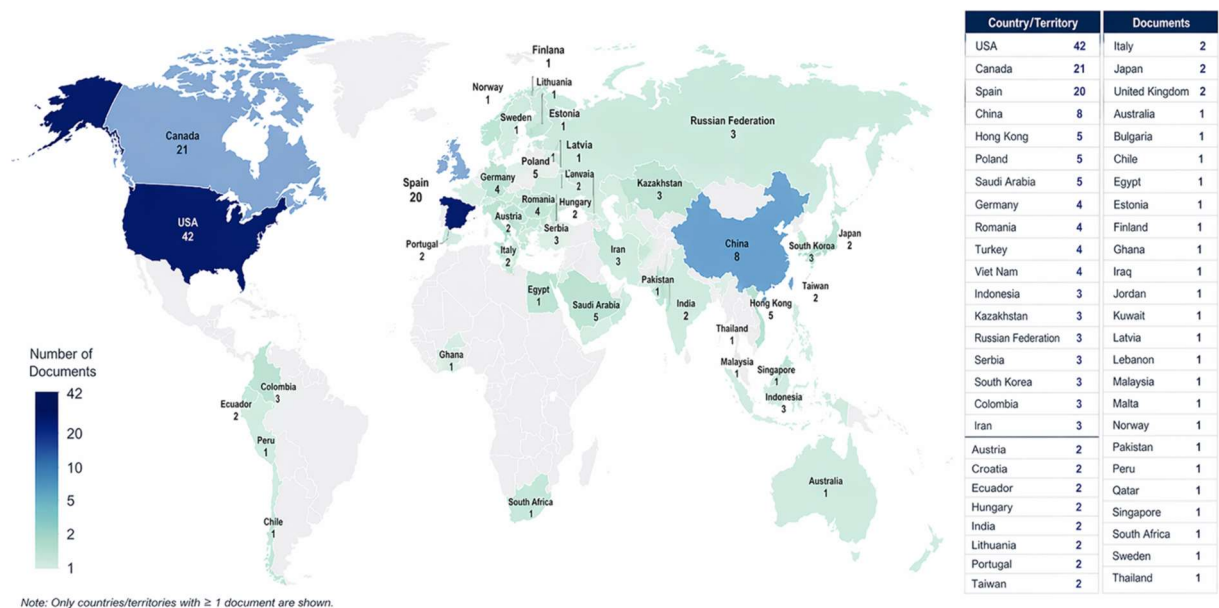


Figure 2. Geographical distribution of publications on artificial intelligence and digital competence in education by country

The geographical distribution of publications reveals a clear concentration of research activity in a limited number of countries, indicating an uneven global development of the field. The United States emerges as the leading contributor with 42 publications, significantly outperforming other countries. This dominance reflects the strong integration of artificial intelligence research within advanced educational and technological ecosystems. Canada (21 publications) and Spain (20 publications) also demonstrate substantial research output, highlighting their active engagement in digital education and AI-related studies. A second tier of countries includes China (8 publications), Hong Kong (5 publications), and several European nations such as Poland and Germany, each contributing a moderate number of studies. These results suggest a growing internationalization of research, particularly across Europe and Asia. However, the relatively lower publication counts compared to leading countries indicate that research capacity and funding in these regions may still be developing. Furthermore, a wide range of countries, including Saudi Arabia, Romania, Turkey, Indonesia, and South Korea, contribute smaller but notable numbers of publications. This distribution points to the expanding global interest in AI in education, although the level of contribution varies significantly. In contrast, many regions, particularly in Africa and parts of South America, remain underrepresented, with only a few countries such as South Africa, Egypt, and Colombia appearing in the dataset. The findings highlight a clear geographical imbalance in research production, with a concentration in developed countries and emerging contributions from developing regions. This pattern suggests the need for broader international collaboration and increased research support to ensure more equitable global development in AI-enhanced information and communication competence in teacher education.

The keyword co-occurrence network provides insight into the conceptual structure of the research field by identifying major thematic clusters and their interconnections. The visualization reveals several distinct but interrelated clusters, each representing a specific research direction within the broader domain of artificial intelligence and information and communication competence in education (Figure 3).

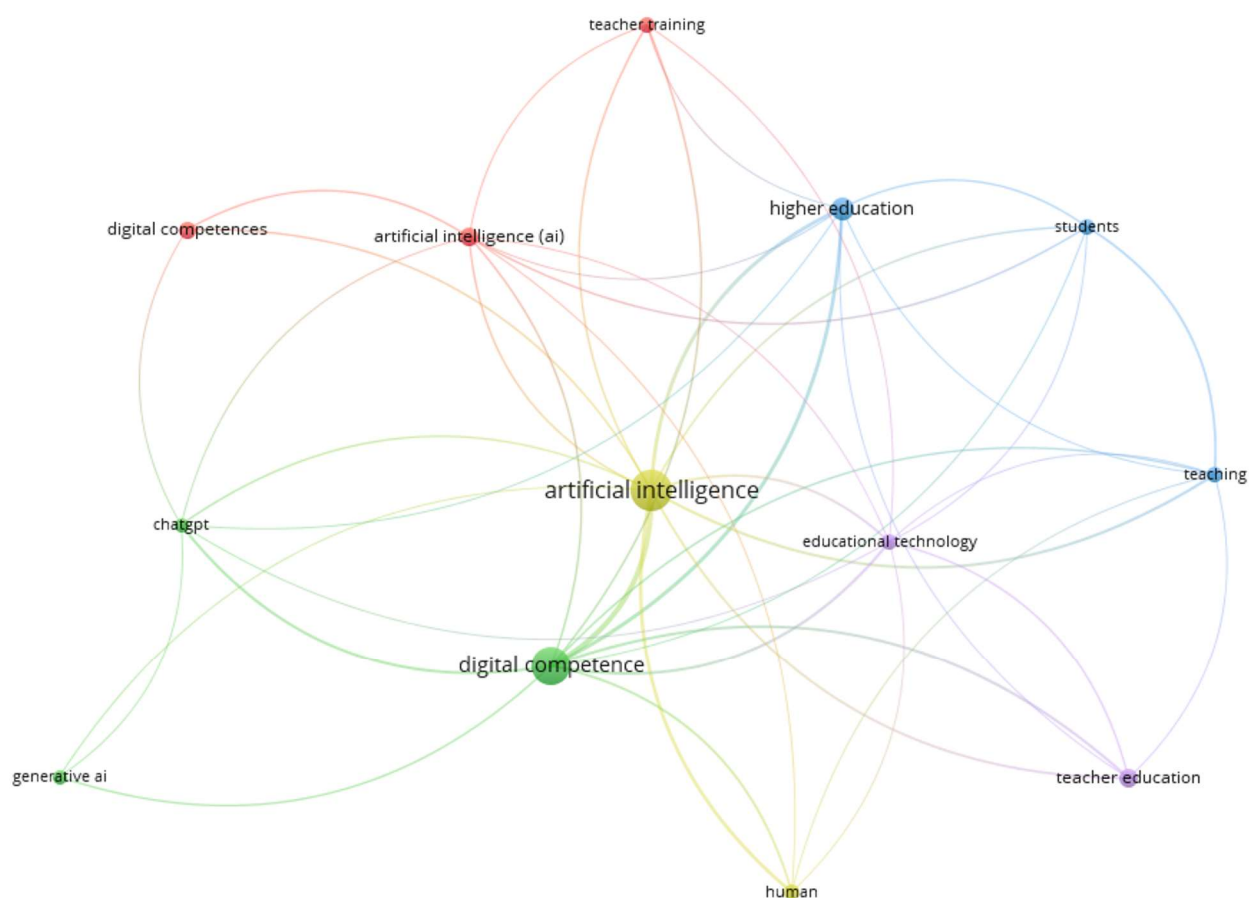


Figure 3. Keyword co-occurrence network of artificial intelligence and digital competence in teacher education

The *central cluster* (yellow) is dominated by the keyword *artificial intelligence*, which serves as the core node connecting all other themes. Its strong links with terms such as *digital competence*, *education technology*, and *higher education* indicate that AI functions as the primary conceptual anchor of the field. This centrality reflects the role of AI as a unifying paradigm that integrates technological innovation with pedagogical development.

The *green cluster* focuses on *digital competence* and its relationship with emerging AI tools. It includes keywords such as *ChatGPT* and *generative AI*, highlighting recent research trends related to the use of generative technologies in education. This cluster reflects a shift toward practical applications of AI tools in developing digital skills among teachers and learners. The presence of these terms suggests that digital competence is increasingly being redefined to include the ability to effectively use AI-driven systems.

The *red cluster* is associated with *teacher training* and foundational AI concepts. It includes keywords such as *artificial intelligence* and *digital competences*, emphasizing the integration of AI into teacher education programs. This cluster highlights the pedagogical dimension of the field, focusing on how future teachers are prepared to work with AI technologies. It reflects ongoing discussions about curriculum design, competency frameworks, and professional development.

The *blue cluster* represents the broader educational context, with keywords such as *higher education*, *students*, and *teaching*. This cluster underscores the institutional and instructional

environments in which AI technologies are implemented. It suggests that research is not limited to teacher preparation alone but also considers the impact of AI on teaching practices and student learning outcomes in higher education settings.

The *purple cluster* centers around *teacher education* and *educational technology*, indicating a specialized focus on the intersection between pedagogy and technological innovation. This cluster highlights the role of structured educational systems and programs in facilitating the integration of AI into teaching practice.

The peripheral nodes, such as *human*, indicate emerging discussions related to ethical, philosophical, and human-centered aspects of AI in education. Although less densely connected, these topics point to growing interest in issues such as human-AI interaction, ethics, and the balance between automation and human agency. The network demonstrates a highly interconnected research field, where artificial intelligence serves as the core element linking multiple thematic areas. The clustering structure reveals a transition from general discussions of digital competence toward more specialized and applied research on AI tools, teacher training, and educational transformation.

Discussion

The findings of this bibliometric analysis provide a comprehensive understanding of the evolving research landscape at the intersection of artificial intelligence and information and communication competence in teacher education. The results confirm that AI has become a central and rapidly expanding research domain, with a significant increase in publications observed in recent years. This trend aligns with previous studies emphasizing the growing importance of AI in transforming educational systems and redefining teacher competencies (Zawacki-Richter et al., 2019; Chen et al., 2020). One of the key findings of this study is the shift from traditional digital competence toward more advanced AI-related competencies. The prominence of highly cited works focusing on generative AI and prompt engineering indicates that digital competence is no longer limited to basic technological skills but increasingly includes the ability to effectively interact with AI systems (Korzynski et al., 2023). This supports the argument that teacher competence frameworks must be updated to incorporate AI literacy, data literacy, and ethical awareness, as suggested in previous research (Ng et al., 2021; Chiu et al., 2023). Furthermore, the results highlight the strong relationship between teachers' digital competence and their attitudes toward AI. Studies identified in the citation analysis emphasize that factors such as trust, perceived usefulness, and readiness to adopt technology significantly influence the successful integration of AI in educational contexts (Galindo-Domínguez et al., 2024; Lucas et al., 2024). This finding is consistent with the Technology Acceptance Model and related frameworks, which underline the importance of psychological and behavioral factors in technology adoption (Scherer et al., 2021). Therefore, teacher education programs should not only focus on developing technical skills but also address motivational and attitudinal dimensions.

The geographical analysis revealed a clear imbalance in global research productivity, with a concentration of publications in developed countries such as the United States, Canada, and Spain. This pattern reflects disparities in research funding, technological infrastructure, and access to AI resources. Similar observations have been reported in earlier bibliometric studies, which note the dominance of developed regions in AI-related educational research (Zhai et al., 2021). The underrepresentation of developing countries suggests the need for increased international collaboration and support to ensure more equitable participation in the global research landscape. The keyword co-occurrence analysis further demonstrates that the field is characterized by a high degree of interdisciplinarity and thematic diversification. The central role of AI as a connecting concept across clusters confirms its function as a unifying paradigm in educational research. At the same time, the emergence of clusters related to generative AI, teacher training, and educational technology reflects the ongoing transformation of the field toward more applied and

practice-oriented research. These findings are consistent with previous literature indicating that AI research in education is moving from theoretical exploration toward practical implementation and competence development (Chen et al., 2020; Garzón et al., 2025). Despite these advancements, the study also identifies several important gaps. Most notably, there is a limited number of studies specifically focused on pre-service English teachers, despite the relevance of AI technologies for language education. As highlighted in the literature, language teaching offers unique opportunities for AI integration through natural language processing, automated feedback, and adaptive learning systems (Zhai et al., 2021). However, the lack of targeted research in this area suggests that the potential of AI for enhancing ICC in language teacher education remains underexplored. In addition, the analysis reveals a fragmentation of research topics and a lack of theoretical coherence in the field. While numerous studies address different aspects of AI in education, there is a need for more integrative frameworks that combine technological, pedagogical, and ethical dimensions of competence. This observation supports earlier claims that the field requires stronger theoretical grounding and more systematic approaches to research synthesis (Zawacki-Richter et al., 2019).

Conclusion

This study provides a comprehensive bibliometric analysis of research on the application of artificial intelligence technologies in enhancing the information and communication competence of pre-service English teachers, offering a systematic overview of the development, structure, and key trends within this emerging field. Based on the analysis of 95 publications indexed in the Scopus database, the findings demonstrate a rapid growth of scholarly interest, particularly since 2018, confirming the increasing relevance of AI in education and teacher training. The results reveal that the research field is evolving from a general focus on digital competence toward more specialized and complex constructs, including AI literacy, generative AI skills, and data-driven pedagogical practices. Citation analysis highlights the growing importance of generative AI tools, such as ChatGPT, as well as the development of measurement instruments for assessing AI-related competencies. At the same time, the keyword co-occurrence analysis confirms that artificial intelligence serves as the central conceptual node linking multiple research directions, including teacher education, higher education, and educational technology. The study also identifies significant geographical disparities in research output, with a clear dominance of developed countries, particularly the United States, Canada, and European nations. This imbalance points to unequal access to technological resources and research infrastructure, emphasizing the need for broader international collaboration and support for underrepresented regions. Furthermore, the findings reveal that, despite the growing body of literature, there remains a limited number of studies specifically focused on pre-service English teachers, indicating an important gap in the research. In addition, the analysis highlights the fragmented nature of the field and the lack of integrated theoretical frameworks that combine technological, pedagogical, and ethical dimensions of AI competence. This suggests the necessity of developing more holistic models for teacher preparation that reflect the complexity of AI-enhanced educational environments. This study contributes to the advancement of knowledge by mapping the intellectual structure of research on AI and ICC in teacher education and identifying key trends, gaps, and future directions. The findings have important implications for educational policy, curriculum design, and teacher training programs, emphasizing the need to integrate AI-related competencies into pre-service teacher education. Future research should focus on developing context-specific models, expanding empirical studies in underrepresented regions, and exploring the pedagogical potential of AI in language education.

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Physical and Mathematical Sciences

DEVELOPMENT OF AI MODELS FOR ISCHEMIC STROKE DETECTION: A COMPARATIVE STUDY OF CNN AND TRANSFORMER ARCHITECTURES

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Abstract: Ischemic stroke is the second leading cause of death worldwide, responsible for approximately 6 million disability-adjusted life years annually. Because each hour of untreated ischemia destroys roughly 1.9 billion neurons, fast and accurate lesion segmentation has direct clinical consequences. This paper compares four deep learning architectures for pixel-wise acute ischemic stroke (AIS) segmentation on the TEKNOFEST-2021 dataset (877 CT and 230 MRI studies from 819 patients): a CNN baseline (U-Net) and three Transformer-based hybrids (TransUNet, UNETR, Swin-UNet). All models were trained under identical conditions using the Adam optimizer, a composite Dice + cross-entropy loss, and a 60/20/20 patient-level split over 50 epochs. All four exceed the clinically accepted DSC threshold of 80%. Swin-UNet achieves the highest overall DSC (88.6%) and pixel accuracy (98.7%); UNETR achieves the best boundary precision (HD95 = 8.9 mm). The largest single gain is a 10.1-point DSC improvement on lacunar stroke detection. Ablation experiments show ImageNet pretraining contributes 5-6 DSC points and elastic deformation augmentation 3.9 points. All Transformer models outperform the CNN baseline with large effect sizes ($d > 0.82$, $p < 0.001$).

Keywords: ischemic stroke, semantic segmentation, deep learning, Transformer, U-Net, TransUNet, UNETR, Swin-UNet, Dice Similarity Coefficient, CT, MRI

1. INTRODUCTION

Ischemic stroke accounts for roughly 70% of all stroke cases, with an estimated lifetime risk of 18.3% for individuals over 25. The clinical shorthand "time is brain" captures something real: approximately 1.9 billion neurons are lost per hour of untreated ischemia. Non-contrast CT and diffusion-weighted MRI (DWI) are the standard imaging modalities, but manual interpretation is slow and inter-observer variability remains a persistent problem.

CNNs, led by U-Net [1], have long been the default for medical image segmentation. The core limitation is that convolution operates locally: it struggles to capture spatial relationships across the full image, which matters when ischemic lesions vary widely in shape, size, and location between patients. Vision Transformers (ViTs) [2] use global self-attention and do not have this problem, but they tend to sacrifice fine-grained spatial detail, which creates its own difficulties in segmentation.

Hybrid architectures (TransUNet [3], UNETR [4], Swin-UNet [5]) aim at combining local feature extraction from convolution with the broader context from self-attention. Whether they actually outperform a strong CNN baseline in stroke segmentation — and by how much — is not

well established, because prior work mostly evaluates architectures in isolation or on different datasets. This paper trains all four models under the same conditions on the TEKNOFEST-2021 dataset and compares them directly.

Our hypothesis is that Transformer-based hybrids will outperform U-Net (DSC > 85%), with the largest margins on lacunar lesions, where the locality constraint of convolution is most limiting.

2. RELATED WORK

U-Net [1] introduced the encoder-decoder architecture with skip connections and remains the standard baseline. Attention U-Net [6] added soft attention gates to improve localisation of small structures. UNet++ [7] took a different approach, using nested skip connections to reduce the semantic gap between encoder and decoder. Neither addressed the locality constraint directly.

On the Transformer side, Dosovitskiy et al. [2] established that a pure ViT encoder can match or surpass CNNs on image classification given sufficient pretraining data. TransUNet [3] imported this encoder into a U-Net decoder for medical segmentation. UNETR [4] extended the approach to 3D volumetric inputs. Swin-UNet [5] replaced global self-attention with shifted-window attention [8], reducing complexity from $O(N^2)$ to $O(N)$ — enough to run on a single consumer GPU rather than requiring multi-GPU setups. Most of these architectures have been evaluated on different datasets under different protocols, so cross-paper performance comparisons are not reliable. The experiments here use a single dataset and a fixed training setup for all four models.

3. DATASET

The TEKNOFEST-2021 Stroke dataset was collected at Akdeniz University Hospital (Antalya, Turkey) under ethics approval KAEK-585. From an initial pool of roughly 67,000 cases, 1,000 were selected based on diffusion-weighted MRI availability and slice thickness of 2-5 mm, leaving 877 CT and 230 MRI studies from 819 patients.

The training split contains 6,651 images: 4,427 stroke-negative, 1,131 acute ischemic stroke, and 1,093 haemorrhagic. Data were partitioned 60/20/20 at the patient level to prevent leakage between sets. Annotations were produced by seven radiologists using RAD-X PACS (v2.0) and reviewed by two senior radiologists with nine years of experience.

4. METHODOLOGY

4.1. Preprocessing

Raw DICOM volumes are converted to NIfTI format. CT Hounsfield values are clipped to the brain window [0, 80] HU and linearly rescaled to [0, 1]. All volumes are resampled to isotropic 1.0 mm voxel spacing and reoriented to RAS standard orientation using SimpleITK.

4.2. Data Augmentation

Lesion pixels account for less than 5% of volume, so class imbalance was handled using a weighted softmax cross-entropy loss with pre-computed per-class weight maps. On-the-fly augmentation was applied throughout training: random $\pm 15^\circ$ rotations and shift-scale-rotate transforms; horizontal, axial, sagittal, and coronal flips; elastic deformation (grid spacing 28 px, magnitude 3 px); and $\pm 10\%$ brightness perturbation. The elastic deformation parameters were chosen to keep deformations within a range that looks plausible for brain tissue — larger values produced artefacts that degraded validation performance in preliminary runs.

4.3. Model Architectures

U-Net is a symmetric encoder-decoder with repeated 3×3 convolutions, max-pooling, and skip connections between encoder and decoder feature maps at each resolution scale (31 M parameters).

TransUNet uses a ResNet-50 backbone to extract feature maps, which are tokenised and passed through 12 Transformer encoder layers ($P = 16$, $L = 12$, $h = 12$ heads, $d = 768$). A cascade upsampling decoder with CNN skip connections reconstructs spatial detail (105 M parameters, ImageNet-21k pretrained).

UNETR applies a pure ViT encoder to 3D volumes, treating the input as $N = \text{HWD}/P^3$ cubic patches. Intermediate representations from layers {3, 6, 9, 12} feed as skip connections into a CNN decoder (92 M parameters, ImageNet-21k pretrained).

Swin-UNet is a pure-Transformer U-Net built from Swin Transformer blocks with shifted-window multi-head self-attention (W-MSA / SW-MSA). Shifted-window attention reduces complexity from $O(N^2)$ to $O(N)$, which is what makes it feasible on a single GPU (41 M parameters, ImageNet-22k pretrained).

Table 1 — Architecture comparison

Property	U-Net	TransUNet	UNETR	Swin-UNet
Encoder type	CNN	CNN + ViT	Pure ViT	Swin Transformer
Input dimension	2D	2D	3D	2D / 3D
Attn. complexity	—	$O(N^2)$	$O(N^2)$	$O(N)$
Parameters (M)	31	105	92	41
Pretrained weights	Opt.	ImageNet-21k	ImageNet-21k	ImageNet-22k

4.4. Training Configuration

All models were trained with Adam ($\text{lr} = 1 \times 10^{-4}$, $\beta_1 = 0.9$, $\beta_2 = 0.999$), a cosine annealing schedule ($T_0 = 10$ epochs), and early stopping (patience = 10) for up to 50 epochs. The composite Dice + cross-entropy loss stabilises training when class distribution is heavily skewed — Dice alone tends to oscillate on this dataset. Batch size was 8 for 2D models and 2 for UNETR. All experiments ran on an NVIDIA Tesla V100 (16 GB VRAM) with random seed 42.

5. RESULTS AND DISCUSSION

5.1. Overall Segmentation Performance

Table 2 shows test-set results. All four models exceed the 80% DSC threshold. Swin-UNet has the highest overall DSC (88.6%) and pixel accuracy (98.7%); UNETR edges it out on boundary precision ($\text{HD}_{95} = 8.9$ mm vs. 9.3 mm). The 7.2-point gap between U-Net and Swin-UNet is large enough to matter clinically — at this scale, the difference in IoU (69.0% vs. 79.5%) translates to substantially better lesion coverage on ambiguous cases.

Table 2 — Segmentation performance on the TEKNOFEST-2021 test set (mean $\pm$ std, 3 runs).

Best values marked with *.

Model	DSC (%)	IoU (%)	HD95 (mm)	Pixel Acc. (%)
U-Net (baseline)	81.4 $\pm$ 1.2	69.0 $\pm$ 1.5	14.7 $\pm$ 2.1	97.3 $\pm$ 0.4
TransUNet	85.9 $\pm$ 0.9	75.3 $\pm$ 1.1	10.2 $\pm$ 1.6	98.1 $\pm$ 0.3
UNETR (3D)	87.2 $\pm$ 0.8	77.4 $\pm$ 1.0	8.9 $\pm$ 1.3 *	98.4 $\pm$ 0.2
Swin-UNet	88.6 $\pm$ 0.7 *	79.5 $\pm$ 0.9 *	9.3 $\pm$ 1.4	98.7 $\pm$ 0.2 *

5.2. Performance by Lesion Subtype

The largest gain is on lacunar stroke: Swin-UNet reaches DSC = 81.4% versus 71.3% for U-Net, a 10.1-point improvement (Table 3). Lacunar lesions are small and diffuse, and this is where a limited receptive field hurts most — U-Net often cannot integrate enough context to distinguish a small lesion from noise. The global attention mechanism appears to help.

Table 3 — DSC (%) by lesion subtype. Best values marked with *.

Model	Large Vessel Occ.	Lacunar Stroke	Haemorrhagic	Specificity (%)
U-Net	84.1	71.3	80.6	96.4
TransUNet	87.4	78.9	84.3	97.8
UNETR (3D)	89.2	80.1	86.7	98.2
Swin-UNet	90.8 *	81.4 *	87.1 *	98.5 *

5.3. Computational Cost

Swin-UNet trains at 95 s/epoch using 7.3 GB VRAM. UNETR requires 310 s/epoch and 14.8 GB — more than twice the memory, more than three times the time (Table 4). For sites without a research-grade cluster, that difference determines what is actually deployable. Swin-UNet is the better option on both axes.

Table 4 — Training convergence and computational cost.

Model	Conv. Epoch	Val. DSC (%)	Time/Epoch (s)	GPU Mem. (GB)
U-Net	38	80.8	42	4.2
TransUNet	44	85.1	118	9.7
UNETR (3D)	47	86.6	310	14.8
Swin-UNet	41	87.9	95	7.3

5.4. Ablation Studies

ImageNet pretraining adds 5-6 DSC points; elastic deformation adds another 3.9 points. Removing either one drops Swin-UNet below 85% (Table 5). Given the dataset size, neither is optional.

Table 5 — Ablation results for Swin-UNet.

Configuration	Val. DSC (%)	Test DSC (%)
Random init., no augmentation	78.1	77.8
ImageNet init., no elastic deformation	85.4	84.7
ImageNet init. + elastic deformation	88.3	88.6 *
TransUNet: random init.	—	79.2
TransUNet: ImageNet init.	—	85.9

5.5. Statistical Significance

Wilcoxon signed-rank tests place all three Transformer improvements over U-Net at $p < 0.001$, with Cohen's d from 0.82 to 1.24 (Table 6). The effect sizes are large and consistent.

Table 6 — Statistical significance vs. U-Net baseline (Wilcoxon signed-rank, $n = 164$ cases).

Comparison	Mean Δ DSC (%)	p-value	Cohen's d
U-Net vs. TransUNet	+4.5	< 0.001	0.82 (large)
U-Net vs. UNETR	+5.8	< 0.001	1.01 (large)
U-Net vs. Swin-UNet	+7.2	< 0.001	1.24 (large)

5.6. Qualitative Analysis

For large vessel occlusion cases, all models produce reasonable masks. The difference is at the boundaries: U-Net tends to produce irregular, fragmented outlines while Transformer models are smoother and more anatomically consistent. For lacunar strokes under 20 mm, U-Net frequently misses lesions entirely. The most consistent failure across all architectures is under-segmentation of posterior circulation infarcts (cerebellar and brainstem), which are underrepresented in the training data. False positive activation on metallic implant artefacts is a secondary issue.

6. CONCLUSION

The Transformer-based models consistently outperformed U-Net. Swin-UNet reached DSC = 88.6% versus 81.4% ($p < 0.001$, $d = 1.24$), with the largest margins on lacunar stroke, where the convolution locality constraint is most limiting. It also trains faster and fits in less memory than UNETR — 95 s/epoch and 7.3 GB versus 310 s/epoch and 14.8 GB — which matters if the goal is eventual deployment on standard hospital hardware rather than a research cluster.

The dataset comes from a single centre, which limits how far the results generalise. Posterior circulation lesions are underrepresented, and no prospective clinical validation has been conducted. Future work should test multi-modal inputs (CT + DWI + CTP + FLAIR) across multiple sites. Any regulatory submission will also require explainability, and methods like attention rollout or Grad-CAM are reasonable starting points.

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METHODOLOGICAL APPROACHES TO THE USE OF ARTIFICIAL INTELLIGENCE IN THE PROFESSIONAL ACTIVITY OF MATHEMATICS TEACHERS

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Abstract: *This article examines methodological approaches to the use of artificial intelligence (AI) tools in the professional activity of mathematics teachers. In the context of digital transformation of education, AI technologies are becoming an important component of modern teaching practice. The study focuses on the development of a methodological model aimed at optimizing teachers' work through the integration of AI tools. Key components of the model include personalization of learning, task differentiation, automated feedback, and data analysis. The article highlights the practical aspects of implementing AI in teaching and its impact on improving instructional efficiency. The results demonstrate that the use of AI contributes to enhancing the quality of the educational process and supports teachers in organizing effective learning environments.*

Keywords: *artificial intelligence, mathematics teachers, methodology, digital technologies, teaching efficiency*

The rapid development of digital technologies has significantly transformed the educational environment, creating new opportunities for improving teaching practices. Among these technologies, artificial intelligence (AI) plays a key role in enhancing the effectiveness of the educational process and optimizing the professional activity of teachers.

In modern education, mathematics teachers face the challenge of addressing diverse student needs while maintaining high-quality instruction. Traditional teaching methods often do not allow for sufficient differentiation and personalization. In this context, the integration of AI tools offers a promising solution by enabling adaptive and data-driven teaching approaches. The methodological framework proposed in this study is based on the integration of artificial intelligence tools into the professional activity of mathematics teachers. The framework aims to support teachers in planning, implementing, and evaluating the learning process more effectively. One of the key components of the methodology is the adaptation of educational content. AI tools allow teachers to generate задания of varying difficulty levels, which helps to address individual differences among students. This approach supports differentiated instruction and ensures that each student receives tasks appropriate to their level of understanding. Another important component is the development of personalized learning trajectories. AI systems can analyze students' performance and provide recommendations tailored to their needs. This enables teachers to organize the learning process in a way that promotes individual progress and improves learning outcomes. Task differentiation is also a central element of the methodology. By using AI tools, teachers can design tasks that vary in complexity and format, allowing students to engage with the material at different levels. This contributes to increased motivation and deeper understanding of mathematical concepts. The organization of feedback is significantly enhanced through the use of artificial intelligence. AI-based systems provide immediate feedback on student performance, identify errors, and suggest improvements. This allows students to correct mistakes

in real time and supports the development of independent learning skills. In addition, AI technologies facilitate the analysis of educational data. Teachers can use data collected from digital platforms to monitor student progress, identify learning gaps, and adjust instructional strategies accordingly. This data-driven approach improves the overall effectiveness of teaching and supports informed decision-making. The implementation of the proposed methodology also involves the use of digital educational platforms and tools. These platforms provide opportunities for interactive learning, automated assessment, and efficient organization of educational materials. Despite the advantages of AI integration, several challenges remain. These include the need for developing teachers’ digital competencies, ensuring access to technological resources, and addressing ethical considerations related to data privacy. Therefore, successful implementation of the methodology requires appropriate training and support for teachers.

The comparative characteristics of traditional and AI-supported teaching approaches are presented in Table 2.

Table 2. Traditional vs AI-Supported Teaching

Criteria	Traditional Teaching	AI-Supported Teaching	Source
Lesson Planning	Manual preparation	AI-assisted content generation	OECD (2021)
Assessment	Time-consuming manual grading	Automated and instant assessment	Holmes et al. (2019)
Feedback	Delayed and limited	Immediate and continuous	UNESCO (2021)
Individualization	Limited	High level of personalization	Luckin (2018)
Decision Making	Based on teacher experience	Data-driven	McKinsey (2020)

Table 2 highlights the key differences between traditional teaching methods and AI-supported approaches. The integration of artificial intelligence enables more efficient lesson planning, faster assessment, and immediate feedback. In addition, AI technologies support personalized learning and data-driven decision-making, which significantly improves the overall effectiveness of the teaching process.

In conclusion, the integration of artificial intelligence into the professional activity of mathematics teachers provides a comprehensive methodological framework for improving the quality of education. The proposed approach demonstrates that AI tools can effectively support lesson planning, automate assessment, and enhance feedback mechanisms, thereby reducing teachers’ workload and increasing instructional efficiency.

Furthermore, the use of artificial intelligence enables the implementation of personalized learning and data-driven decision-making, which are essential components of modern education. These factors contribute to higher student engagement and improved learning outcomes.

Despite existing challenges, such as the need to develop teachers’ digital competencies and ensure access to technological resources, the integration of AI remains a перспективное направление развития образовательной практики. Future research should focus on the empirical evaluation of AI-based methodologies and the development of practical guidelines for their implementation in different educational contexts.

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Ақпараттық технологияларды физика пәнінде қолдану

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Аннотация: Мақалада жоғары оқу орындарында заманауи ақпараттық технологияларды қолданудың негізгі артықшылығы ретінде олардың физика пәнін оқыту үдерісін жаңаша ұйымдастыруға мүмкіндік беретіні көрсетілген. Сонымен қатар, бұл технологиялар пәндер арасындағы байланысты нығайтып, білім алушылардың дүниетанымын кеңейтуге және олардың жеке қабілеттерін анықтап, дамытуға тиімді жағдай жасайтыны атап өтілген.

Түйінді сөздер: физика, үдеріс, технология, қабілет, ақпараттық, шығармашылық, пән.

КІРІСПЕ

Қазіргі жаһандану кезеңінде білім беру жүйесі қоғам дамуының басты тіректерінің бірі саналады. Әсіресе, ақпараттық технологиялардың жедел дамуы оқыту мазмұны мен әдіс-тәсілдеріне айтарлықтай өзгерістер енгізіп отыр. Қазақстанда білім беру саласын жаңарту мәселесіне ерекше назар аударылып, білім сапасын көтеру, оқушылардың шығармашылық әлеуетін дамыту және олардың бәсекеге қабілеттілігін арттыру негізгі міндеттердің қатарында қарастырылады.

Осыған байланысты оқу-тәрбие үдерісіне ақпараттық-коммуникациялық технологияларды (АКТ) енгізу – бүгінгі күннің өзекті талабы. АКТ мүмкіндіктері оқытуды жаңа деңгейде ұйымдастыруға, оның тиімділігін арттыруға және білім алушылардың танымдық қызығушылығы мен белсенділігін күшейтуге кең жол ашады.

НЕГІЗГІ БӨЛІМ

Қазақстандағы білім беру жүйесі бүгінгі күні жаңашыл бағытта дамып келеді. Бұл үдерісте заманауи технологияларды енгізудің рөлі ерекше. Ақпараттық-коммуникациялық технологияларды пайдалану оқу үдерісін икемді, қолжетімді әрі нәтижелі етуге мүмкіндік береді. Сонымен қатар, ақпараттық технологиялар білім алушыларды тек дайын ақпаратты қабылдаушы емес, оны іздеп табатын, саралайтын және тәжірибеде қолдана алатын тұлға ретінде қалыптастыруға жағдай жасайды. Электрондық оқулықтар, онлайн платформалар мен мультимедиялық ресурстар оқу материалын көрнекі әрі түсінікті түрде ұсынуға көмектеседі.

Қазіргі мұғалімнің рөлі де өзгеруде: ол тек білім беруші емес, сонымен бірге бағыттаушы, ұйымдастырушы және кеңесші қызметін атқарады. Осыған байланысты педагогтардың кәсіби деңгейін үнемі жетілдіру – білім сапасын арттырудың басты шарттарының бірі. Мұғалімдердің жаңа технологияларды меңгеруі олардың оқыту әдістерін жетілдіруге ықпал

етіп, оқу үдерісін жаңаша ұйымдастыруға, оқушылардың қызығушылығын арттыруға және жеке, сараланған оқытуды жүзеге асыруға мүмкіндік береді.

Қазіргі уақытта көптеген білім беру мекемелерінде цифрлық ресурстарды қолдану тәжірибесі кеңінен таралуда. Бұл өз кезегінде білім сапасының артуына оң әсерін тигізуде. АКТ-ны қолданудың артықшылықтарына оқу материалының түсініктілігі мен көрнекілігінің артуы, уақытты үнемдеу, оқушылардың белсенділігін күшейту, әр оқушының деңгейіне сәйкес жеке тапсырмалар беру мүмкіндігі және қашықтықтан білім алу мүмкіндіктері жатады.

Дегенмен, АКТ-ны енгізу барысында белгілі бір қиындықтар да кездеседі. Олардың қатарында техникалық құралдардың жеткіліксіздігі, интернет желісінің әлсіздігі, мұғалімдердің цифрлық сауаттылық деңгейінің әрқелкі болуы және оқушылардың назарын басқа факторлардың бөлуі бар. Бұл мәселелерді шешу үшін білім беру ұйымдарын заманауи техникалық құралдармен қамтамасыз ету, педагогтардың біліктілігін арттыру курстарын жүйелі түрде ұйымдастыру және цифрлық ресурстарды тиімді пайдалану әдістемесін жетілдіру қажет[1].

Қазіргі кезеңдегі білім беру жүйесінің қарқынды дамуы педагогтардан тек дәстүрлі оқыту әдістерімен шектелмей, шығармашылық және зерттеушілік тұрғыда жұмыс жүргізуді талап етеді. Бүгінгі ақпараттық қоғам жағдайында мұғалімнің басты міндеті – білім алушыларға заман талабына сай сапалы білім беру ғана емес, сонымен қатар олардың жан-жақты дамуына жағдай жасау. Бұл міндетті жүзеге асыру үшін педагог үнемі ізденіс үстінде болып, жаңашыл әдістер мен технологияларды тиімді қолдана білуі қажет.

Ақпараттық технологиялардың кеңінен енгізілуі білім беру үдерісінің мазмұны мен құрылымына елеулі өзгерістер әкелуде. Компьютерлік құралдар мен цифрлық ресурстар негізінде ұйымдастырылған оқу оқушылардың логикалық ойлау қабілетін дамытып, құбылыстар арасындағы өзара байланыстарды анықтауға және заңдылықтарды терең түсінуге бағыттайды. Мұндай тәсілдер білім алушылардың танымдық белсенділігін арттырып қана қоймай, олардың болашақ кәсіби дағдыларының қалыптасуына да ықпал етеді.

Ақпараттық қоғам жағдайында қолданылатын заманауи педагогикалық технологиялар оқыту тиімділігін арттыруда маңызды орын алады. Әсіресе, физика пәнін оқыту барысында ақпараттық-коммуникациялық технологияларды пайдалану ерекше нәтиже береді. Бұл тәсілдер оқушылардың өзіндік білім алу дағдыларын жетілдіруге, оқу уақытын ұтымды пайдалануға және білім деңгейін түрлі тест тапсырмалары арқылы жедел бағалауға мүмкіндік туғызады[2].

Сонымен бірге, шығармашылық сипаттағы есептерді орындау кезінде білім алушылар физикалық құбылыстарды тереңірек ұғынып, оларды тәжірибемен байланыстыра алады. Қажетті ақпаратқа жылдам қол жеткізу де оқу үдерісінің тиімділігін арттырады. Ең бастысы – ақпараттық технологиялар табиғаттағы көзге көрінбейтін немесе бақылауға қиын процестерді модельдеу арқылы көрсетуге жағдай жасайды. Бұл оқушылардың пәнге деген қызығушылығын арттырып, күрделі ұғымдарды жеңіл меңгеруіне көмектеседі.

Қорытынды

Жалпы алғанда, ақпараттық-коммуникациялық технологияларды білім беру жүйесінде қолдану – қазіргі кезеңнің маңызды талаптарының бірі. АКТ құралдары оқыту сапасын арттырып, білім алушылардың танымдық қабілеттерін жан-жақты дамытуға мүмкіндік береді.

Сонымен қатар, педагогтардың кәсіби біліктілігін арттыру және жаңа технологияларды меңгеруі білім беру үдерісінің тиімділігін күшейтетін негізгі факторлардың бірі болып табылады. Болашақта АКТ-ны кеңінен пайдалану арқылы бәсекеге қабілетті, білімді ұрпақ қалыптастыруға толық негіз бар.

Білім мен тәжірибенің үйлесуі мұғалімге теориялық және практикалық әдістерді тиімді таңдауға мүмкіндік береді. Осы арқылы ақпараттық-коммуникациялық технологияларды жүйелі түрде қолдану оқыту әдістерін жетілдіріп, білім сапасын арттырады. Оқушылардың уақытын тиімді ұйымдастырып, оларға жаңа әрі пайдалы ақпарат ұсыну – заманауи технологиялардың басты жетістіктерінің бірі.

Жаңа ақпараттық технологиялардың негізгі артықшылығы – мұғалімге оқу үдерісін жаңаша ұйымдастыруға, пәндер арасындағы байланысты нығайтуға, оқушылардың дүниетанымын кеңейтуге және олардың жеке қабілеттерін анықтап, дамытуға кең мүмкіндік беруінде.

Компьютерді оқу барысында қолданудың тиімді жақтары:

- оқушы мен мұғалім арасында жағымды қарым-қатынас қалыптасады, себебі оқушы өзін еркін сезінеді;
- оқушылардың белсенділігі, жауапкершілігі және шығармашылық қабілеттері дамиды;
- білім алушы өз бетімен жұмыс жасап, нәтижесін көре алады және өзін-өзі бақылауға дағдыланады.

Қорытындылай келе, ақпараттық қоғам жағдайында оқушылардың ойлау қабілетін дамытуға және компьютерлік оқытуды жетілдіруге бағытталған педагогикалық технологиялардың тиімділігі өте жоғары деп бағалауға болады [3].

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Geographic Sciences

ГЕКЕРИЧАЙСКИЙ БАССЕЙН: ИСТОРИЯ ПОЧВ И ПРИНЦИПЫ БОНИТИРОВКИ, МЕТОДИКА ОПРЕДЕЛЕНИЯ ПОПРАВочНЫХ КОЭФФИЦИЕНТОВ

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Аннотация. В статье уделено внимание проблемам, связанным с историей бонитировки почв, освещены теоретические основы, принципы и методы данной проблемы. Оценочные работы в целом, в том числе бонитировка почв, невозможны без математического анализа методов, связанных с природными свойствами почв и урожайностью сельскохозяйственных культур. С учётом этого в процессе бонитировки почв были использованы также математические методы.

Ключевые слова: бонитировка, бассейн реки Гекеричай, Большой Кавказ, гранулометрический состав, шкала бонитета.

В Азербайджане принятые в последние годы важные законы и нормативные акты, связанные с земельной реформой, свидетельствуют о предстоящих коренных изменениях в аграрной структуре республики и земельно-имущественных отношениях. В период формирования новых общественно-экономических отношений и, на их основе, новых форм собственности и землепользования значение мероприятий, связанных с земельным кадастром, в том числе бонитировки почв, многократно возросло.

Несмотря на то, что качественная оценка почв, то есть их бонитировка, имеет очень древнюю историю, её современное научное изучение в нашей республике началось лишь с 60-х годов прошлого века.

Уже в 60–70-е годы в республике были опубликованы на русском и азербайджанском языках несколько методических рекомендаций по бонитировке пастбищных, виноградных, чайных и лесных почв. Однако отсутствие азербайджаноязычных письменных источников, касающихся как теоретических, так и методических проблем этого важного научного направления, создаёт определённые трудности для специалистов, интересующихся бонитировкой почв. В этом отношении представляемая статья, охватывающая вопросы бонитировки почв бассейна реки Гекеричай, может служить ценным научным пособием для студентов и аспирантов высших учебных заведений, научно-исследовательских институтов, а также для специалистов различных направлений — географов, землеустроителей, экономистов и других.

Бонитировка почв представляет собой учение, охватывающее широкий круг теоретических и практических проблем почвоведения.

В статье рассматривается агроэкологическое состояние почв бассейна реки Гекеричай и основные особенности почвенного покрова данной территории.

Широко освещены результаты наблюдений различных исследователей и научные материалы, полученные в ходе изучения распространённых на территории типов почв.

Особое внимание уделено историческим аспектам бонитировки почв. Известный теоретик А.А. Ярилов отмечал: «наука без истории не существует». В целом история бонитировки почв как в Азербайджане, так и за рубежом, в том числе в бывшем СССР, является недостаточно разработанной, поэтому в статье этому вопросу уделено значительное внимание.

С целью оказания помощи исследователям, интересующимся бонитировкой почв бассейна реки Гекеричай и непосредственно занимающимся данной проблемой, в статье освещены теоретические основы, принципы и методы этого направления. Известно, что оценочные работы в целом, включая бонитировку почв, невозможны без математического анализа данных о природных свойствах почв и урожайности сельскохозяйственных культур. С учётом этого в работе также использованы математические методы, применяемые при бонитировке почв.

Почвенная бонитировка является самостоятельной областью почвоведения, представляющей собой учение, которое изучает научно-теоретические основы оценки почвы как природного тела и как средства производства, а также разрабатывает её принципы и методы.

Бонитировка почв представляет собой важную проблему, которая интересует не только почвоведов, но и агрономов, экономистов, землеустроителей и географов. В историческом плане данное мероприятие осуществлялось различными способами в разные периоды и в разных странах. В настоящее время работы по качественной оценке почв (бонитировке) широко применяются во многих странах мира. Эта проблема изучается и внедряется также в нашей республике.

Следует отметить, что сложные природные условия Азербайджана, в том числе бассейна реки Гекеричай, разнообразие рельефа, климата и биологических факторов обусловили значительную неоднородность плодородия почв. Это, в свою очередь, усложнило экономические показатели производства, увеличивая или снижая затраты на выращивание сельскохозяйственных культур. Поэтому учёт различий плодородия почв, то есть их генетико-производственная классификация и оценка, является одной из важнейших теоретических и практических задач бонитировки.

Специалистам, непосредственно работающим в сельском хозяйстве, хорошо известно, что на практике часто встречается ситуация, когда в почвенных картах, подготовленных проектными институтами для хозяйств, не указывается качественная оценка (балльность) почвенных контуров. Очевидно, что по таким картам невозможно определить, какие почвы лучше или хуже внутри хозяйства, а также насколько почвы одного хозяйства более или менее благоприятны по сравнению с другим (3). В таких условиях значительно усложняется оценка деятельности хозяйств. Нередко бывает так, что два хозяйства с одинаковым уровнем работы оказываются в разных категориях — одно в числе передовых благодаря более плодородным почвам, другое — в числе отстающих из-за худших почв.

В современных условиях значение бонитировки почв ещё более возросло в связи с приватизацией земель, их куплей-продажей и использованием в качестве залога (1). Например, при налогообложении или продаже земель одинаковой площади, но разного качества, необходимо обязательно учитывать этот фактор, иначе приравнивание участков с различным плодородием приводит к нарушению социальной справедливости и замедляет внедрение научно-технических достижений в сельском хозяйстве. Чтобы этого избежать, требуется наличие данных о сравнительной оценке плодородия почв, то есть их бонитете, которые получаются в результате специальных исследований, проводимых по определённым принципам и методам (2). Опыт развитых стран показывает, что учёт

различий плодородия почв в системе земельно-имущественных отношений является мощным стимулом не только повышения продуктивности, но и сохранения и повышения плодородия почв.

Таким образом, основная цель бонитировки почв заключается в сравнительной оценке качества почв или в разработке их генетико-производственной классификации.

История земледелия в нашей стране уходит в первое тысячелетие до нашей эры. Известно, что в зависимости от географических условий Азербайджана плодородие почв имело исключительное значение для земледелия, садоводства, овощеводства, а также выращивания различных видов дикорастущих растений.

Качественная оценка почв в республике началась в конце 50-х — начале 60-х годов. Эти исследования можно условно разделить на следующие исторические этапы:

I этап — период до 1965 года, когда, за исключением отдельных работ академика В.Р. Волобуева (1961, 1963), крупных исследований по бонитировке почв практически не проводилось.

II этап — 1966–1969 годы, который можно считать продуктивным этапом развития бонитировки почв. В этот период была защищена первая диссертационная работа по данной теме, выполненная Ю.И. Костюченко (1966). Автор впервые исследовал влияние факторов плодородия на урожайность зерновых культур и их корреляционные связи в горно-каштановых и серо-бурых почвах Приараксийской зоны. При составлении шкалы бонитета почв Физулинского и Джебраильского районов были выбраны соответствующие критерии и поправочные коэффициенты, учитывающие особенности территории, а также проведена агропроизводственная группировка. В этот же период заслуживают внимания исследования М. Бабаева (1967) по изучению и оценке генетических особенностей орошаемых почв, а также работы Р.Г. Мамедова (1969), предложившего использование агрофизических свойств в качестве критериев бонитировки почв.

III этап — начиная с 1969 года и последующих лет — стал наиболее продуктивным и быстро развивающимся периодом в истории бонитировки почв.

В Азербайджане в конце 60-х — начале 70-х годов в связи с переходом к региональной специализации сельского хозяйства и интенсивным методам землепользования возникла острая необходимость в вопросах бонитировки и экономической оценки почв (4, 7). В этой связи в 1969 году постановлением Совета Министров Азербайджана и распоряжением Президиума АН Азербайджана в Институте почвоведения и агрохимии была создана лаборатория агроэкологии и бонитировки почв под руководством Ш.Г. Гасанова.

С первых дней перед лабораторией стояли важнейшие задачи:

- изучение агроэкологических факторов, влияющих на плодородие почв и урожайность сельскохозяйственных культур;
- характеристика структуры земельного фонда республики и состояния земель под различными сельскохозяйственными культурами;
- проведение бонитировки сельскохозяйственных и лесных почв для целей земельного кадастра, включая определение критериев оценки и поправочных коэффициентов в соответствии с биологическими требованиями растений;
- составление шкалы бонитета почв республики;
- агропроизводственная группировка и районирование сельскохозяйственных и лесных земель;
- определение баллов бонитета и коэффициентов сравнительной ценности земель по природно-экономическим и административным районам и ландшафтным зонам;
- составление карт бонитета и картограмм почв по хозяйствам, районам и по республике в целом и др.

Широкий охват этих задач, их высокая научная значимость, защита диссертаций и успешное выполнение хозяйственных договоров способствовали развитию данного научного направления.

Для обеспечения единой методической основы исследований по бонитировке почв в республике в 1973 году коллективом авторов (В.Р. Волобуев, М.Е. Салаев, Ш.Г. Гасанов и Ю.И. Костюченко) были подготовлены и опубликованы «Методические указания по проведению бонитировки почв в Азербайджане» (5). В том же году была составлена бонитетная картограмма почв Азербайджана в масштабе 1:500 000 (Ш.Г. Гасанов, Р.А. Алиева).

В 70–80-е годы в лаборатории проводились исследования по нескольким направлениям:

I. Бонитировка пастбищных почв (Г.Ф. Алиев, 1973; Г.Ш. Ягубов, 1975; Г.Ш. Мамедов, 1978; Ф.Д. Айвазов, 1989). Наибольший интерес представляют исследования Г.Ш. Мамедова в западной части Мильской равнины. В отличие от предыдущих работ, автор при оценке пастбищных почв использовал в качестве критериев внутреннее качество почвы и кормовую единицу (8, 9). Положительным нововведением стало использование биоклиматического потенциала (БКП) в качестве поправочного коэффициента. На основе этих исследований были опубликованы методические рекомендации по бонитировке пастбищных почв Азербайджанской ССР и их рациональному использованию (1978).

II. Бонитировка чайных и чайнопригодных почв (Д.Р. Ахадов, 1979; А.Г. Велиев, 1982). Впервые агроэкологические особенности и бонитировка чайных почв были изучены Д.Р. Ахадовым в условиях влажных субтропиков Астаринского района. Автор определил критерии и поправочные коэффициенты для оценки почв с учётом требований чайного растения. В результате исследований А.Г. Велиева в Астаринском, Ленкоранском и Масаллинском районах была составлена шкала бонитета чайных почв и проведено их агропроизводственное районирование.

III. Бонитировка почв под виноградниками (Ш.А. Бадалов, 1981; А.Г. Велиев, 1982; С.М. Гусейнов, 1985). Первые исследования в этом направлении были проведены Ш.А. Бадаловым. Автор изучил влияние физико-химических свойств почв на сахаристость винограда, разработал шкалу бонитета и картограмму почв, а также определил оптимальные значения почвенных факторов и соответствующие поправочные коэффициенты. Он также предложил использовать показатели 200-сантиметрового почвенного слоя при бонитировке многолетних насаждений. Влияние рельефных факторов (экспозиции и крутизны склонов) на плодородие виноградных почв было учтено в работах С.М. Гусейнова.

В результате этих исследований были опубликованы методические рекомендации по бонитировке виноградных и многолетних культурных почв Азербайджанской ССР.

III этап — охватывающий 1969 год и последующие годы — стал наиболее продуктивным и стремительно развивающимся периодом в истории бонитировки почв.

В Азербайджане в конце 60-х — начале 70-х годов в связи с переходом к региональной специализации сельского хозяйства и интенсивным методам использования земель возникла острая необходимость в вопросах бонитировки почв и их экономической оценки (4, 7). В этой связи в 1969 году специальным постановлением Совета Министров Азербайджана и распоряжением Президиума АН Азербайджана в Институте почвоведения и агрохимии была создана лаборатория агроэкологии и бонитировки почв под руководством Ш.Г. Гасанова.

С первых дней перед лабораторией стояли важнейшие задачи, среди которых: изучение агроэкологических факторов, влияющих на плодородие почв и урожайность сельскохозяйственных культур; характеристика структуры земельного фонда республики и

состояния земель под различными сельскохозяйственными культурами; проведение бонитировки сельскохозяйственных и лесных почв для целей земельного кадастра с определением критериев оценки и поправочных коэффициентов в соответствии с биологическими требованиями растений; составление шкалы бонитета почв республики; агропроизводственная группировка и районирование сельскохозяйственных и лесных земель; определение баллов бонитета и коэффициентов сравнительной ценности земель по природно-экономическим и административным районам и ландшафтными зонам; составление карт бонитета и картограмм почв по хозяйствам, районам и по республике и др.

Широкий масштаб поставленных задач, их научная значимость, защита диссертационных работ и успешное выполнение хозяйственных договоров способствовали развитию данного научного направления.

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В 70–80-е годы в лаборатории проводились исследования по нескольким направлениям:

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II. Бонитировка чайных и чайнопригодных почв (Д.Р. Ахадов, 1979; А.Г. Велиев, 1982). Впервые агроэкологические особенности и бонитировка чайных почв были изучены Д.Р. Ахадовым на территории Астаринского района в условиях влажных субтропиков. Автор определил критерии и поправочные коэффициенты оценки с учётом требований чайного растения. В результате исследований А.Г. Велиева в Астаринском, Ленкоранском и Масаллинском районах была составлена шкала бонитета чайных почв и проведено их агропроизводственное районирование.

I. Бонитировка виноградных почв (Ш.А. Бадалов, 1981; А.Г. Велиев, 1982; С.М. Гусейнов, 1985). Первое исследование по бонитировке виноградных почв было проведено Ш.А. Бадаловым. В процессе оценки автор изучил влияние физико-химических свойств почвы на сахаристость винограда; им была разработана шкала бонитета почв и составлена картограмма, а также установлено влияние карбонатности почв на урожайность и качество винограда. На основе оптимальных значений почвенных факторов был определён поправочный коэффициент для оценки. Автор также предложил при бонитировке почв под многолетние насаждения использовать показатели 200-сантиметрового почвенного слоя. Влияние рельефных факторов — экспозиции и крутизны склонов — на плодородие виноградных почв и их балльные оценки было учтено в работах С.М. Гусейнова. В результате исследований были опубликованы методические рекомендации по бонитировке почв под виноградники и многолетние культуры (1979).

II. Бонитировка орошаемых почв под хлопчатник и зерновые культуры (Р.А. Алиева, 1971; А.Э. Микаилов, 1986). В работах Р.А. Алиевой по бонитировке орошаемых хлопковых почв Сальянского района важным аспектом стало использование гранулометрического

состава почвы, а также признаков засоления и осолонцевания в качестве поправочных коэффициентов. А.Э. Микаилов в своих исследованиях Ширванской равнины, помимо ранее предложенных критериев, выявил связь между урожайностью зерновых и хлопка и выровненностью территории, и использовал этот показатель как поправочный коэффициент при оценке земель.

III. Бонитировка лесных почв (Ф.Л. Пириева, 1984; С.Р. Тагиев, 1991). Первое диссертационное исследование в этой области было выполнено Ф.Л. Пириевой (10). Автор изучил внутренние свойства лесных почв южного склона Большого Кавказа и использовал их в качестве критериев оценки и поправочных коэффициентов, на основе чего составил шкалу бонитета территории. Другое исследование было проведено С.Р. Тагиевым на северо-восточном склоне Большого Кавказа; в этом случае гранулометрический состав почвы впервые был использован не как поправочный коэффициент, а как основной критерий оценки.

Одним из наиболее значимых событий 70-х годов стала работа Ш.Г. Гасанова (1972) по крупномасштабному исследованию юго-западной части Азербайджана. Исследователь, изучив закономерную связь между качеством почв и урожайностью сельскохозяйственных культур, составил шкалы бонитета и картограммы для восьми административных районов (12). В его картограммах почвенные контуры получили новое содержание, выраженное в баллах и классах бонитета.

Следует отметить, что в 70–80-е годы бонитировка почв проводилась с охватом различных регионов и различных сельскохозяйственных культур, однако во всех этих исследованиях существовала общая методическая основа. Общая схема работ заключалась в следующем: выбор эталонных почв и критериев оценки на исследуемой территории; построение закрытой шкалы бонитета на основе математических расчётов с использованием этих критериев; определение поправочных коэффициентов через корреляционные связи между урожайностью сельскохозяйственных культур и изменчивыми показателями почв; применение поправочных коэффициентов и построение открытой шкалы бонитета; агропроизводственная группировка типов почв на основе балльных показателей; и, наконец, составление картограммы бонитета для исследуемой территории (11). В настоящее время такой подход к оценке почв получил в почвоведении название «традиционная бонитировка».

70-е годы XIX века считаются началом научной деятельности основоположника генетического почвоведения В.В. Докучаева. В 1877–1881 гг. по поручению Вольного экономического общества он проводил исследования чернозёмной полосы России. Результаты этих исследований были отражены в классическом труде В.В. Докучаева «Русский чернозём». Фактически год публикации этой работы — 1883 — может считаться годом становления генетического почвоведения. В результате этих исследований были заложены также научно-теоретические основы современной бонитировки почв.

После завершения изучения чернозёмов В.В. Докучаев и его ученики продолжили исследования сначала в Нижегородской (1882–1886), а затем в Полтавской губернии (1888–1894). Перед обеими экспедициями, организованными земствами, была поставлена одна задача — качественная оценка почв для определения размера налогов. Несмотря на ограниченный практический характер задания, В.В. Докучаев придал этим работам широкое научно-теоретическое значение. Он писал, что правильные результаты оценки могут быть получены только после установления природных и экономических условий территории; лишь всесторонний учёт природно-исторических и экономических факторов позволяет избежать ошибочных выводов. В этих экспедициях, помимо почвоведов, участвовали климатологи, ботаники и экономисты, что обеспечило комплексный характер исследований,

включавших не только почвы, но и экономические условия хозяйства, уровень земледелия и урожайность сельскохозяйственных культур.

Большой вклад в развитие генетического почвоведения и бонитировки почв внёс Н.М. Сибирцев, ученик В.В. Докучаева и активный участник всех его экспедиций. В 1895 году он лично руководил экспедицией по оценке почв Псковской губернии.

Н.М. Сибирцев в 1900 году стал автором первого учебника по генетическому почвоведению. В этом учебнике излагалась сущность генетической теории В.В. Докучаева о почве и факторах её образования. В книге также была выделена специальная глава, посвящённая бонитировке почв. В этой главе Н.М. Сибирцев затрагивал спорные вопросы бонитировки: природно-исторический метод оценки почв, их классификацию и другие важные проблемы. Положения Н.М. Сибирцева о бонитировке почв, изложенные в учебнике, не утратили своего научного и практического значения и в современный период.

По мнению В.В. Докучаева, качественная оценка почв, то есть хозяйственных угодий, может быть объективной только в том случае, если при разделении почв и земель на классы, разряды и группы это деление проводится на основе их природных свойств и показателей. Он писал:

«1) природные свойства почвы являются важнейшим и основным фактором её доходности, поэтому они должны служить основой при изучении других факторов (например, экономических);
2) этот фактор является постоянным и устойчивым;
3) изучение этого фактора должно отличаться объективностью и научностью;
4) всестороннее изучение почв может и должно способствовать повышению сельскохозяйственного производства как на местном уровне, так и в масштабах всей России;
5) оценка почв по их природным свойствам во многих случаях является единственно возможным путём;
6) без всестороннего научного изучения почв никакая точная статистико-экономическая и статистико-сельскохозяйственная оценка не может быть достаточно обоснованной и полной».

Таким образом, В.В. Докучаев и Н.М. Сибирцев считали, что при бонитировке почв прежде всего необходимо изучение их природных свойств, на основе которых определяется сравнительная оценка плодородия. Все работы по этому методу делились на два этапа. На первом, природно-историческом этапе определялись природные качества почв на основе их морфо-генетических, химических, физических и фитозоологических характеристик. Эта часть работы выполнялась почвоведом. Затем начинался второй этап — сельскохозяйственно-экономическое изучение территории, которое выполнялось специалистами-статистиками. В.В. Докучаев отмечал, что оба этапа оценки тесно связаны между собой, и первый этап должен служить основой для второго. Этот метод впервые был применён в Нижегородской губернии и поэтому часто называется Нижегородским, или русским методом оценки почв.

В конце XIX века в России наряду с докучаевским методом бонитировки широко использовались также два других метода — статистический и морфологический.

В некоторых губерниях европейской части России бонитировка почв проводилась не почвоведом, а экономистами-статистиками. Суть применяемого ими метода заключалась в следующем:

1. оценка почв осуществлялась с помощью анкетных опросов;
2. заполнение анкет поручалось местным органам управления и владельцам земель;
3. распространение, сбор и проверка анкет возлагались на представителей полиции.

В.В. Докучаев критически относился к этому методу, указывая, что в его основе содержится большое количество субъективных факторов. Однако, по его мнению, к

статистико-опросным данным при бонитировке почв следует подходить внимательно и при необходимости использовать их как ценные показатели. Например, сведения о многолетней урожайности сельскохозяйственных культур могут служить важным индикатором качества почв. Поэтому наличие широкого комплекса данных о почве (её составе и свойствах, природных условиях территории, урожайности культур, системе земледелия и т.д.), их взаимный контроль являются достаточно надёжной и научно обоснованной основой для объективной оценки почв и определения их бонитета.

В царской России наряду с природно-историческим методом В.В. Докучаева и Н.М. Сибирцева применялись также статистико-опросные методы оценки почв. Эти методы вошли в историю бонитировки под названием «морфологические методы». Рассмотрим некоторые из них. Так, почвовед Р.В. Рисположенский, отвергая химические и механические лабораторные исследования, при оценке почв использовал их морфологические признаки, особенно цвет. Другой исследователь — Г.Ф. Нефёдов — при составлении почвенных карт отображал не почву как целостное природное тело, а отдельные её свойства (содержание гумуса, фосфора и др.), что больше напоминало агрохимические картограммы, чем почвенные карты. Однако вскоре эти методы подверглись резкой критике со стороны почвоведов и специалистов других отраслей.

После Октябрьской революции 1917 года в СССР бонитировка почв длительное время находилась в состоянии застоя. Лишь после постановления ЦК КПСС и Совета Министров от 9 марта 1955 года «Об изменении практики планирования в сельском хозяйстве» отношение к бонитировке почв существенно изменилось. Она стала актуальной и приобрела общегосударственное значение. Вскоре под руководством академика С.С. Соболева был создан координационный совет научно-исследовательских и учебных учреждений для решения научных и методических проблем бонитировки почв.

Впервые на I съезде почвоведов СССР в 1958 году была организована специальная секция по бонитировке почв. Затем на Всесоюзном совещании по бонитировке почв и агрохимической характеристике, проведённом в Почвенном институте имени В.В. Докучаева (1959), был принят проект методики составления областных, краевых и зональных шкал бонитета, предложенный С.С. Соболевым. После утверждения в 1963 году Министерством сельского хозяйства СССР «Программы и методики бонитировки почв СССР» в стране начались широкомасштабные исследования в этой области.

В 60–80-е годы значительный вклад в развитие бонитировки почв в СССР внесли П.П. Адерхин, Н.А. Благовидова, Ф.А. Гаврилюк, И.Д. Давлятин, К.В. Зворыкин, Р. Каск, П.А. Керзум, Н.В. Кимберг, В.Ф. Клебанович, А.П. Клопотовский, И.А. Крупеников, И.И. Карманов, В.П. Кузьмичев, Т.Н. Кулаковская, А.Г. Медведев, А.М. Мамытов, В.А. Семёнов, Н.И. Смейан, С.Н. Тайчинов, Н.Ф. Тюминцев, А.С. Фатьянов, С.А. Шувалов и другие исследователи.

Оценка бонитировки почв и хозяйственных угодий, как правило, проводилась с использованием различных методик в зависимости от целей исследования. При этом определение бонитетных баллов осуществлялось с учётом местных почвенно-климатических условий и выбора соответствующих критериев. Все эти работы можно разделить на два основных направления (И.И. Карманов, 1980).

Первое направление включало исследования, в которых использовались корреляционные связи между количественными показателями свойств почвы и урожайностью сельскохозяйственных культур для построения шкал бонитета. Хотя работы в этом направлении основывались на схожих принципах, они различались конкретными методами (11), поэтому их можно разделить на три группы.

К первой группе относятся методы построения шкал бонитировки на основе пропорциональной корреляции почвенных свойств. Согласно этим методам, бонитетные баллы почв рассчитывались пропорционально тем свойствам почвы, которые имели

корреляцию с урожайностью сельскохозяйственных культур. Полученные шкалы проверялись по данным урожайности культур. Шкала, построенная на основе свойств почвы, принималась как основная, а затем уточнялась с помощью поправочных коэффициентов, учитывающих не включённые в основную шкалу свойства и признаки почв. Этот метод широко применялся при региональной бонитировке почв в СССР (Ф.Я. Гаврилюк, 1970, 1972; Земельный кадастр Мордовской АССР, 1970; В.В. Ильинский, Н.Г. Шишкина, А.И. Саталкин, 1971; М.Г. Холина, 1972; Бонитировка почв Ставропольского края, 1973; Методические указания по проведению бонитировки почв в Азербайджанской ССР, 1973; И.И. Гантимуров, 1974; Б.В. Горбунов, Г.М. Конобыва, 1975; М.Т. Куприченков, 1975; П.Г. Адерхин, Б.П. Ахтырцев, К.К. Мусиков, 1976; Н.Н. Вадковская, 1976; Г.Б. Гольдина, 1976; В.И. Кумахов, 1976; Р.И. Лунева, Л.Н. Рябина, 1976 и др.).

Ко второй группе относятся методы, имеющие общие черты с первой группой. Однако в этих методах, помимо основной шкалы бонитета, дополнительно использовалась шкала урожайности. В результате корреляции баллы, определённые по свойствам почвы, могли изменять своё значение. Этот метод также получил широкое распространение (Земельный кадастр Литовской ССР, 1970; В.А. Семёнов, 1970; М.Ф. Курочкин, И.С. Муртазин, 1971; Качественная оценка пахотных земель и сенокосов Башкирской АССР, 1972; Ф.Т. Исаев, 1973; С.Н. Тайчинов, 1973; К.К. Бривкали, И.К. Гемете, 1974; А.П. Клопотовский, 1974; Бонитировка почв Западной Сибири; Н.Ф. Тюменцев, 1975 и др.).

Существуют также интересные взгляды зарубежных учёных на критерии оценки почв. По мнению французского исследователя А. Демалона, свойства почвы оказывают значительное влияние на питание растений. Исходя из этого, он предлагал строить шкалу продуктивности на основе корреляции между урожайностью растений и свойствами почвы, а классификацию почв — на основе многолетней урожайности культур. Однако такой подход, по сути, не является вполне правильным: во-первых, урожайность одной культуры не может служить достаточным показателем оценки почв, так как необходимо учитывать все культуры севооборота; во-вторых, подобная классификация скорее отражает уровень агротехнического мастерства земледельца, поскольку грамотное применение агротехники ведёт к повышению продуктивности почвы.

Английский почвовед Э. Рассел также отмечал значительные трудности оценки почв по урожайности растений. Он считал возможным применение данного метода лишь в отдельных случаях, например, для приблизительной оценки естественного плодородия почв разных классов.

Некоторые исследователи считают, что при оценке почв в качестве основных критериев следует использовать результаты химического и агрохимического анализов. Однако ограниченность такого подхода была отмечена и подвергнута критике ещё в начале XX века П.А. Костычевым. Он указывал, что оценка почв только на основе химических показателей может приводить к ошибочным выводам. По его мнению, при сравнительной оценке почв необходимо учитывать их генезис, требования культурных растений, географическое положение территории, мощность почвенного профиля и качество подпахотного горизонта.

Другой подход заключается в определении бонитетных баллов только на основе природных свойств пахотного горизонта, без учёта свойств подпахотных слоёв. Однако данный метод также не является научно обоснованным, поскольку под почвой следует понимать не только верхний пахотный слой (0–25/30 см), но и весь профиль, в пределах которого развиваются корневая система растений и протекают почвообразовательные процессы. Формирование урожайности сельскохозяйственных культур зависит не только от свойств пахотного горизонта, но и от характеристик нижележащих горизонтов почвенного

профиля. Поэтому бонитетные показатели, основанные лишь на свойствах пахотного слоя, не отражают объективно сравнительное качество почв.

В качестве примера часто приводятся чернозёмы Кубани, которые считаются одними из самых продуктивных почв в мире для зерновых культур. Урожайность озимой пшеницы здесь достигает 70–100 ц/га. При этом содержание гумуса в пахотном горизонте составляет 4–5%, что сопоставимо с почвами южных чернозёмов, где урожайность примерно в три раза ниже. Однако высокая продуктивность кубанских чернозёмов обусловлена не только качеством пахотного слоя, но и значительной мощностью гумусового горизонта (160–200 см), а также высоким запасом гумуса в почвенном профиле (650–750 т/га). В южных чернозёмах мощность гумусового горизонта составляет лишь 60–70 см, а запас гумуса — 325–375 т/га.

Таким образом, при оценке бонитета необходимо учитывать не только пахотный горизонт, но и весь почвенный профиль (горизонты А, В и С). В этом случае бонитетные баллы более объективно отражают сравнительное плодородие почв.

Диагностические признаки и показатели при бонитировке почв могут различаться в зависимости от типа почв и природной зоны. Мощность почвы, запасы гумуса, гранулометрический состав и другие физико-химические свойства по-разному влияют на урожайность сельскохозяйственных культур в различных природных условиях. Поэтому в качестве основных диагностических критериев следует использовать те свойства почвы, которые имеют устойчивую корреляцию с урожайностью и могут быть выражены количественно.

Однако в отдельных случаях связь между диагностическими признаками и урожайностью может отсутствовать. Это может быть обусловлено следующими причинами:

- а) неправильным выбором диагностических показателей;
- б) низким качеством почвенно-картографических и аналитических материалов;
- в) отсутствием точного учёта урожайности сельскохозяйственных культур.

После установления корреляционной зависимости между почвой и урожайностью выделяются основные почвенные свойства, которые используются в процессе бонитировки. Эти показатели должны корректироваться и совершенствоваться в зависимости от местных почвенно-климатических и экономических условий.

Наиболее важными обобщёнными показателями плодородия почв являются мощность гумусового горизонта и запасы гумуса. Гумус представляет собой интегральный показатель почвенного плодородия, отражающий совокупность физических, химических и биологических свойств почвы. Содержание гумуса непосредственно связано с накоплением в почве азота, фосфора, калия, серы, кальция и микроэлементов (марганца, кобальта, никеля, цинка и др.). Поэтому гумус при бонитировке почв выступает как комплексный и ключевой критерий.

При бонитировке почв содержание гумуса может выражаться двумя способами: в пахотном (или верхнем) горизонте — в процентах, либо в горизонте распространения корневой системы — в тоннах на гектар. Показатель гумуса в процентах обычно применяется для маломощных (слабомощных) почв с небольшой толщиной почвенного профиля. В действительности в горно-луговых почвах все положительные свойства плодородия сосредоточены в слое толщиной всего в несколько сантиметров. В маломощных и некоторых примитивных почвах процентное содержание гумуса фактически отражает общее количество органического вещества в этих почвах (2). Если накопление гумуса распространяется и на подпахотные горизонты, то при бонитировке почв он не всегда учитывается в форме запасов.

В формировании урожая большое значение имеет не только запас гумуса в почве, но и мощность гумусовых горизонтов (А+В). Поскольку в горизонте А+В сосредоточена

основная часть корневой системы растений и здесь наиболее интенсивно протекают процессы почвообразования, формируются благоприятные физические и агрохимические свойства почвы. Мощность гумусовых горизонтов в различных почвах неодинакова, как неодинакова и глубина проникновения корневой системы растений. Во всех случаях, если глубина распространения корней превышает мощность пахотного слоя, это обязательно должно учитываться при бонитировке почв. Это подтверждается также высокой корреляцией между урожайностью растений и мощностью гумусовых горизонтов.

Существует закономерность, согласно которой с уменьшением мощности горизонта А+В ослабевает его корреляционная связь с урожайностью растений.

Мощность гумусового горизонта и запасы гумуса являются показателями, наиболее полно отражающими внутреннее состояние почвы и её плодородие, а также являющимися выражением процессов почвообразования. Не случайно при бонитировке почв Нижегородской губернии В.В. Докучаев в первую очередь учитывал мощность почвенного профиля и содержание гумуса.

Участие гумуса в формировании урожая сельскохозяйственных культур неодинаково. Интересным является то, что при снижении содержания гумуса в почве его роль в формировании урожая становится более выраженной. Исследования показывают, что начиная с мощности горизонта А+В 150–160 см и запасов гумуса 600–650 т/га дальнейшее их увеличение уже не приводит к росту урожайности (4). Следует отметить также, что каждая культура имеет собственные экологические требования к содержанию гумуса. Так, требования зерновых культур к гумусу существенно отличаются от требований винограда. Например, почвы, неблагоприятные для зерновых культур, могут быть благоприятными для винограда. Наличие обратной корреляции между сахаристостью винограда и содержанием гумуса ($r = 0,56-0,88$), а также прямой корреляции между кислотностью виноградного сока и содержанием гумуса ($r = 0,72$) (В.Ф. Валков) подтверждает это положение: с увеличением запасов гумуса сахаристость винограда снижается, а кислотность сока повышается.

При бонитировке почв важным критерием является также запас фосфора в почве. Это не случайно, поскольку фосфор является важнейшим элементом питания растений и играет ключевую роль в их физиологической деятельности. Все обменные процессы в растительном организме связаны с содержанием фосфора; без него невозможно формирование структуры живой клетки. Недостаток фосфора в почве отрицательно влияет на развитие и урожайность растений. Он способствует увеличению доли зерна и улучшению его качества у зерновых культур, повышению содержания сахара в плодах и овощах, крахмала в картофеле. Фосфор не только повышает урожайность и качество сельскохозяйственных культур, но и увеличивает их устойчивость к неблагоприятным факторам среды, таким как засуха, мороз и болезни. Поэтому можно с полным основанием утверждать, что, как и азот, фосфор является жизненно необходимым элементом.

Различные почвы содержат фосфор в неодинаковых количествах: в малоплодородных песчаных почвах его содержание составляет около 0,01%, а в наиболее плодородных чернозёмах достигает 0,20%. В верхних слоях почв его больше, чем в нижних горизонтах, что связано с накоплением и разложением растительных остатков корневой системы. Основная часть фосфора в почве находится в минеральной форме, тогда как органический фосфор в основном сосредоточен в составе гумуса.

При бонитировке почв в качестве критерия используется запас фосфора в слоях 0–20 см и 0–50 см (т/га). Он определяется на основе общего содержания фосфора (%) и плотности почвы (г/см³).

Важным фактором плодородия является также содержание катионов в почве, их состав и соотношение. Использование суммы поглощённых оснований (ЁАС) в качестве критерия оценки характерно для бонитировочных работ, проводившихся в нашей

республике. Фактически среди поглощённых оснований наиболее важными для питания и жизнедеятельности растений являются катионы Ca^{2+} и Mg^{2+} . Достаточное содержание этих элементов в почве является основным условием нормального развития растений и получения высоких урожаев.

Исследования (В.Д. Панников, 1987) показывают, что недостаток Ca^{2+} в почве приводит к прекращению образования новых корней и корневых волосков, повреждает корневую систему растений. При длительном дефиците кальция разрушаются ткани сформировавшихся корней, что в конечном итоге может привести к гибели растения. Кальций участвует в обмене азота, транспорте углеводов, использовании запасных форм белка и других важнейших биохимических процессах, обеспечивая физиологическую активность, рост и продуктивность растений.

Магний входит в состав хлорофилла, фитина и пектиновых веществ. Он участвует в окислительно-восстановительных реакциях, влияет на активность фосфатаз и других ферментов, регулируя физиологические процессы в растении (1). Недостаток магния в почве снижает синтез хлорофилла и отрицательно влияет на процесс фотосинтеза.

Превалирование Ca^{2+} и Mg^{2+} в составе поглощённых оснований является важным условием плодородия. Исследования, проведённые в республике, показали достаточно тесную корреляционную связь между урожайностью сельскохозяйственных культур и суммой поглощённых оснований. Однако, как и в случае других критериев (гумус, фосфор), эта связь может изменяться в зависимости от особенностей конкретной культуры.

Определение поправочных коэффициентов для почв бассейна реки Хакарчай

При составлении основной шкалы бонитировки в качестве объекта оценки выбираются те свойства и признаки почвы, которые имеют устойчивую корреляционную связь с урожайностью сельскохозяйственных культур. Такая оценка является корректной для типичных, нормальных почв. Однако в природе нормальные почвы встречаются редко. Их плодородие может изменяться под воздействием ряда факторов (эрозия, засоление, солонцеватость, гидроморфизм, гранулометрический состав, мощность почвенного слоя, степень окультуренности и др.).

Хотя эти факторы имеют локальный характер, они должны учитываться в оценке посредством поправочных коэффициентов. Таким образом, в основной шкале бонитировки балльные значения типов и подтипов почв определяются для нормальных условий, а баллы почв, отличающихся от них, рассчитываются с использованием поправочных коэффициентов.

Поправочные коэффициенты определяются на основе специальных полевых и лабораторных исследований. Далее рассматривается влияние каждого признака на плодородие почв и урожайность, а также порядок их учёта с помощью поправочных коэффициентов.

а) Учёт гранулометрического состава почв с помощью поправочного коэффициента. Гранулометрический состав является очень важным свойством почвы. От него зависят многие её свойства и признаки. Обычно, чем легче гранулометрический состав почвы, тем меньше в ней содержание гумуса и питательных веществ. По мере увеличения доли илистых частиц в почве её потенциальное плодородие зависит не только от богатства питательными веществами, но и от физических свойств.

Тяжёлые глинистые почвы, несмотря на высокое содержание илистых частиц, считаются малоплодородными из-за неблагоприятных физико- и водно-физических свойств. Отношение сельскохозяйственных культур к гранулометрическому составу почвы также неодинаково. Каждая культура имеет свой оптимум в этом отношении. Существуют растения, у которых требования к гранулометрическому составу почвы изменяются в очень

узких пределах (2). Однако большинство сельскохозяйственных культур предпочитает лёгкие и среднесуглинистые почвы. Например, картофель плохо развивается на тяжёлых глинистых почвах, но его наибольшая урожайность наблюдается на супесчаных и лёгкосуглинистых почвах.

Отношение сельскохозяйственных культур к гранулометрическому составу почвы можно видеть и из следующей таблицы (таблица 1).

Таблица

1

Отношение сельскохозяйственных культур к гранулометрическому составу почвы (В.Ф. Вальков, 1986)

Таблица 1

Земли			
Песчаные и супесчаные	Сорго	пшеница	рис
Озимая рожь	овёс	ячмень	кукуруза
Рожь	просо	кукуруза	фундук
Картофель	гречиха	soя	слива
Арахис (земляной орех)	ячмень	подсолнечник	вишня
Арбуз	soя	фасоль	хурма
Дыня	подсолнечник	лён	фейхоа
Тыква	помидоры	сахарная свёкла	клевер (чёрный клевер)
Маслины	яблоки	абрикосы	
	груши	вишня	
	чай	грецкие орехи	
	виноград	гранаты	
	лимоны	фейхоа	
	айва	люцерна	
	инжир	хлопок	
	табак	сливы	
		Dates	

Во многих работах по бонитировке земель бассейна реки Гекари (в том числе по бонитировке земель в целом) поправочный коэффициент принимался равным «1,0». Это также можно увидеть из приведённой ниже таблицы.

Таблица №2

Гранулометрический состав	поправочные коэффициенты		
	бурые горно-лесные	бурые горно-лесные	каштановые
глина	0,80	0,80	0,80
тяжёлая глина	0,90	0,90	0,90
средняя глина	1,00	1,00	1,00
лёгкая глина	0,89	0,89	0,89

а) С учётом эрозии почв с использованием поправочных коэффициентов. Одним из факторов, оказывающих очень резкое влияние на плодородие почвы, является процесс

эрозии. Его отрицательное воздействие можно сравнить лишь с сильным засолением и осолонцеванием. Под влиянием эрозионного процесса большинство свойств и характеристик почвы претерпевают коренные изменения. В ходе эрозии, прежде всего, ухудшаются химические, физические и водно-физические свойства и режимы почвы. Наибольший ущерб наносится гумусу, который является важнейшим фактором плодородия: при этом его количество и запасы в почвенном профиле уменьшаются, а состав претерпевает неблагоприятные изменения. Одновременно наблюдается снижение содержания других питательных веществ и ослабление биологической активности почвы.

При сильных формах эрозии почва завершает своё природно-историческое развитие постепенным смывом верхнего слоя, и нередко на поверхность выходят лишь нижние горизонты, состоящие из материнской породы. Снижение плодородия почвы в той или иной степени зависит от степени её смывости. Это определяется в результате специальных почвенно-эрозионных исследований.

Исследователи часто делят почвы на четыре группы по степени смывости: слабая, средняя, сильная и очень сильная. Такое деление является условным, поскольку может варьироваться в зависимости от типа почвы, зональных и региональных особенностей. При оценке почв специалисты и эрозиоведы данной области определяют поправочные коэффициенты, используя готовые материалы исследований.

Таблица №3

степень смывости	поправочные коэффициенты		
	бурые горно-лесные	бурые горно-лесные	каштановые
несмытые	1,00	1,00	1,00
слабо смытые	0,8	0,7	0,6
среднесмытые	0,5	0,5	0,4
сильно смытые	0,2	0,2	0,2

При определении конечных баллов качества земель и составлении открытых шкал почв бассейна реки Гехари с применением поправочных коэффициентов, при составлении основных шкал качества земель почв бассейна реки Гехари почвенные показатели (гумус, азот, ЕКО), распределённые в пределах зоны, были собраны и проанализированы с использованием математико-статистических методов. В соответствии с методикой оценки качества земель, разработанной для нашей республики, баллы качества земель почв в некоторых случаях сопоставляются с показателями продуктивности сельскохозяйственных растений, выраженными в баллах. Такой подход на протяжении многих лет является методической основой оценки качества земель в Азербайджане.

Данная научная проблема интенсивно изучалась Г. Ш. Мамедовым в 80–90-х годах. Результаты этих исследований отражены в ряде публикаций. Однако следует отметить, что иногда связь между природными диагностическими признаками и продуктивностью может не наблюдаться. Это связано с:

- а) неправильным выбором диагностических признаков;
- б) низким качеством почвенно-картографических и аналитических материалов, характеризующих почвенный покров оцениваемой территории;
- с) отсутствием точного и детального учёта продуктивности сельскохозяйственных культур.

Тем не менее ряд исследователей обращал внимание на сопоставление основных шкал качества почв с показателями продуктивности сельскохозяйственных культур.

Изучение корреляции между генетическими характеристиками или внутренними диагностическими показателями почвы и продуктивностью сельскохозяйственных культур

позволяет составить основную шкалу плодородия исследуемой территории, принимая гумус, азот и ЕКО в качестве критериев плодородия.

Таблица №4

The main quality scale of the soils of the Hakarichay basin

название почв	Гумус, т/га			Азот, т/га		ЕКО (ёмкость катионного обмена), мг-экв/100 г (или мг/экв, как в исходнике)		Баллы			Итого Сред- ние баллы
	0-20	0-50	0-100	0-20	0-50	0-20	0-50	Humus	Azot	UEC	
карбонатные бурые горно- лесные почвы	106,38 106	201,2595	-	5,3792	13,1104	39,7 86	38,40 75	101	98	80	87
бурые горно- лесные почвы	77,1077	170,6181	-	8,05 137	13,23 105	38,64 84	38,64 75	95	121	79	88
смытые бурые горно- лесные почвы	100,53 100	211,05100	-	5,86100	12,60 100	46,27 100	51,2 100	100	100	100	100
каштановые почвы	71,8362	152,4665	254,0,74	4,28 73	9,45 75	28,59 86	28,08 80	67	74	83	75

В традиционной оценке земель после того, как на основной шкале определяются баллы оценки земель для типа и подтипа почв, стоимость отдельных земельных единиц (видовое разнообразие) устанавливается с применением поправочных коэффициентов. Только после этого определяются итоговая шкала оценки земель исследуемой территории, их коэффициент сравнительной ценности и производственные группы сельскохозяйственного назначения.

Поскольку плодородие и продуктивность сельскохозяйственных культур изменяются под влиянием ряда природных и антропогенных факторов (гранулометрический состав, засоление, осолонцевание, эрозия, остаточность, орошение и др.), данный аспект необходимо учитывать при оценке земель.

В целом поправочные коэффициенты, используемые для определения конечных баллов бонитировки, были взяты из таблиц 3 и 4.

Для определения конечных баллов шкалы бонитировки использовалась следующая формула.

$$B=B_a \times \Theta_{qr} \times \Theta_y$$

Таким образом, **B** — это конечный балл качества почвы, **B_э** — балл качества почвы, взятый с основной шкалы качества почв, **Э_{qr}** — поправочный коэффициент гранулометрического состава, а **A_y** — поправочный коэффициент степени смывости.

Таблица №5

Открытая шкала качества земель бассейна реки Гекари (Хакаричай)

Название почвы	Баллы
Глинистые несмытые бурые горно-лесные почвы	70
Тяжелоглинистые слабосмытые бурые горно-лесные почвы	55
Среднеглинистые сильносмытые бурые горно-лесные почвы	18
Лёгкоглинистые сильносмытые бурые горно-лесные почвы	16
Глинистые несмытые каштановые почвы	60
Тяжелоглинистые слабосмытые каштановые почвы	41
Среднеглинистые смытые каштановые почвы	15
Лёгкоглинистые несмытые каштановые почвы	67

Комплексные природные условия бассейна реки Гекари (Хакаричай), разнообразие рельефа, климата и биологических факторов обусловили разнообразие плодородия почв. Это, в свою очередь, усложнило экономические показатели производства, увеличив и снизив затраты на выращивание сельскохозяйственных культур. Поэтому оценка плодородия основных типов почв, распространённых в бассейне, является одной из важнейших задач.

В современных условиях значение оценки земель возросло в связи с приватизацией, куплей-продажей и залогом земель. Общеизвестно, что фермеры, владеющие землёй одинаковой площади, но разного качества, не имеют одинаковых экономических и финансовых возможностей, поэтому данный аспект должен учитываться при налогообложении земель или их купле-продаже. В противном случае сопоставление равных по площади участков с разным плодородием в конечном итоге приводит к нарушению социальной справедливости и замедлению внедрения научно-технических инноваций в сельском хозяйстве. Для предотвращения этого необходимо иметь информацию о разнообразии плодородия земель бассейна реки Гекари, их сравнительной ценности и оценке качества. Эта информация получается в результате исследований, проводимых по специальным принципам и методам, то есть бонитировки земель бассейна реки Гекари. Следует отметить, что опыт развитых стран показывает: учёт разнообразия почвенного плодородия в системе регулирования земельных отношений может служить мощным стимулом не только повышения урожайности, но и повышения плодородия почв.

Изучение корреляции между генетическими характеристиками или внутренними диагностическими показателями почвы и продуктивностью сельскохозяйственных растений позволило принять в качестве критериев качества почв гумус, азот и ЕКО при составлении основной шкалы качества почв бассейна реки Гекари. Используя указанные критерии, нами была составлена основная шкала качества почв бассейна реки Гекари (таблица 4). Здесь карбонатные бурые горно-лесные почвы получили 87 баллов, бурые горно-лесные — 88, смытые бурые горно-лесные — 100, а каштановые почвы — 75 баллов.

Поскольку плодородие и продуктивность сельскохозяйственных растений изменяются под влиянием ряда природных и антропогенных факторов (гранулометрический состав, засоление, эрозия и др.), этот аспект необходимо учитывать при оценке почв. По этой

причине используемые поправочные коэффициенты должны выбираться очень тщательно с учётом природно-экономических, региональных условий, а также требований возделываемых культур (5). При оценке почв бассейна реки Гекари нами были составлены открытые шкалы качества почв с применением поправочных коэффициентов с учётом указанных аспектов (степень смывости, гранулометрический состав) (таблица 4).

Как видно из бонитетных шкал земель бассейна реки Гекари, плодородие или производственный потенциал земель, распространённых на территории, различается.

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Technical Sciences

Analysis of Seismic Resistance and Structural Stability of a Multi-Story Reinforced Concrete Building: A Comparative Study of Heavy and Lightweight Concrete (The Case of Tbilisi)

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Abstract

This paper examines the methodology and calculation results for the construction of a 20-story reinforced concrete building designed in the city of Tbilisi. The study includes a dynamic analysis of the building under seismic and wind loads using the "LIRA SAPR 2024" software package. The primary goal of the work is to evaluate the impact of using heavy versus lightweight concrete on the load-bearing capacity and economic efficiency of the building. Results indicate that the use of lightweight concrete significantly reduces the building's self-weight, which is directly proportional to the reduction in seismic loads.

Introduction

Modern urban architecture is increasingly focused on the construction of high-rise buildings due to the shortage of free land and rising population density. Designing such structures presents a complex challenge for engineers: ensuring high seismic resistance and dynamic stability while maintaining economic feasibility.

Georgia, and Tbilisi in particular, is characterized by complex seismotectonic conditions. According to current standards, this territory belongs to a high seismic activity zone, which directly influences the structural solutions for high-rise reinforced concrete buildings. The use of traditional heavy concrete increases the total mass of the building, which, according to Newton's Second Law ($F = ma$), leads to a proportional increase in seismic inertial forces.

In recent decades, the use of lightweight concrete in load-bearing structures has become relevant in international engineering practice. Lightweight concrete not only reduces the vertical loads transferred to the foundation but also significantly improves the building's dynamic response to seismic impacts. However, its use requires caution, as its lower modulus of elasticity affects the building's deformability and comfort criteria under wind loads.

The objective of this work is to demonstrate the effectiveness of using lightweight concrete using the example of a 20-story building in Tbilisi. The study details:

- Dynamic parameters and vibration modes.
- Analysis of seismic and wind load impacts using "LIRA SAPR 2024".

- Comparative technical and economic analysis of heavy vs. lightweight concrete.
 - Evaluation of wind-induced vibration accelerations according to occupant comfort criteria.
- high-rise projects in Tbilisi and Batumi. Given the increasing rate of high-rise construction in Georgia, ensuring seismic resistance is a critical issue. Strengthening earthquake-resistant measures is essential in seismically active regions.

2. Modeling and Methodology

The structural calculation was performed in the LIRA SAPR 2024 software package using the Finite Element Method (FEM). Modeling utilized spatial rod and plate elements to accurately describe the building's characteristics.



Fig.1 Architectural project

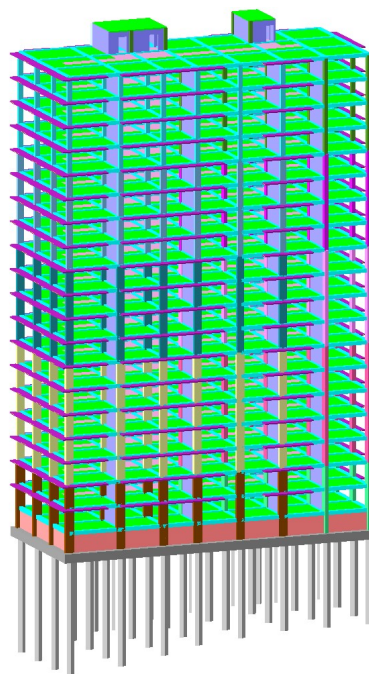


Fig.2 Reporting spatial model
- general view

2.1. Structural Scheme

The building is designed as a frame-diaphragm system:

- **Columns:** Main vertical elements absorbing axial loads.
- **Diaphragms:** Provide building rigidity and absorption of horizontal seismic forces.
- **Floor Slabs:** Treated as rigid disks distributing loads between vertical elements.

2.2. Soil Interaction

A soil model was used where resistance under the foundation slab is accounted for via variable coefficients C1 and C2. This allows for the evaluation of the joint work of the building and foundation.

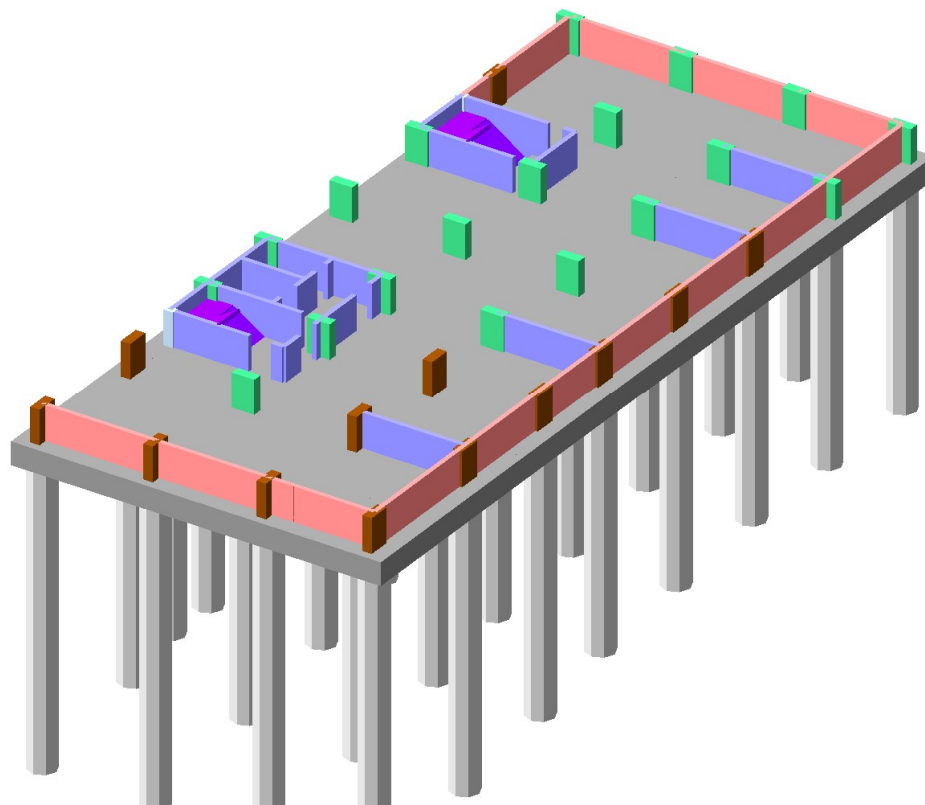


Fig.3. Reporting spatial model

3. Physical and Mechanical Material Parameters

The study compares two variants of concrete:

1. Heavy Concrete (B30): Density $\rho = 2500 \text{ kg/m}^3$ and modulus of elasticity $E = 3,25 \cdot 10^4 \text{ MPa}$.
2. Lightweight Concrete (B30): Density $\rho = 2000 \text{ kg/m}^3$ and modulus of elasticity $E = 2,20 \cdot 10^4 \text{ MPa}$.

Using lightweight concrete reduces the building's mass by 20%. However, the reduction in the modulus of elasticity (approx. 32%) affects structural rigidity, requiring additional deformation control.

4. Seismic and Wind Analysis

4.1. Seismic Impact In accordance with Georgian seismic standards (PN 01.01-09), a seismic coefficient of $A = 0.17$ is adopted for Tbilisi. The analysis included 20 vibration modes and a non-linear dynamic analysis using real accelerograms to observe behavior during peak earthquake phases.

Earthquake analysis parameters (Georgia, PN 01.01.-09)

Soil category: II

Relative acceleration of soil A in proportion of acceleration of gravity g: 0.17

Values of design coefficients according to PN 01.01.-09

Coef. of nonlinear deformation of soil K0 (table 4.1): 1.0

Coef. for account of allowed damages K1 (table 3): 0.35

Structural design coefficient K2 (table 4): 1.50

Coefficient of responsibility of the structure K3 (table 5): 1.0

Coefficient for energy dissipation Kpsi (table 6): 1.0

Direction cosines of earthquake load resultant in global system

CX: 1.0000 CY: 0.0000 CZ: 0.0000 $CX^2 + CY^2 + CZ^2$

Buttons: [OK] [Cancel] [Help]

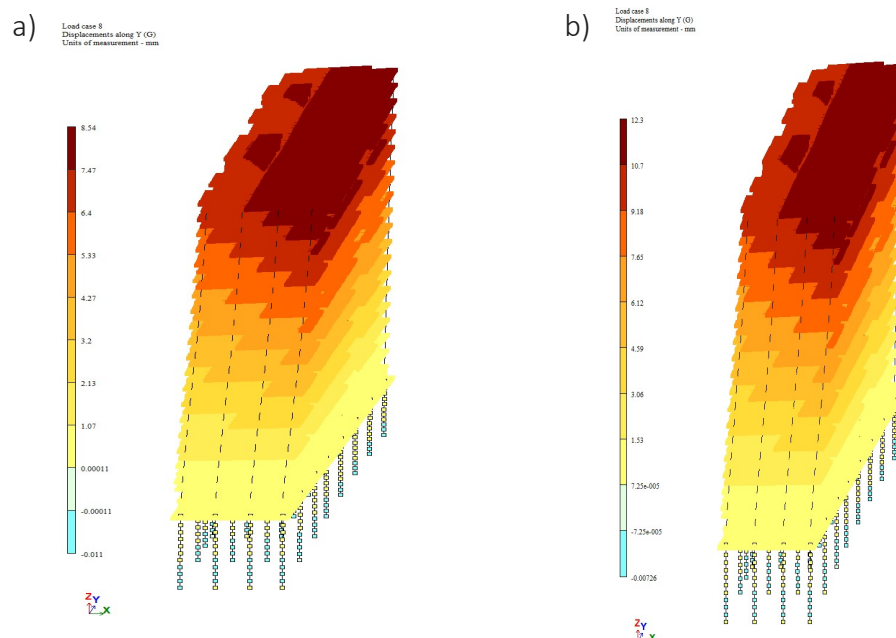


Fig.4 Displacement due to wind load in the Y-direction:

a) heavy concrete $H_x = 8.54$ mm; b) lightweight concrete $H_x = 12.3$ mm.

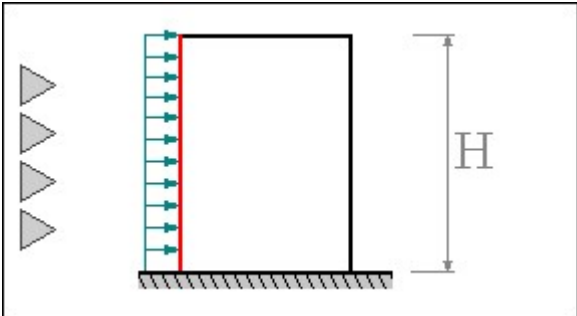
4.2. Wind Load and Comfort Criteria The wind load (85 kg/m^2) included static and pulsating components. With lightweight concrete, the lower mass and rigidity lead to increased vibration accelerations. According to international standards (ISO 10137), top-floor acceleration should not exceed $0.15\text{--}0.20 \text{ m/s}^2$ to ensure occupant comfort.

Static Wind Load The standard wind load, occurring once every 20 years, is 0.85 kPa (85 kg/m^2), according to "Construction Climatology" (PN.01.05-08), Table 18; No. 59. The wind load on the structure must be determined in two directions: transverse (along the X-axis) and longitudinal (along the Y-axis) to identify which direction yields the greater displacement. The standard wind load value must be converted into a design value using the established formula.

$$w = w_0 \cdot k(z_e) \cdot c \cdot \gamma$$

Where: w_0 - The standard wind load of 85 kg/m^2 . $k(z_e)$ - A coefficient depending on the building height and the construction site location (SNiP 2.01.07-85*, Table 11.2). c - The aerodynamic

coefficient. It is taken as 0.8 for windward pressure and 0.6 for leeward suction (SNIIP 2.01.07-85, Table 11.1.7). The partial safety factor for loads (overload coefficient), γ equal to 1.4. Table 1 presents the wind load values applied to the reinforced concrete load-bearing frame, accounting for the variation in height.

Wind loads - in the direction of pressure (SNIP 2.01.07-85*)			
Input data			
Region of the site	Type of structure	Model	Parameters
Type of the site - B	1.Surfaces vertical and diverged from vertical not more than by 15°		H = 64.00 m
Wind region - VII	Surface - Windward side		
$\omega_0 = 85.00$ kg/m2	Calculation step = 1.00 m		
	$Y_f = 1.40$		

Output data

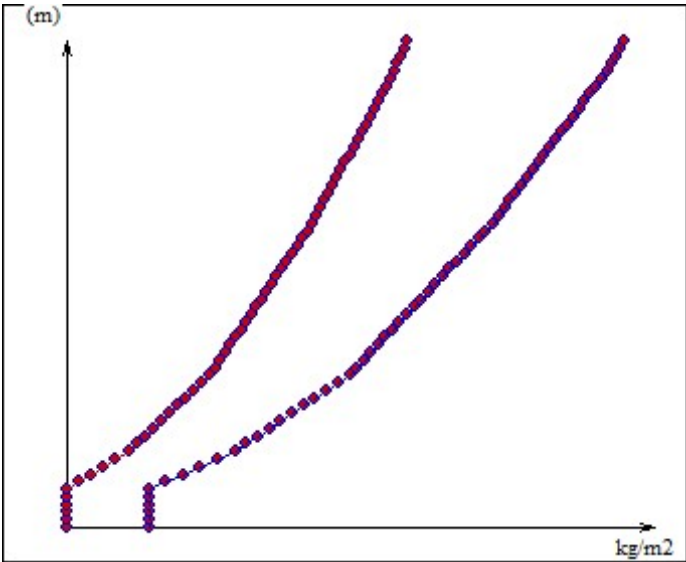


Table 1. Distribution of wind load by height taking into account the aerodynamic coefficient.

Distance to, m	Normative load, kg/m ²	Design load, kg/m ²	Distance to, m	Normative load, kg/m ²	Design load, kg/m ²
0.00	34.00	47.60	1.00	34.00	47.60
2.00	34.00	47.60	3.00	34.00	47.60
4.00	34.00	47.60	5.00	34.00	47.60
6.00	36.04	50.46	7.00	38.08	53.31
8.00	40.12	56.17	9.00	42.16	59.02
10.00	44.20	61.88	11.00	45.56	63.78
12.00	46.92	65.69	13.00	48.28	67.59
14.00	49.64	69.50	15.00	51.00	71.40
16.00	52.36	73.30	17.00	53.72	75.21
18.00	55.08	77.11	19.00	56.44	79.02
20.00	57.80	80.92	21.00	58.65	82.11
22.00	59.50	83.30	23.00	60.35	84.49
24.00	61.20	85.68	25.00	62.05	86.87
26.00	62.90	88.06	27.00	63.75	89.25
28.00	64.60	90.44	29.00	65.45	91.63
30.00	66.30	92.82	31.00	67.15	94.01
32.00	68.00	95.20	33.00	68.85	96.39
34.00	69.70	97.58	35.00	70.55	98.77
36.00	71.40	99.96	37.00	72.25	101.15
38.00	73.10	102.34	39.00	73.95	103.53
40.00	74.80	104.72	41.00	75.48	105.67
42.00	76.16	106.62	43.00	76.84	107.58
44.00	77.52	108.53	45.00	78.20	109.48
46.00	78.88	110.43	47.00	79.56	111.38
48.00	80.24	112.34	49.00	80.92	113.29
50.00	81.60	114.24	51.00	82.28	115.19
52.00	82.96	116.14	53.00	83.64	117.10
54.00	84.32	118.05	55.00	85.00	119.00
56.00	85.68	119.95	57.00	86.36	120.90
58.00	87.04	121.86	59.00	87.72	122.81
60.00	88.40	123.76	61.00	88.91	124.47
62.00	89.42	125.19	63.00	89.93	125.90
64.00	90.44	126.62			

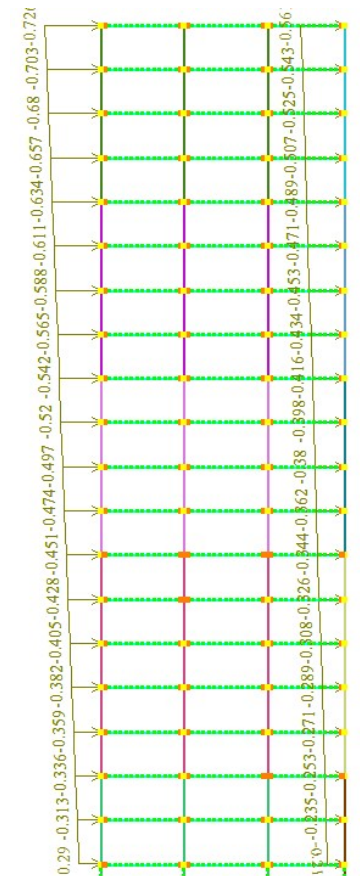


Fig.5. Wind load on a reinforced concrete frame

5. Discussion of Results

The analysis showed that using lightweight concrete resulted in:

1. **Seismic Loads:** Decreased by 15-18% due to reduced inertial mass.
2. **Reinforcement:** Required reinforcement area in columns and diaphragms decreased by 10-12%.
3. **Deformations:** Horizontal displacements increased by 8-10%, but remained within allowable limits ($H/500$).

6. Conclusion

The study confirms that using lightweight concrete for a 20-story building in Tbilisi is fully justified. It provides weight optimization, reduced seismic risks, and material cost savings. However, designers are advised to pay close attention to comfort criteria, as current Georgian norms do not fully regulate this aspect.

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HOW AI IS TRANSFORMING CYBER DEFENSE

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ABSTRACT

As cyber threats continuously evolve in scale, complexity, and sophistication, traditional reactive defense mechanisms are proving increasingly inadequate for securing modern digital infrastructures. This comprehensive white paper explores the transformative impact of Artificial Intelligence (AI) and Machine Learning (ML) on cyber defense architectures. By systematically analyzing recent developments across threat intelligence, zero-day malware detection, automated incident response, User and Entity Behavior Analytics (UEBA), and the protection of critical infrastructure, we elucidate how AI is shifting the cybersecurity paradigm from reactive mitigation to predictive and autonomous defense. Furthermore, this document critically examines the dual-use nature of AI, addressing the rising threat of adversarial machine learning—including data poisoning, inference evasion, and model extraction attacks—that malicious actors currently employ to subvert AI-driven security tools. Synthesizing findings from extensive recent literature, including reports from the World Economic Forum (WEF), the European Union Agency for Cybersecurity (ENISA), and leading academic institutions, this paper presents a detailed evaluation of current AI capabilities, the challenges of integration, and the strategic imperatives for future cyber defense ecosystems.

Keywords: *Artificial Intelligence, Machine Learning, Cyber Defense, Anomaly Detection, Adversarial Machine Learning, SOAR, Threat Intelligence, Critical Infrastructure Protection*

INTRODUCTION

The digital battlefield is undergoing a profound transformation. Over the past decade, the rapid proliferation of cloud computing architectures, mobile ecosystems, 5G networks, and the Internet of Things (IoT) has exponentially expanded the attack surface available to malicious actors. According to the World Economic Forum's recent global risk reports, the business benefits of digital transformation are accompanied by unprecedented cyber risks, primarily driven by the automation and democratization of attack tools. Threat actors—ranging from script kiddies to state-sponsored Advanced Persistent Threats (APTs)—are no longer relying solely on manual exploits; they are leveraging artificial intelligence to launch highly sophisticated, polymorphic, and persistent attacks that easily bypass traditional security perimeters.

Historically, cyber defense has been a fundamentally reactive discipline. Signature-based Intrusion Detection Systems (IDS), heuristic antivirus solutions, and basic firewall rules operate by identifying known malicious patterns and static indicators of compromise (IoCs) such as file hashes, IP addresses, and domain names. While highly effective against legacy, known threats, these deterministic systems are inherently limited by their reliance on historical data. They require prior knowledge of an attack—often in the form of a recorded signature published by a security vendor—to successfully intercept it. Consequently, they are entirely blind to "zero-day" vulnerabilities: novel exploits that have not yet been documented.

To bridge this critical capability gap, organizations and nation-states are increasingly turning to Artificial Intelligence and Machine Learning. AI introduces a paradigm shift in cyber defense by enabling systems to analyze vast amounts of network telemetry in real-time, identify subtle

deviations from established baselines, and predict future attack vectors before they fully materialize. Machine learning algorithms, particularly Deep Neural Networks (DNNs), are now capable of automating threat hunting, triaging security alerts, and orchestrating incident response at a speed and scale that far surpasses human cognitive capacity.

However, the integration of AI into cybersecurity is not a panacea; it is a double-edged sword. As defenders harness machine learning to fortify networks, attackers are simultaneously weaponizing AI to orchestrate cognitive warfare, generate highly convincing spear-phishing campaigns at scale, and execute adversarial attacks specifically designed to mathematically trick defensive AI models. This white paper delves into the intricate dynamics of this emerging technological arms race, dissecting the primary domains where AI is revolutionizing cyber defense while critically analyzing the vulnerabilities introduced by these very same technologies.

Table 1. Comparison of Legacy Cyber Defense vs. AI-Driven Defense

Feature	Legacy Defense (Reactive)	AI-Driven Defense (Proactive)
Detection Method	Signature-based: Relies on known hashes and blacklists of previous attacks.	Behavioral-based: Uses anomaly detection to identify "unknown" or zero-day threats.
Response Speed	Manual/Delayed: Requires human intervention to triage and contain threats.	Autonomous: Millisecond-level response via automated SOAR playbooks.
Threat Scope	Known Quantities: Excellent for blocking repetitive, established malware.	Evolving Threats: Detects polymorphic code and subtle lateral movement patterns.
Data Processing	Siloed: Struggles with massive datasets and disparate log formats.	Unified: Synthesizes OSINT, Dark Web, and internal telemetry through NLP.
Scalability	Linear: Requires adding more analysts as the network grows.	Exponential: Scales to millions of endpoints without increasing human overhead.
Decision Logic	Deterministic: Binary (Yes/No) based on rigid, pre-defined rules.	Probabilistic: Risk-based scores that adapt to changing network conditions.

To visualize this paradigm shift, Table 1 contrasts the fundamental operational differences between legacy reactive systems and the emerging AI-driven autonomous ecosystem.

AI-DRIVEN THREAT INTELLIGENCE AND PREDICTIVE ANALYTICS

Threat intelligence is the lifeblood of modern proactive cybersecurity. It involves the continuous collection, processing, and analysis of data regarding adversarial tactics, techniques, and procedures (TTPs). Traditionally, threat intelligence was a highly manual, labor-intensive process, plagued by massive data volumes and significant operational latency. Security Operation Centers (SOCs) were, and often still are, overwhelmed by "alert fatigue"—a phenomenon where analysts are bombarded with thousands of false-positive alerts daily, leading to burnout and the potential for genuine, stealthy threats to slip through the cracks.

Natural Language Processing in OSINT:

Artificial Intelligence fundamentally resolves data ingestion bottlenecks through advanced data parsing and predictive analytics. AI-driven threat intelligence platforms autonomously scrape

and process structured data from security logs (SIEMs) alongside vast troves of unstructured data from the dark web, hacker forums, social media, and technical blogs (Open Source Intelligence, or OSINT). By employing sophisticated Natural Language Processing (NLP) models, these systems can read and understand threat discourse in multiple languages, extract newly mentioned vulnerabilities (CVEs), and map them to the MITRE ATT&CK framework automatically. This synthesizes fragmented data points into cohesive, actionable threat profiles in real-time.

Real-Time Anomaly Detection and UEBA:

The core utility of AI in active defense lies in its transition from deterministic rules to probabilistic modeling. Machine learning models establish dynamic baselines of normal network and user behavior, a domain known as User and Entity Behavior Analytics (UEBA). Instead of looking for a specific malicious file, the AI monitors behavioral indicators: unusual lateral movement across network segments, anomalous data exfiltration volumes at odd hours, or unexpected privilege escalation by a standard user account.

When behavior deviates from the established historical pattern, the AI calculates a risk score. If the score exceeds a dynamic threshold, the system flags it as an anomaly. This methodology allows for the detection of "living off the land" (LotL) attacks, where adversaries use legitimate administrative tools (like PowerShell or WMI) to conduct malicious activities, which would otherwise go unnoticed by signature-based tools.

Predictive Cyber Posturing:

Furthermore, predictive analytics empowers organizations to adopt a truly proactive posture. By analyzing historical attack data, global threat feeds, and local network vulnerabilities, ML algorithms can forecast likely future targets and attack vectors. For instance, if an AI model observes an uptick in reconnaissance activities targeting specific open remote desktop protocol (RDP) ports common in the healthcare sector globally, it can automatically recommend or deploy pre-emptive firewall rules and stricter multi-factor authentication (MFA) policies to localized networks to mitigate the impending attack.

Key Insight: Industry studies demonstrate that AI algorithms utilizing UEBA and behavioral analytics can reduce false-positive rates by up to 70%, allowing human analysts to focus exclusively on highly sophisticated, genuine security events, thereby drastically reducing the Mean Time to Detect (MTTD).

MACHINE LEARNING ARCHITECTURES IN MALWARE DETECTION

The limitations of signature-based detection are most glaring in the realm of malware. Adversaries routinely employ obfuscation techniques—such as code packing, encryption, polymorphism, and metamorphism—to alter the binary signature of malware while preserving its underlying malicious payload. This renders traditional antivirus solutions obsolete against modern, automated malware generation campaigns.

Static vs. Dynamic Analysis with Deep Learning

To combat sophisticated malware, defenders rely on Deep Learning (DL) architectures. Unlike traditional machine learning techniques (such as Random Forests or Support Vector Machines) that require manual feature engineering by human experts, deep learning models autonomously extract hierarchical representations from raw data.

Static Analysis via Convolutional Neural Networks (CNNs):

Static analysis examines malware without executing it. A breakthrough in this field involves visualizing malware. By converting raw binary code into grayscale images (where each byte represents a pixel intensity), researchers can deploy CNNs—originally designed for computer vision—to visually identify malicious structural patterns. Obfuscation attempts often fail to hide the underlying structural "texture" of the malicious code, allowing the CNN to classify the image as malicious with high accuracy.

Dynamic Analysis via Recurrent Neural Networks (RNNs):

Dynamic analysis involves running the suspicious file in a secure sandbox and monitoring its behavior. RNNs, and specifically Long Short-Term Memory (LSTM) networks, excel at processing sequential data. They are deployed to analyze the temporal sequence of Application Programming Interface (API) calls and system operations executed by a program. If an application attempts to modify critical registry keys, inject code into a legitimate process, and rapidly encrypt user files, the LSTM recognizes the temporal signature of ransomware, regardless of whether the file's hash has ever been seen before.

Zero-Day Threats and Zero-Shot Learning

The most pressing challenge remains the detection of absolute zero-day malware. Recent breakthroughs in AI research have introduced "Zero-Shot Learning" (ZSL) to cybersecurity. ZSL enables an AI model to correctly classify and detect novel malware families it has never explicitly encountered during its training phase. By leveraging semantic relationships and behavioral attributes rather than explicit examples—learning the concept of malicious behavior rather than just memorizing malicious files—zero-shot models drastically reduce an organization's reliance on constantly updated threat databases.

AUTOMATED INCIDENT RESPONSE AND AUTONOMOUS SYSTEMS

Detecting a breach is only the first step; the speed of response dictates the extent of the damage. In a traditional SOC, identifying a threat triggers a manual investigation. Analysts must query logs, isolate affected endpoints, communicate with stakeholders, and orchestrate a remediation strategy. In fast-moving scenarios like automated ransomware propagation or automated data wiping, human response times (often measured in hours or days, known as Mean Time to Respond or MTTR) are severely insufficient.

1. The essence of AI applications in healthcare

AI applications in healthcare are built upon three foundational processes that mirror, and in some respects extend, the core activities of clinical medicine. First, data acquisition and representation: AI systems ingest raw clinical data- whether structured (laboratory values, vital signs) or unstructured (free-text notes, radiology images)- and transform it into mathematical representations that algorithms can process. Second, pattern recognition and inference: trained models identify statistically significant patterns in these representations and generate outputs such as diagnostic classifications, risk scores, treatment recommendations, or anomaly alerts. Third, decision support and action: these outputs are presented to clinicians, administrators, or patients as structured decision-support information that informs- but does not replace- human judgment.

Security Orchestration, Automation, and Response (SOAR)

AI transforms incident response through intelligent automation. AI-driven Security Orchestration, Automation, and Response (SOAR) platforms act as the central nervous system of a defense architecture. When a severe threat is validated by the AI detection model, the SOAR platform can execute predefined, complex "playbooks" autonomously at machine speed.

For example, if an AI detects an active data exfiltration attempt linked to a compromised user credential, it does not merely alert an analyst. The autonomous system can instantly:

- Revoke the compromised user's identity and access tokens.
- Isolate the infected endpoint from the corporate network at the switch level.
- Block the malicious command-and-control (C2) IP address at the perimeter firewall.
- Initiate a forensic memory dump and disk snapshot of the compromised machine for later analysis.

This rapid, autonomous containment neutralizes the threat in milliseconds, halting lateral movement and preventing data loss.

The Imperative of Explainable AI (XAI)

A critical barrier to the wide-scale adoption of fully autonomous response is the "black box" nature of complex AI models. Chief Information Security Officers (CISOs) and network administrators are understandably hesitant to grant an AI the absolute authority to sever network connections or quarantine mission-critical database servers without understanding the rationale behind the decision. A false positive resulting in the shutdown of a critical business system can be just as costly as a cyberattack.

Consequently, the development of Explainable AI (XAI) is paramount. XAI frameworks are designed to provide human-readable logic trails alongside AI decisions. Instead of simply outputting "Threat Level: 99%", an XAI system displays the exact data points, anomalous behaviors, and probabilistic weights that led the system to its conclusion. This transparency builds trust and allows human oversight to validate the AI's autonomous actions.

SECURING CRITICAL INFRASTRUCTURE WITH AI

The protection of critical infrastructure—such as power grids, nuclear facilities, water treatment plants, transportation networks, and healthcare systems—presents unique cybersecurity challenges. These environments rely heavily on Industrial Control Systems (ICS) and Supervisory Control and Data Acquisition (SCADA) systems. Historically, these operational technology (OT) networks were "air-gapped" (physically isolated from the internet). However, the drive toward Industry 4.0, predictive maintenance, and IoT integration has bridged IT and OT networks, exposing legacy, unpatched infrastructure to modern cyber threats.

Physical and Digital Anomaly Detection

AI is uniquely suited to defend critical infrastructure because ICS environments, unlike standard IT networks, operate with high regularity and determinism. A water treatment pump or a centrifuge operates within very specific, predictable physical parameters (e.g., pressure, temperature, rotational speed).

Machine learning algorithms are increasingly deployed to monitor the delicate physical processes controlled by digital systems. Using complex datasets (such as the Secure Water Treatment or SWaT dataset), researchers have demonstrated that AI can cross-reference network traffic with physical sensor telemetry. If a nation-state actor attempts to maliciously alter the chemical mixture in a water facility—even if they use stolen legitimate credentials to completely bypass digital access controls—the AI monitors the physical telemetry of the sensors. Any deviation from the physical operational baseline instantly triggers a critical alert, identifying the intrusion based on the laws of physics rather than a digital signature.

THE DOUBLE-EDGED SWORD: ADVERSARIAL AI AND ATTACK VECTORS

While AI overwhelmingly empowers defenders, the inherent vulnerabilities of machine learning models have given rise to a dangerous new discipline: Adversarial Machine Learning (AML). Malicious actors are increasingly targeting the AI algorithms themselves, seeking to degrade their accuracy, force misclassifications, or extract sensitive data. The realization that AI models can themselves be "hacked" represents a profound shift in the cybersecurity landscape.

Data Poisoning Attacks

Poisoning attacks target the AI during its training phase. Because machine learning models require massive datasets to learn, attackers find ways to inject subtly manipulated, malicious data into the training pool. Over time, the model learns incorrect associations. For example, an attacker might feed thousands of slightly altered malicious files labeled as "benign" into a cloud-based antivirus training set. Once deployed, the poisoned model will systematically allow similar malicious files to bypass the filter. In continuous-learning environments (where the AI learns from daily network traffic), poisoning represents a critical, long-term threat to system integrity.

Inference Evasion Attacks

Evasion attacks occur during the operational (inference) phase, against already trained and deployed models. Attackers craft "adversarial examples"—inputs that have been intentionally perturbed in ways that are imperceptible to human analysts but completely disrupt the AI's mathematical classifications.

In malware detection, an attacker might append a specific sequence of statistically engineered "junk bytes" to a malicious payload. While the payload remains lethal and executes perfectly, the junk bytes fundamentally alter the file's statistical distribution. This causes a deep learning model to confidently classify the file as benign software.

Model Extraction and Inversion

Furthermore, attackers utilize Model Extraction to steal intellectual property and probe defenses. By repeatedly querying an AI model via a public API and analyzing its outputs, an attacker can train a localized "shadow model" that replicates the proprietary AI's functionality. This shadow model can then be used in an offline sandbox to repeatedly test and refine evasion techniques without alerting the defender, until a successful bypass is found.

Model Inversion attacks go a step further, reconstructing sensitive training data directly from the model's output responses, potentially leaking proprietary corporate network topologies, intellectual property, or Personally Identifiable Information (PII) that was used to train the model.

Defensive Mechanisms: Securing the AI

Securing AI models against these threats requires robust defensive strategies. Adversarial Training is the most prevalent technique, wherein defenders proactively generate thousands of adversarial examples and inject them into their own training set, effectively inoculating the model against known evasion techniques. Additionally, techniques like Defensive Distillation smooth the mathematical decision boundaries of neural networks, making it significantly harder for attackers to calculate the necessary perturbations required to force a misclassification.

RESULTS OF RECENT RESEARCH (2024–2026)

An extensive review of academic literature, white papers, and global security reports published between 2024 and 2026 reveals a strong consensus on both the efficacy and the vulnerabilities of AI in cyber defense.

Policy and Economic Directives: High-level reports from the World Economic Forum (2025) and the European Union Agency for Cybersecurity (ENISA, 2024) emphasize the mandatory adoption of AI to manage enterprise risk. They highlight the emergence of a definitive "AI arms race" where the economic cost-benefit analysis strictly favors AI integration to combat automated threats. Survival against modern APTs without AI is deemed statistically improbable.

IoT and Edge Computing Defenses: Research focusing on the Internet of Things demonstrates that edge-deployed AI models—using federated learning frameworks—can achieve over 97% anomaly detection accuracy in highly constrained environments (like smart sensors) using less than 3% labeled data. This effectively solves the persistent issue of data scarcity and bandwidth limitations in IoT networks.

Advancements in Deep Learning Efficacy: Comprehensive reviews (e.g., IEEE Access, 2025; Frontiers in Big Data, 2024) of over 100 recent AI models confirm that hybrid architectures (combining CNNs for static analysis and RNNs for dynamic analysis) consistently outperform classical machine learning algorithms by margins of 15-20% in zero-day detection.

Adversarial Resilience as a Priority: Recent studies and dissertations (DTU, 2024; ResearchGate, 2025) underline the critical necessity of Adversarial Machine Learning. The academic consensus dictates that AI security models are fundamentally incomplete and unsafe for

enterprise deployment unless they incorporate continuous adversarial stress-testing and XAI metrics to verify the robustness of their decision boundaries.

CONCLUSION

The integration of Artificial Intelligence into cyber defense marks a permanent, irreversible shift in the architecture of digital security. Driven by the critical inadequacy of traditional signature-based methods and the rapidly escalating volume of automated cyberattacks, AI offers unparalleled capabilities in real-time anomaly detection, zero-day threat identification, and autonomous incident response. By processing vast, complex datasets through deep neural networks, AI empowers organizations to pivot from a posture of reactive damage control to one of proactive, predictive threat mitigation.

However, as clearly demonstrated by the proliferation of adversarial attacks—such as data poisoning, inference evasion, and model extraction—AI is not an invulnerable shield. The technology introduces novel, highly technical attack vectors that sophisticated adversaries will inevitably exploit. The defenders' AI can, and will, be targeted.

Therefore, the future of cyber defense relies not merely on the deployment of AI, but on the deployment of secure, resilient, and explainable AI. Organizations must embrace a holistic security posture that combines advanced machine learning algorithms with rigorous adversarial training, Zero Trust network architectures, continuous human oversight, and dynamic global threat intelligence. Only through this balanced, defense-in-depth approach can defenders maintain superiority and secure critical infrastructure in the rapidly evolving digital battlefield.

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ВОДНЫЕ РЕСУРСЫ ЗОНЫ ДЕЯТЕЛЬНОСТИ ЕСИЛЬСКОЙ БАССЕЙНОВОЙ ИНСПЕКЦИИ

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Поверхностные водные ресурсы

Водные ресурсы зоны деятельности Есильской бассейновой инспекции складываются из ресурсов бассейна р.Есиль в пределах Республики Казахстан, в т.ч. из его составляющих бассейнов р.Колутон, р.Жабай, р.Терсаккан, р.Аккан-Бурлук, р.Иман-Бурлук, а также бассейна бесточных озер Шалкар, Тарангул, отнесенных к общему бассейну р.Есиль. Отдельным бассейном выделена р.Чаглинка, впадающая в бесточное оз.Чаглытенгиз. Междуречье Ишим-Иртыш представлено бессточной территорией, ограниченной бассейнами рек Селеты, Ишим, Чаглинка. С севера участок междуречья ограничен государственной границей Республики Казахстан с Российской Федерацией. Бассейн р.Селеты впадающей в бесточное оз. Селеты–Тенгиз, в полном составе входит в Селеты-Есильский бассейн [1-4].

Водные ресурсы бассейна р.Есиль оценивались по наблюдениям на постах РГП «Казгидромет»:

- р.Есиль – с.Тургеневка, с.Волгодоновка, с. Каменный карьер, с.Западное, п. Сергеевка, г.Петропавловск и п.Долматово;
- р. Мойылды – с. Николаевка;
- р.Колутон – с.Колутон;
- р.Жабай – г.Атбасар (устьевая часть);
- р.Аккан-Бурлук – с.Возвышенка;
- р.Иман-Бурлук – п.Соколовка;
- р.Чаглинка – с. Северное;
- р.Селеты – с.Изобильное.

Гидрография. Акмолинская область

Особенности строения гидрографической сети Акмолинской области в значительной мере обусловлены характером ее поверхности. Равнинность центральной части области наряду с расположением по ее периферии возвышенностей определила основные направления стока от окраинных частей территории к центру.

Основной водной артерией является р. Есиль с рядом крупных притоков, стекающих на севере с Кокшетауской возвышенности, а на юге с острогов гор Улытау.

К бассейну р. Есиль, имеющей внешний сток, доносимый ею до р. Иртыш, относится более половины площади Акмолинской области. Остальная часть рассматриваемой территории принадлежит к области замкнутого стока. Сюда относится район Тенгиз-Коргалжинской впадины и примыкающий к ней бассейн реки Нура и ряда других водотоков, заканчивающихся в бессточных озерах Тенгиз, Коргалжин, Керей, Кыпшак, Кожаколь и др.

По существу, не имеет внешнего стока также северо-восточная часть области, в пределах которой протекает р. Селеты, впадающая в бессточное озеро Селеты-Тенгиз (бывшая Кокшетауская область).

Общее количество рек и временных водотоков длиной более 10 км на территории Акмолинской области достигает почти 400.

Наиболее крупными являются Есиль, Колутон, Жабай, Терс-Аккан, Селеты, Чаглинка.

Временные водотоки имеют различные размеры, наиболее крупные из них достигают 100-150 км при площади водосбора до 3,0 тыс. км² и более.

Особенность режима рек и временных водотоков Акмолинской области, имеющих почти исключительно снеговое питание, является резкая неравномерность распределения стока в течение года. Весенний снеговой сток, проходящий на реках в апреле-мае, составляет в среднем около 90% годового стока. У временных водотоков удельный вес стока весеннего сезона в годовом достигает 97-100%.

Реки области по характеру внутригодового распределения стока в целом достаточно однородны, имеющиеся небольшие различия обусловлены главным образом несколько отличными условиями грунтового питания рек северных и южных районов области. На отдельных реках северной части территории небольшой сток за счет притока грунтовых вод имеет место в течение всего теплого периода, а частично и зимой (реки Ишим, Жабай, Селеты и др.). Большинство малых водотоков является временно действующими. В южных районах все реки, за исключением р. Нура, в летние месяцы пересыхают.

Характер внутригодового распределения стока в различные годы несколько меняется в зависимости от размеров весеннего половодья.

При относительной устойчивости во времени условий грунтового питания в маловодные годы обычно имеет место уменьшение доли стока весеннего сезона в годовом и увеличение относительного веса меженного стока. В многоводные годы наблюдается обратная картина.

Основные особенности режима рек и временных водотоков Акмолинской области определяются условиями их питания.

В соответствии с исключительным значением талых снеговых вод в питании водотоков рассматриваемой территории основной фазой их режима является резко выраженное весеннее половодье, вслед за которым наступает глубокая межень, вплоть до полного пересыхания малых водотоков, а нередко и относительно крупных.

В пределах Акмолинской области весеннее половодье в среднем начинается 5-10 апреля.

Характерные даты начала весеннего половодья:

- раннее – 20-25 марта;
- позднее – 20 апреля.

По годам сроки начала половодья колеблется от второй половины марта до третьей декады апреля. Заканчивается половодье на большинстве водотоков чаще всего в мае и лишь на наиболее крупных реках растягивается до июля. Длительность половодья колеблется в среднем от 10 до 30 дней.

Равнинность значительной части территории Акмолинской области, большое количество бессточных понижений, характерных для степей Казахстана, создают благоприятные условия для задержания вод поверхностного стока и образования озерных водоемов.

На территории Акмолинской области (в старых границах) насчитывается около 4000 озер, из которых примерно 90% имеет площадь зеркала меньше 1 км², количество озер площадью зеркала более 1,1 км² около 300.

Территория бывшей Кокшетауской области, присоединенная к Акмолинской области, является переходной частью от центрального Казахского мелкосопочника к Западно-Сибирской низменности с наиболее пониженными участками в долинах рек Есиль и Чаглинка. Территория региона принадлежит к зоне недостаточного увлажнения, в связи, с чем ресурсы поверхностных вод сравнительно не велики. Сток рек и временных водотоков формируется в основном за счет снеговых талых вод. Речная сеть развита слабо. В пределах региона насчитывается около 100 водотоков длиной 10 км и более, рек длиной свыше 100 км шесть, свыше 200 км одна. На территории региона насчитывается 1515 озер из них 1320 пресных, большая часть озер сосредоточена на равнине. К группе горных озер относятся оз. Боровое, Большое Чебачье, Щучье, Майбалык, которые достаточно глубоки и значительны по площади. Вода пресных озер не используется в хозяйственной деятельности, используется в целях рекреации, т.к. на берегах озер Щучинско-Боровской курортной зоны расположены лечебно-оздоровительные комплексы, детские оздоровительные центры и дома отдыха. Практикой доказано, что забор воды из озер приводит к их усыханию. Исключением является озеро Щучье, на водозабор из которого выдано разрешение на специальное водопользование только в резервных целях, на случаи отключения Кокшетауского группового водопровода [7].

На территории Акмолинской области имеются три крупных водохранилища многолетнего регулирования: Астанинское на р. Есиль, Селетинское на р. Селеты и Чаглинское на р. Чаглинка.

Северо-Казахстанская область

По устройству поверхности Северо-Казахстанская область представляет собой низменную, слегка волнистую, слаборасчлененную равнину с большим количеством неглубоких западин, занятых озерами и крайне незначительным развитием речной сети. Находящиеся среди степи озерные впадины местами образуют слабовыраженные лощины, из которых наиболее крупной является система бывшей р. Камышловка.

Равнинная поверхность бывшей Северо-Казахстанской области обусловила своеобразный гидрографический облик последней, характеризующая почти полным отсутствием речной сети и наличием большого количества озер. На территории области насчитывается около 3500 озер с общей площадью 3,44 тыс. км², количество болот составляет около 450 единиц с общей площадью 0,86 тыс. км². Озера преимущественно бессточные, временно проточные водоемы встречаются в долине р. Есиль и по древним речным долинам, например, в долине р. Камышловка существование большого количества местных озер обязано поверхностному стоку талых вод, атмосферным осадкам и в некоторых случаях также грунтовым водам.

Основной водной артерией является р. Есиль, которая после впадения реки Нижний Бурлук, протекает транзитом. В пределах области расположен участок реки протяженностью 690 км.

Река Есиль в пределах данной области принимает лишь несколько временных водотоков длиной 5-10 км.

Естественный гидрологический режим реки с конца 60-х годов изменен с вводом в эксплуатацию каскада водохранилищ. Это Сергеевское водохранилище многолетнего регулирования и Петропавловское - сезонного регулирования.

Водные ресурсы Северо-Казахстанской области складываются из ресурсов бассейна р. Есиль в т.ч. из его составляющих бассейнов: Бабык-Бурлук, р. Иман-Бурлук, р. Акан-Бурлук.

Сток основных рек

Река Есиль берет начало из родников в горах Нияз в Карагандинской области (северная окраина Казахского мелкосопочника). Длина ее составляет 2450 км, в том числе в пределах Акмолинской области - 1027 км, Северо-Казахстанской области - 690 км, и далее

пересекает Тюменскую область и часть Омской областей. Самыми значительными притоками по водности и длине являются реки Колутон, Жабай, Терс-Аккан и др. (Акмолинская область), Акан-Бурлук, Иман-Бурлук и др., (Северо-Казахстанская область). Площадь водосбора - 155 тыс. км². Общее падение реки от истока до устья 513 м, средний уклон - 0,21%.

Водный режим реки характеризуется ярко выраженным весенним паводком и длительной меженью. Продолжительность половодья в верхнем и среднем течении реки составляет 1-1,5 месяца и увеличивается вниз по течению до 2-3 месяцев. На долю весеннего половодья приходится 86-95% годового стока. Большая неравномерность распределения стока характерна не только внутри года, но из года в год. Годовые объемы стока в многоводный год могут превышать сток маловодного года более чем в сто раз. Одной из особенностей многолетнего хода стока р. Есиль является тенденция группировки многоводных и маловодных лет, что значительно осложняет его использование в народном хозяйстве.

Река Есиль зарегулирована Астанинским, Сергеевским и Петропавловским водохранилищами.

Поверхностный сток р. Есиль используется для водоснабжения г. Астана, г. Петропавловск, сельских населённых пунктов Акмолинской и Северо-Казахстанской областей, полива участков регулярного и лиманного орошения, дачных массивов и других.

Река Колутон берет начало на плоской распаханной равнине, в 1 км к северо-западу от с.Новорыбинка и впадает р. Есиль справа двумя рукавами на 1971 км от устья. Длина реки составляет 223 км, площадь водосбора – 16,5 тыс. км² Общее падение реки - 82,8 м., средний уклон 0,37%. Самыми значительными притоками являются реки Боксук-Кайракты, Аршалы и Талкара. Общая протяженность рек в бассейне (длиной более 10 км) 1660 км. Средний многолетний объем годового стока – 19700 тыс.м³.

Река Колутон является водоемом хозяйственно-питьевого и рыбохозяйственного назначения. Воду реки также использовали для орошения сельскохозяйственных культур. Но в настоящее время из-за отсутствия электроэнергии, нехватки горючего и выхода из строя оросительных систем водозабор на нужды сельского хозяйства почти отсутствует.

Река Жабай берет начало из родников на южном склоне Кокшетауской возвышенности, в 1 км к западу от кордона Малиновского (Кокшетауская область) и впадает справа в р. Есиль на 1869 км у с. Магдалиновка. длина реки 196 км, площадь водосбора – 8,5 км². Самыми значительными притоками по длине являются реки Саркрома, Жиладинка, Ацилы и др. Общая протяженность рек в бассейне (длиной более 10 км) около 1000 км.

Река Жабай является водоемом хозяйственно-питьевого и рыбохозяйственного назначения. Воду используют также и на орошение, но ввиду общего спада сельскохозяйственного производства, в настоящее время частично используется для полива дачных участков и огородов.

Среднемноголетний объем стока 199,0 млн. м³, фактически в створе г. Атбасара – 654,0 млн. м³ или 76% от нормы.

Река Терс-Аккан берет начало в отрогах возвышенностей Улытау, на плоском водоразделе с р. Кенгир, впадает слева в р. Есиль на 1687 км от ее устья. Длина – 334 км, площадь водосбора – 19500 км². Общее падение реки 334 м, средний уклон 1,0%.

Река является водоемом хозяйственно-питьевого и рыбохозяйственного назначения. Воду использовали также и на орошение, но в настоящее время орошаемые участки почти не эксплуатируются.

Река Аккан-Бурлук берет начало из оз. Якши-Янгизтау с западного берега, впадает в р. Есиль справа на 1280-м км от устья длина реки 176 км. Площадь водосбора 6720 км², в

том числе бессточная 731 км². Общее падение реки 188 м, средний уклон 1,0%. Основные притоки – р. Бабык-Бурлук, Кулай-Айыр, Шарык и др.

Река является водоемом хозяйственно-питьевого и рыбохозяйственного назначения. Воду используют также в небольшом объеме и на орошение.

Река Иман-Бурлук берет начало в холмистой лесной местности из оз. Имантау, впадает в р. Есиль с правого берега на 1119 км от устья. Длина реки 177 км, площадь водосбора 4630 км². Река имеет несколько небольших притоков длиной от 19 до 60 км, самый значительный из них р. Сары-Узек.

Река является водоемом хозяйственно-питьевого и рыбохозяйственного назначения. Воду использовали также и на орошение, но в настоящее время орошаемые участки почти не эксплуатируются.

Река Селеты берет начало от слияния балок в 7 км у северо-востоку от с. Елизаветинка и впадает двумя рукавами в озеро Селеты-Тенгиз, расположенное в бывшей Кокшетауской области. Длина реки – 407 км, площадь водосбора – 18,6 тыс. км². Средний многолетний объем годового стока – 49500 тыс.м³.

Самыми значительными притоками являются реки Акмурза, Ащилы-Айрык и Кедей. Река Селеты – водоем хозяйственно-питьевого и рыбохозяйственного назначения. Вода реки также используется для полива огородов и дачных участков. Сток реки в ее среднем течении зарегулирован Селетинским водохранилищем, являющимся источником водоснабжения г.Степногорска.

Река Чаглинка берет начало с Кокшетауской возвышенности в 8 км к юго-западу от с. Цуриковка, впадает в оз. Шаглы-Тенгиз. Длина – 234 км, площадь водосбора – 9,220 тыс. км². Общее падение реки 314 м. Средний уклон 1,3%. Имеет несколько притоков длиной от 15 до 50 км, наиболее крупные реки Терис-Бутак и Кылшакты. У г. Кокшетау р. Чаглинка протекает через оз. Копа, подпитывая его. У г. Кокшетау на р. Чаглинка расположено Чаглинское водохранилище, являющееся одним из главных источников водоснабжения города. Р.Чаглинка протекает по территории двух областей - Северо-Казахтанской и Акмолинской. По всем перечисленным рекам в таблице 1 приведены фактические объемы стоков и проценты от среднемноголетней нормы стоков, модуль годового стока за 2024 год по основным рекам.

Таблица 1 – Модуль годового стока за 2024 год по основным рекам

Река, гидропост	Площадь водосбора, тыс. км ²	Факт.сток, млн.м ³	Модуль стока м ³ /сек на 1 км ²
Акмолинская область			
Итого фактический за 2024 год	48,74		
в т. ч. по основным рекам:			
р.Есиль – с.Тургеневка, с.Волгодоновка, с. Каменный карьер	8,64	3416	12,54
- р.Жабай (г.Атбасар)	8,53	1301	351,9
- р.Колутон (с. Колутон)	16,5	382	0,73
р. Мойылды – с. Николаевка	0,47	86,8	5,86
р. Селеты – с. Изобильное	14,6	899	1,95
Северо-Казахстанская область			
Итого фактический за 2024 год	471,34		
р. Есиль – с. Западное, г. Сергеевка, г. Петропавловск, с. Долматово	459	33373	2,31
-р.Аккан-Бурлук (с.Возвышенка)	6,25	745	3,78
- р.Иман-Бурлук (с.Соколовка)	4,07	217	1,7
р. Чаглинка – с. Северное	1,75	240	4,36

Подземные водные ресурсы Есильского бассейна

По Акмолинской области месторождения размещаются как в речных долинах, так и в ограниченных по площади структурах трещинных и трещинно-карстовых пород. Для крупного централизованного водоснабжения наибольшее значение имеют водозаборы, расположенные в долинах рек Есиль и Нура. Они каптируют аллювиальные песчано-гравийные отложения или подстилающие их палеозойские породы. Глубины скважин изменяются от 50 до 80-100 метров.

В 2024 году по Акмолинской области были вновь утверждены запасы месторождений по следующим участками подземных вод:

По району Биржан Сал. Участок Степняк, утвержденные запасы – 0,8294 тыс. м³/сут, из них В – 0,1728 тыс. м³/сут, С1 – 0,6566 тыс. м³/сут.

В 2024 году по Акмолинской области по Есильской бассейновой инспекции общий объем утвержденных запасов подземных вод по категориям А+В+С+С1 составил 7,8841 тыс. м³/сут (0,00288 млн. м³/год). На территории Северо-Казахстанской области в 2024 году поисково-разведочных работы на подземные воды не проводились [7].

За период 2024 года месторождений минеральных, лечебных и лечебно- столовых вод не утверждалось.

За 2024 год по Акмолинской области забрано – 12,85 млн. м³ подземных вод

- использовано – 12,44 млн. м³

- из них шахтных – 3,75 млн. м³;

Подземные воды месторождений Акмолинской области эксплуатируются для хозяйственно - бытовых и производственных нужд населения и предприятий области и частично для сельскохозяйственного водоснабжения сельских населенных пунктов.

По Северо-Казахстанской области месторождения разведаны в бассейнах р. Есил, междуречья Есиль-Иртыш. В гидрологическом отношении Северо-Казахстанская область

относится к южной краевой части Иртышского и Торгайского Среднеазиатских бассейнов. Территория области бедна доброкачественными и дебитными источниками водоснабжения, особенно северная половина области, поэтому подземные воды не могут служить как для промышленного, так и гарантированного водоснабжения сельского хозяйства. Подземные воды вскрываются шахтными и трубчатыми колодцами глубинной залегания водоносных горизонтов 30-50 метров. В области функционируют филиалы Есиль су, РГП «Нуринский групповой водопровод», которые обеспечивает питьевой водой многие сельские населенные пункты Акмолинской и Северо-Казахстанской областей.

За 2024 год по Северо-Казахстанской области забрано – 9,25 млн. м³ подземных вод:
- использовано – 9,16 млн.м³.

На конец отчетного 2024 года по Есильской бассейновой инспекции числится 685 участков с утверждёнными запасами подземных вод, из них по Акмолинской области - 420, по Северо-Казахстанской области – 265.

Всего по Есильскому бассейну за 2024 год из месторождений с утвержденными запасами забрано – 22,44 млн. м³ подземных вод:

- использовано – 21,94 млн. м³
- из них шахтных – 3,75 млн.м³.

Подземные воды использовались для хозяйственно-бытовых и производственно-технических нужд, сельскохозяйственного водоснабжения, регулярного орошения.

Качество подземных вод во многом зависит о степени загрязнения рек, почвы, атмосферы, самоочистительной способности почвогрунтов, защищенности водоносных пластов и других факторов.

На нужды экономики за период с 2010 по 2024 г. в бассейне реки Есиль забраны следующие объемы подземных вод.

Таблица 2 – Объемы подземных вод в бассейне реки Есиль использованные на нужды экономики региона в период 2010-2024 г.г.

Годы	забрано всего	Использовано							Пр. нуждв	Потери всего
		всего	хоз/быт.нужд ы	производ. Нужды	регулярное орошение	сельхоз- водоснаб	прудово- рыбное	обводнен.пас тбищ		
1	2	3	4	5	6	7	8	9	10	11
2010	37 593,3	36 541,4	5 461,90	1 908,6	172	28 686,90	0	260	0	1 052,00
2011	37403,40	36 748,8	5 244,70	1 988,8	181	29 130,30	0	101	0	654,6
2012	36 600,1	36 002,7	4 690,20	2 347,2	350	28 400,70	0	0	0	631
2013	36 344,6	35 353,2	4 274,20	1 689,5	0	12 792,20	0	0	0	765,40
2014	32 006,1	31 032,9	5 770,70	1 931,7	0	23 330,50	0	0	0	820,20
2015	31 797,8	30 821,7	6 621,90	2 154,2	7	23 045,50	0	0	0	842,10
2016	33499,7	31375,1	10612,5	3 481,0	0	14974,6	0	0	0	0
2017	25697,11	25185,9	7525,58	6127,9	32,43	10258,47	0	0	0	511,15
2018	19079,63	18431,9	7225,94	5448,5	23,87	4136,68	0	0	0	647,65
2019	16722	15827	8695	3945	2,86	2920	0	0	0	895
2020	15507	11993,1	5918,53	2996,2	0	3000	0	0	0	3513,87
2021	15369,05	14381,6	6097,78	4433,9	7,57	3623,77	0	0	218,61	987,38
2022	14365,86	12738,0	5573	3314,5	0,55	3848,75	0	0	1,24	1627,84
2023	17373,91	16635,94	6574,74	6693	0,1	3380,24	0	10,4	7,16	738,26
2024	22442,37	21935,08	10785,1	7451,2	0	2630,73	0	23	5,11	507,29
2025	23242,5	22200,1	10742,8	7953,8	061	3530,6	0	24	4,88	562,4

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КӨКСАРАЙ КОНТРРЕТТЕГІШІНІҢ НЕГІЗГІ МАҚСАТЫ ТУРАЛЫ

Ибрайханов Ерболат

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Сырдария өзені арнасының жіберу қабілетінің шектеулілігінен 1991 жылдан бастап артық сулар Арнасай сағасына үнемі жіберіліп тұрды. Ол 2004 жылы толып кетті. Өзбекстан су төгінділерін реттеу мақсатында 2004 жылы Арнасайда екі қоршау құрылыстарын (бөгеттерін) салды. Сол уақыттан бері Шардара су қоймасынан Арнасай көлдері жүйесіне суды төгу көлемі су қоймасын пайдалану қағидаларымен бекітілген секунднына 2160 текше метрден секунднына 600-700 текше метрге дейін шектелді.

Сондықтан қажеттілігіне қарай және қолданыстағы қағидаларға қарамастан Шардара су қоймасынан Сырдария өзенінің арнасы бойынша қыста суды жіберу көлемі ұлғайтылды. Бұл тиісті материалдық залалдар тудырған бірқатар апатты су тасқындарына, ирригациялық жүйелерді және Оңтүстік Қазақстан және Қызылорда облыстарындағы жекелеген елді мекендерді су басуға әкеп соқты.

Қазіргі уақытта Қызылорда қаласынан төмен Қараөзек ағысының бас жағында қосымша су жинау құрылысы салынды, ол 2006 жылдың күзінен бастап, ағысқа судың артық шығындарының бөлігін төгуге және Әйтеке бөгетінен төмен учаскедегі өзеннің негізгі арнасын жарым-жартылай босатуға мүмкіндік береді.

Бұл бағыттағы ең өзекті мәселелердің бірі Сырдария өзені бассейнінің сағасындағы өзен ағысын реттеу болып табылады, оның шешілуі осы трансшекаралық өзен ресурстарын пайдалануда Қазақстанның тәуелсіздігін қамтамасыз етеді.

Осы жағдайларда Қазақстан үшін «Сырдария өзенінде Көксарай су реттегіші құрылысы» жобасын әзірлеу қажеттілігі туындады.

Сырдария өзенінде Көксарай су реттегіші құрылысын салуға қатысты созылып кеткен дауда соңғы әрі шешуші нүктені Қазақстан Республикасының Президенті Нұрсұлтан Назарбаев қойды. Елдің оңтүстік өңірі тұрғындарының қауіпсіздігін қамтамасыз ету проблемасының маңыздылығы жайлы ойлай отырып: «Осындай үлкен шығындарға барып, жаңа су қоймасын салу деген оңай шешім емес. Бірақ бізде амал жоқ, сондықтан мәселені түпкілікті шешеміз: Көксарай салынады. Бұл, мысалы, Қазақстанның батысынан оңтүстігіне өткізілген газ құбыры сияқты әлеуметтік объект; ол табыс әкелмесе де көптеген проблемаларды шешуге көмектеседі», деп атап көрсетті.

Сонымен, 2008 жылдың көктемінде Мемлекет басшысы Қазақстан Үкіметіне 2008 жылы Сырдария өзенінде тасқынға қарсы Көксарай су реттегішін салуды бастау туралы тапсырмалар берді, ал Үкімет қаулысымен Төтенше жағдайлар министрлігі оны орындау бойынша бағдарлама әкімшісі болып анықталды. Үкімет Төтенше жағдайлар министрлігіне резервтен техникалық жобаны, жобалау-сметалық құжаттаманы әзірлеуді, «Сырдария өзенінде тасқынға қарсы Көксарай су реттегішінің» құрылысын бастауды қаржыландыруды қамтамасыз ету үшін кезек күттірмейтін шығындарға қаражат бөлді.

Инженерлік-қорғаныс, гидротехникалық құрылыстарды және «Медеу», Үлкен Алматы, Қарғалы, Сарқант, Ыстық, Қаскелең, Бартоғай су қоймасының биік таулы бөгетімен Д.А.Қонаев атындағы Үлкен Алматы арнасы, «Талғар» бөгеті, Төменгі Көлсайдағы су жинаушы құрылыс сияқты кешендерді салудағы және эксплуатациялаудағы, сонымен қатар, «Астана қаласын Есіл өзенінің су тасқынынан инженерлік қорғау» объектісін салудағы үлкен

жұмыс тәжірибесін ескере отырып, Төтенше жағдайлар министрі бұйрығымен «Қазселденқорғау» ММ осы стратегиялық нысанның құрылысын орындаушы болып белгіленді.

Құрылыстың атқарушы жобалаушысы етіп республика бойынша су объектілерін жобалау бойынша мамандандырылған «Казгипроводхоз институты» ӨК жобалау институты белгіленді. Құрылыстың техникалық идеясы негізделді және су реттегішті салудың ықтимал орны толығымен зерделенді, инженерлік-ізденіс жұмыстарының нәтижесінде Сырдария өзенінің жағасында 3-4 млрд. текше метр су шоғырландыратын Көксарай ойпатынан басқа ойпат жоқ екені анықталды.

«Казгипроводхоз институты» ӨК орындаған техникалық – экономикалық негіздемеге (ТЭН) келесі гидротехникалық құрылғылар кірді:

- су жіберетін мүмкіндігі бар негізгі гидротүйін – 2 300,0 м³/с.
 - су жіберетін мүмкіндігі бар бұру арнасы – 500,0 м³/с, ұзындығы 16,0 ш.
 - су жіберетін мүмкіндігі бар жинақтаушы құрылыс – 500 м³/с.
 - Көксарай су реттегіші қоймасының кешенін құрайтын ұзындығы 44,7 ш бөгет.
 - су жіберетін мүмкіндігі бар су жібергіш құрылыс – 500 м³/с.
 - су жіберетін мүмкіндігі бар жеткізуші арна – 500 м³/с, ұзындығы – 10,0 ш.
 - бұру арнасындағы «Шөгірлі» көпірі.
 - «Арыс – Шәуілдір» жолы бойынша жүруді қамтамасыз ететін жеткізуші арнадағы көпір.
- «Сырдария өзеніндегі Көксарай тасқынға қарсы су реттегішінің» құрылысы:
- Сырдария өзенінің бассейнінде ықтимал су басу аймағына кіретін Оңтүстік Қазақстан және Қызылорда облыстары аумағындағы елді мекендердің қауіпсіздігін қамтамасыз етуге;
 - су реттегіште жиналған таза 3 млрд. м³ қысқы су ағыны есебінен республиканың су балансын реттеуге;
 - Кіші Арал теңізіндегі су деңгейін ұлғайтуға;
 - Арнасайға бөлу арқылы су ресурстары шығынын болдыртпауға мүмкіндік береді, яғни 1995 жылдан 2008 жылға дейін Арнасайға 35 млрд. текше м. тасталған, оны Аралды толтыру және Оңтүстік Қазақстан мен Қызылорда облыстарының өсімін жақсарту үшін пайдалануға болатын еді;
 - Шардара ГЭС-нің қысқы электроэнергиясын өндіруді 20 – 25 % – ға ұлғайтуға;
 - Сырдария өзенінің алқабы мен атырауында экологиялық жағдайды жақсартуға мүмкіндік береді;
 - су реттегішінің алабы істен шыққаннан кейін су басқан аймақтың 90%-дан астамы жем-шөп дайындауға арналған Лиман алқабы және мал жайылымы ретінде пайдаланылатын болады.

Объектінің стратегиялық маңыздылығын ескере келе, 2008 жылғы 15 сәуірден бастап Төтенше жағдайлар министрлігінің «Қазселденқорғау» ММ «Сырдария өзеніндегі тасқын суға қарсы «Көксарай» су реттегішінің» құрылысын бастады.

Көксарай су реттегішінің құрылысына бірінші болып ТЖМ «Селденқорғау құрылыс» РМҚК бас мердігерінің арнайы техникалары келді. Сонымен қатар, республиканың әрбір бұрышынан, мыңжылдық құрылысына қатысуға келісім білдірген «Базис» корпорациясы, «АҚСУ» АҚ, «Спецзащита» ЖШС, «Стройинвест» ЖШС, «МО-1» ЖШС сияқты көптеген құрылыс ұйымдары жұмылдырылды.

2008-2009 жылдары Көксарай су реттегішінің құрылысына 150-ден астам құрылыс ұйымы тартылды. Жұмысшылар саны 7 500 адамнан асты, ал арнайы техника саны 3000 бірліктен астам және 900 бірліктен астам қосалқы техникалар мен жабдықтар, оның ішінде бір ауысымда өндіріс қуаттылығы 4920 текше метрді құрайтын 3 бетон түйіндері болды. Құрылыс жұмысшыларының көбі жергілікті халықтан болды, ал бұл өз кезегінде дағдарыс кезінде өңірдегі экономикалық оң ахуалды ұстап тұрды және халық арасындағы жұмыссыздық саласындағы көптеген әлеуметтік проблемаларды шешті. Әлемдік дағдарыс жағдайында халықты жұмыспен қамту мәселесі және барлық өндірістік мүмкіндіктерді пайдалану

тиімділігі бірінші орында тұрды. Құрылысқа бөлінген қаражатты үнемдеу және оны мақсатты жұмсау барлық кеңестерде бақыланды және талқыланып отырды. Жергілікті өндіріс материалдарын басым пайдалану және жеткізудің оңтайлы көліктік сызба нұсқаларымен объектінің өзіндік құнын төмендетудің барлық мүмкіндіктері құрылыс сметасының құнының төмендеуіне ықпал етті.

2010 жылғы 18 наурызда Қазақстан Республикасының Президенті Н.Ә.Назарбаевтың қатысуымен Көксарай су реттегіші құрылысының кешені стратегиялық маңызды объект ретінде іске қосылды. Бұл уақытта Көксарай белсенді толтыру фазасында болды және біз Сырдария өзенінің сағасындағы ағынның жағдайын реттей алдық. Салтанатты рәсімде Мемлекет басшысы барлық құрылысшыларға жеделдіктері мен олардың орасан зор еңбектері үшін алғысын білдірді. 3 млрд. текше метр қысқы ағынды су реттегіштің су қоймасына шоғырландыру үшін 2010 жылдың соңына дейін аталған объектіні дайындауды міндеттеді.

2011 жылдың басына қарай Көксарай су реттегіші барынша жобалық қуатымен – 3,0 млрд. текше метр судың су қоймасы көлемімен тасқынға қарсы режимде жоспарға сәйкес уақытында іске қосылды, бұл Сырдария өзені жағасындағы елді мекендердің қауіпсіздігін толығымен қамтамасыз етті.

2010-2011 жылдардағы су тасқыны кезеңіндегі су қоймасындағы шоғырландырылған ағынның көлемі 2,2 млрд. текше метрді құрады. Вегетациялық кезеңнің басталуымен су реттегішті эксплуатациялау ережесіне сәйкес Көксарай су қоймасынан Сырдария өзенінің арнасына құю үшін және Кіші Аралды толтыру үшін су жіберу басталды.

Сырдария өзенінің бассейніне келіп түйіскен екі облыстың орасан зор аумағы Елбасының батыл шешімінің арқасында көп жылдарға тыныш өмірмен және сумен қамтамасыз етілді.



Сурет 1 – Көксарай контрреттегішіне ұшақтан қарағандағы көрінісі

Сонымен Көксарай контрреттегішінің негізгі мақсаты мыналар:

1. Шардара су қоймасы арқылы жоғары тасқын суларын апатсыз өткізуге ықпал ету;
2. Елді мекендердің жаға маңы аумақтарын суға көмілуден келетін зиян-шығындарын минимумға жеткізу үшін, қыс мезгіліндегі тасқын суларды жинау.
3. Құрғақшылық жылдары төменгі ағысында суармалы жерлерді сумен қамтамасыз ету және Сарышығанақ бұғазымен қоса, Солтүстік Арал теңізіне су жіберу.

4. Атыраулық көлдер жүйесінде оларға ыңғайлы уақыттарда суға көсу жағдайларын жақсарту.

Құйылмалы тасқынға қарсы Көксаарай контрреттегіші Оңтүстік Қазақстан облысы Арыс ауданында Сырдария өзені маңында орналасқан. Өзенмен Шардара су қоймасынан арқашықтығы – 165км, өзеннің жағасымен ең жақын елді мекендер – Қожатоғай, Жиделі, Байырқұм ауылдары. Контрреттегіштің орналасқан ауданы асфальттандырылған жолмен аудан орталығы Арыс (50 км) және Шардара қаласымен (150 км) байланысқан, Сырдария өзені арқылы автокөпір қарастырылатын нысанға тікелей түйіседі. Контрреттегіш халық аз қоныстанған шөлді мекенде орналасқан. Су қоймасының айдыны табаны бұрынғы қаракөл шаруашылықтары «Ақдала» және «Задария» жерлері жайылымындарын алып жатыр.

Көксаарай контрреттегішінің кешені құрамына кіретін құрылымдар:

- Сырдария өзеніне суды тастайтын бас суалу торабы мен су қабылдағыш;
- Бас су алу торабынан шығатын суды жеткізу каналы, ПК 157+80 байланыстыру құрылымы мен ПК 52+93 көпірі бар, контрреттегіштің су қоймасына бағытталған;
- контрреттегіштің бөгеті;
- су шығару құрылымы;
- суды алып кету каналы;
- қалашықты қоршау бөгетшесі (дамбасы),
- мазарды қоршау бөгетшесі;
- су қоймасы айдыныдағы су жинау желісі;
- сорғы станциясы №1 және суландыру желісі;
- пайдалану жолдары;
- пайдалану қызметі нысандары;
- электрмен қамту, жарықтандыру, автоматика және байланыс;
- бақылау-өлшеу аппаратурасы;
- бөгетті мониторинг жүргізудің автоматтандырылған жүесі.

Көксаарай бас су торабы құрамы

Бас су торабы құрамы, өтімі $1800 \text{ м}^3/\text{с}$ суды жеткізу және алып кету арнасы бар су тастағыш пен өтімі $500 \text{ м}^3/\text{с}$ бастаған, сол және оң жағалық дамбылардан тұрады. Су тастағыш пен бастаған біртұтас құрылыстан тұрады. Су торабының конструкциясы сызбада беріледі.

Суды әкету арнасы жер арнада түбінің ені 150,0м, құламасы ылдильғы 1:3 етіп орындалған. Ағынның толқыны алдын алу үшін екі жағынан 160,0м арақашықтықта қорғаныс дамбылары орнатылған. Сырдария өзенінде су тасығнада жерлерді судан көмілуден қорғау үшін, қарама-қарсы оң жағада ұзындығы 1986м, бөгетшесі жотасының биіктігі 215,0м қорғаныс дамбысы тұрғызылған.

Суды жеткізу арнасының оң жағалық бөгетшесінің ұзындығы – 171м, сол жағалықтың ұзындығы – 737м. 213,0м белгіде ені 5м берма бар, диаметрі 15-20см тас төсенішпен бекітілген.

Бас су торабында су тастау және су алу бөліктерінде негізгі жапқыштар сегментті түрдегі, саны тиісінше 5 және 3, 16,0х5,0м саңылауды жабады, максималды арын – 6м.

Сол жағалық қорғау дамбысы: ПК 13+60 бастап 2212м, жотасындағы ені – 5,0м, жоғарғы және төменгі жақтаулары 3,0. Биіктігі, өзендегі өтім $2300 \text{ м}^3/\text{с}$ кезіндегі жоғары су жиегінен 0,5м қормен орындалған.

Сол жағалық қорғау бөгетшесі, өтімі $1000 \text{ м}^3/\text{с}$ асқанда, Сырдария өзенінің сол жағасында орналасқан ауыл шаруашылығы алқаптарын, елді мекендерді, жайылымдарды қорғау үшін арналған. Бөгетше ұзындығы – 11527,6м, ені 5м, жоғары жақтауының ылдильғы 1:5 және төменгісінікі 1:3,5, бөгетше жотасының биіктік белгісі – 217,0м.

Су жеткізу каналы су торабы су қабылдағышынан 200м төменде, бастауын алады. Пк 10+60 және Пк 16+00 телімінде канал трассасы Сырдария өзенінің арнасын кесіп өтеді, оң жағаға шығып, жайылма астылық террасаға қосылып, контррретегіш су қоймасының айдынына түседі. Ол 500 м³/с өтімге есептелген, мұз жүрмеуінсіз. Ені 55-65м аралығында, жалпы ұзындығы – 33200м.

Суды жеткізу каналы жұмысы су қоймасының толу циклдігіне негізделген. Жыл сайын қыс кезеңінде контррретегіш толады, ал көктемгі-жазғы кезеңдерде босатылады. Осындай жағдайларда су жеткізу каналы артық құламамен жұмыс істейді, бұл каналда су жылдамдығының өсуіне алып келеді. Салыстырмалы қысқа аралықта құлайтын судың кинетикалық энергиясын сөндіру үшін ПК 157+80 мен ПК 162+00 аралығында жалғастыру құрылымы қарастырылған, ол құрылымның өзінде және су жеткізу каналының соңында су қозғалысының қауіпсіз гидравликалық шартын тудырады. Құрылым сульфаттөзімді В25 темірбетонынан орындалған және понурдан, суағардан, суұрма құдықтан және рисбермадан тұрады. Құрылым конструкциясы суретте көрсетілген.

Бөгеттің айдыны рельефтің табиғи ойыс жерлерін пайдаланып, Сырдария өзенінің оң жағасында тұрғызылған. Су қоймасын батыс, солтүстік және солтүстік-шығыс жағынан шектейтін, тежеу бөгетімен сыйымдылық жасалған. Су қоймасының ең үлкен ұзындығы 33км, оңтүстік-батыстан солтүстік-шығысқа қарай бағытталған, су бетінің орташа ені 14км.

Контрретегіштің айдыны келесі көрсеткіштермен сипатталады:

- толық сыйымдылығы 3 км³;
- ҚТД биіктік белгісі 212,9 м БТД;
- ҚТД кезіндегі су айдынының ауданы 466 км²;
- ең жоғарғы тереңдігі 9 м.

Көксарай контрретегішінің көлемі мен аудандарының топографиялық сипаттамасы мен байланыстылықтары 22-суретте көрсетіледі. Контрретегіштің бөгеті бірінші класты капиталдылққа жатқызылған, су қоймасының көлемі 1000 млн.м³ жоғары су торабының тежеу құрылымы ретінде. Бөгетті осы көлемдегі көрсеткіштері:

- Бөгет жотасының биіктік белгісі 215,35 м БТД;
- бөгет жотасы ені 8 м;
- жотасы бойынша бөгеттің ұзындығы 44,7 км;
- топырақ үйіндісінің орташа биіктігі 7,23 м.

Топырақ үйме бөгет, өсінен жоғары бьеф жағына қарай 500м дейін жолақта, бөгет трассасы бойымен орналасқан карьерлерде қазып алынған, жергілікті грунттардан тұрғызылған. Бүкіл ұзындығы бойымен бөгет табаны ретінде үш грунт қызмет атқарады: саздақ, құм немесе қалың құмдақ және шамалы қалыңдықтағы 3-4м дейін құм.

Сонымен, бөгет үш типтегі конструкциядан тұрады:

а) саздақты табандағы үйінді біртекті бөгет;
б) тереңдігі 3м сүзілу жолын ұлғайту үшін саздақтан жасалған ілме тісті үйінді біртекті бөгет;

в) құм немесе құмдақты көметін саздақтан жасалған тісті бөгет және тереңдігі 1,1-ден 4м-ге дейін баратын шамалы су сіңімді саздаққа 0,5м-ге дейін кіріп тұрады.

Пайдалану кезеңінде қарсы көлікті бөгет жотасы бойынша өткізу шартымен, бөгет жотасының ені бүкіл 44,7км ұзындыққа 8м етіп тағайындалған. Төменгі жақтауында, кәріздеу жүйесін пайдалану және пьезометрлерге бақылау жүргізу үшін ені 10м берма орнатылған. Бөгеттің жоғарғы жақтауы бөгет жотасы деңгейінде бекітілген. Себебі, су қоймасы толығымен жұмыс істейді, ал бекітудің төменгі шекарасы бөгеттің жоғары тісі деңгейінде тағайындалған. Жоғары беткейі темірбетонмен бекітілген. Бөгеттің төменгі жақтауы қалыңдығы 0,2м шағал төсенішпен көмкерілген.

Көксарай контрреттегішінің кәріздік жүйесі төмендегі мақсаттарда соғылған: - бөгет денесі және табаны арқылы сүзіліп шыққан суды төменгі бьефке ұйымдасып алып кету үшін; - төменгі жақтамада депрессиялық қисықты тоңудан қорғау үшін; - төменгі жақтаудың орнықтылығын көтеру мақсатында депрессиялық қисықты төмендету үшін. Бөгет конструкциясы төлқұжатта келтіріледі. Басқа да құрылымдарды жобалау және пайдалану мақсатында төмендегі әдебиеттер қолданылды [1-8].

Су шығару құрылымы контрреттегішті босату үшін мақсатталған және пайдалануға ыңғайлы, док конструкциялы түріндегі ашық су шығарғыштан тұрады, техникалық күйін тексеруге қолжетімді. Су шығарғыш құрылым 203,0м белгіге дейін босату үшін тереңдік сегментті жапқыштармен көмкерілген төрт негізгі арқалықтан және контрреттегішті толығымен босатуға арналған жазық жылжымалы жапқыштармен жабылған мұнаралы су шығарғыштан тұрады. Ол понур, суағар, тезағар, суұрма құдық және рисбермадан тұрады. Құрылымның орта бөлігінде белгісі 200,5м табалдырықты басқару мұнарасымен екі түпкі құбыр орнату қарастырылған.

Суды алып кету каналы су шығару құрылымынан Сырдария өзеніне суды бұру үшін мақсатталған және су қоймасы айдынында лимандардың қолайлы режимін қамтамасыз ету үшін контрреттегіштен суды қысқа мерзімдік тасталуы (1-2 ай) ескеріліп, сең жүрмейтін кезеңде жұмыс істейді, булану мен сүзілуге су шығынын азайтады. Ұзындығы 9,9 км су әкету каналы 500 м^3 өтімге есептелген және түбінің ені 90м жер арнада соғылған, ПК0-дегі түбінің биіктігі – 199,5м, каналдың еңістігі 0,00015, тереңдігі – 4,4м, ағыс жылдамдығы – 1,17 м/с.

Кесте 1. Су қоймасын босату, 4 сегментті жапқыш, ВхН=10,0х2,0м,
2 түпкі тесік, ВхН=2,0х2,0м.

Жоғарғы бьефтегі СД белгісі, м	Су қоймасының көлемі, W, млн м ³	Көлемдер айырмасы, W, млн м ³	Құрылымның толық өтімі, Q м ³ /с	Құрылымның орташа өтімі, Q, м ³ /с	Бастау уақыты, t, тәулік, 203,0м белгіге дейін
50% қамтамасыздықтағы жыл. Толық толуы 3,0 км ³					
212,90	3000		500		
		1000		500	23,15
210,60	2000		500		
		1080		480,35	24,10
207,80	920		460,69		
		120		458,17	3,03
207,50	800		455,65		
		150		432,90	4,01
207,0	650		410,15		
		150		389,01	4,46
206,40	500		367,86		
		90		351,29	2,97
206,00	410		334,72		
		110		302,43	4,21
205,50	300		270,13		
		100		249,32	4,64
205,00	200		228,51		
		120		163,52	8,49
204,00	80		98,53		
		40		75,47	6,13
203,50	40		52,41		
		15		38,38	4,52
203,10	25		24,35		
		10		21,33	5,43
202,50	15		18,30		
Барлығы					95,14

Кесте 2 - Су қоймасын босату, 4 сегментті жапқыш, ВхН=10,0х2,0м,
2 түпкі тесік, ВхН=2,0х2,0м.

Жоғарғы бьефтегі СД белгісі, м	Су қоймасының көлемі, W, млн м ³	Көлемдер айырмасы, W, млн м ³	Құрылымның толық өтімі, Q м ³ /с	Құрылымның орташа өтімі, Q, м ³ /с	Бастау уақыты, t, тәулік, 203,10м белгіге дейін
50% қамтамасыздықтағы жыл. Толық толуы 1,0 км ³					
207,80	920		460,69		
		120		458,17	3,03
207,50	800		455,65		
		150		432,90	4,01
207,0	650		410,15		
		150		389,01	4,46
206,40	500		367,86		
		90		351,29	2,97
206,00	410		334,72		
		110		302,43	4,21
205,50	300		270,13		
		100		249,32	4,64
205,00	200		228,51		
		120		163,52	8,49
204,00	80		98,53		
		40		75,47	6,13
203,50	40		52,41		
		15		38,38	4,52
203,10	25		24,35		
		10		21,33	5,43
202,50	15		18,30		
Барлығы					42,46

Кесте 3 - Сырдария өзені ағынына байланысты су шығару құрылымының төменгі бьефіндегі деңгейлік режимнің есебі

Баланс элементтері	Жыл айлары						
	I	II	III	IV	V	VI	VII
Қамтамасыздығы P=50%							
Шардара су қоймасынан ТБ су жіберу, млн м ³ / м ³ /с	<u>1188</u> 452	<u>1176</u> 447	<u>1475</u> 561	<u>465</u> 177	<u>806</u> 307	<u>1472</u> 560	<u>1523</u> 579
Көксарай контррет. су алу, млн м ³ / м ³ /с	<u>342</u> 130	<u>342</u> 130	<u>342</u> 130	-	-	-	-
Көксарай контррет. су тастау, млн м ³ / м ³ /с	-	-	-	<u>240</u> 395	<u>610</u> 235	<u>50</u> 46	-
КҚР төмен су жіберу, млн м ³ / м ³ /с	<u>846</u> 322	<u>834</u> 317	<u>1133</u> 431	<u>465</u> 572*	<u>1413</u> 527	<u>1522</u> 587	<u>1523</u> 587
№3 жарма- дағы өзен-дегі СД белгісі, м	201,30	201,30	201,80	202,70	202,40	202,50	202,50
Су шығарғыштағы су жиегі, 50%	Су тасталмайды			203,20	202,90	203,00	203,00

Кестеге түсініктемелер: 1. Сырдария өзені мен Көксарай контрреттегішінің өтімдік сипаттамалары Шардара су қоймасының су балансынан алынды; 2. Өзендегі деңгейлік көрсеткіштер, суды әкету каналымен Сырдария өзені қосылатын орынға сәйкес келетін, №3 жармадағы $Q=f(H)$ графикі бойынша анықталды; 3. Су шығарғыштың төменгі бьефіндегі су жиегі КҚР су тастағышы мен суды әкету каналының өтімдік көрсеткіштеріне сәйкес келеді; 4. Көксарай контрреттегішінің жұмыс істеуі басталуы ретінде сәуір айының III онкүндігі қабылданды.

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БОЙЛЫҚ САҢЫЛАУЛЫ ҚҰМТҰТҚЫШ ЖАҢА КОНСТРУКЦИЯЛАРЫ

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Қазақ Ұлттық су шаруашылығы және ирригация университеті, ғылым магистры, «Су ресурстары» БББ аға оқытушысы

Қазіргі уақытта Қазақ Ұлттық су шаруашылығы және ирригация университетінде еңбек ететін, қауымдастырылған профессор С.Жолдасовтың бойлық саңылаулы құмтұтқыштардың жаңа конструкцияларына алынған патенттеріне тоқталсам деп едім.

Таулы және тау бөктерінде орналасқан өзендерде көктемгі-жазғы тасқын кезеңдерінде өте көп мөлшерде тасындылар тасымалданады, олар, каналдарға түсіп, әртүрлі деңгейдегі құрылымдарды пайдалану қиыншылықтарын туғызады. Тасындылардың арналарға түсуінің алдын алу үшін, олардың пайда болуының негізгі факторларын анықтау керек. Авторлар бұл факторларға келесілерді жатқызады [1, с.36-39]:

- 1) тау ағынының гидравликалық ерекшеліктері;
- 2) құрылымдарда тасындылармен күресуге қолданылатын шаралардың жетілдірілмегендігі;
- 3) каналға түсетін тасындылардың әрқилы шоғырлануы;
- 4) вегетация кезеңінде өзендерден өте көп мөлшерде су алынуы.

Вегетация кезеңінде ағын өте көп мөлшерде су тасымалдайды. Егер, тасындылармен күресу үшін ешқандай шаралар қарастырылмаса, олар каналдарға түседі. Каналдарға тасындылар түсуінің алдын алу өте өзекті мәселелердің бірі болып саналады, бұл мәселені жылдамырақ шешсе, көп мөлшерде мемлекеттік қаржыны үнемдеуге жол ашылар еді.

Каналдарда тасындыларды тұтудың тиімділігін арттыру үшін, біз бойлық тасындытұтқыш саңылаулы құмтұтқыштарға эксперименталдық зерттеулер жүргіздік [2, Б.58-66], және әртүрлі конструкцияларда бірнеше тәжірибелер топтамасын жасаған соң, алдын-ала патент негізінде құмшағалтұтқыштың нұсқасы таңдап алынды [3].

Эксперименталдық зерттеулер нәтижелері негізінде біз өнертабысқа өтінім бердік. Бұл өнертабыс гидротехникалық құрылысқа, оның ішінде тасындытұтқыш құмтұтқыш-галереяларға жатады, және галерея құм шығарғыштарда тасындылардың шөгуін төмендету үшін пайдаланылуы мүмкін.

Салыстыру үшін екі ұқсас нұсқа таңдап алынды. Оның біріншісі, бұл каналдарға арналған құмшағалтұтқыш, ол құмқойыртпақтан (пульповод) және канал осіне параллель орналасқан бойлық саңылау тесіктері бар галерея түріндегі құм шығарғыштың кіру бөлігінің төмен жағынан түйісетін, құм тұтуға арналған құрылғыдан тұрады [4]. Бірақ бұл құмшағалтұтқыштың бір айқын кемшілігі бар – галереяның шеткі саңылауы және оған жақын орналасқан құмшығарғыш телімі ақырындап тасындылармен көміле бастайды да, құмқойыртпақ галереясының жұмысы тиімділігін төмендетеді, бұл өз кезегінде бүкіл құмшағалтұтқышты істен шығарады.

Екінші нұсқаға келетін болсақ, бұл құмшағалтұтқыш [3], құмқойыртпақтан, осы құрылғының бас жағында тангенциал жанама дәнекерленген дөңгелек немесе тікбұрышты қималы тік құбыршадан тұрады. Суағынның жоғарғы қабаттарынан тік құбыршаға құмқойыртпаққа жанама кіреді, тангенциал енуіне орай, құмқойыртпақ құбырындағы шоғырланған ағын, галереяға бір бағытта ағып келетін негізгі ағынды қосымша айналдыра түседі. Бұрандалы құйынды ағын тасымалдау қабылетін бірнеше есе өсіреді, сол себепті бастапқы бөлігінде және құмқойыртпақтың бүкіл ұзындығы бойымен тасындылар

шөгуі орын алмайды жәнебарлық тосқынсу тастау каналына шығады және одан ары қарайөзенге немесе жергіліктің табиғи ойыстарына қайта тасталады.

Бірақ бұл құмшағалтұтқыштың да бір кемшілігі бар – бойлық құмтұтқыштар құмқойыртпақтың сол жағына орналасқандықтан, яғни жоғарғы бьеф жағынан, галереяның бойлық саңылаулары ірілеу тасынды түйіршіктерімен жылдам толып қалады, және сонысымен құмшағалтұтқыш жұмысы тиімділігін төмендетеді.

Біздің өнертабысқа өтінім берердегі мақсатымыз, құмшағалтұтқыш жұмысы сенімділігін және құмқойыртпақтағы ағынның тасымалдау қабілетін көтеру болды.

Бұл құмшағалтұтқыш құмқойыртпақтан және бойлық саңылаулы тесіктерден тұратын галерея түріндегі тасынды тұтуға арналған құрылғыдан тұрады, ол құмқойыртпақтан кейін канал осіне параллель орналасқан, яғни төменгі бьефте жәнеқұмқойыртпаққа төмен жағынан жалғанған.

Бізге қажетті нәтижеге, құмқойыртпақтан кейін канал осіне параллель орналасқан бойлық саңылаулы тесіктерден тұратын галерея түріндегі тасынды тұтуға арналған құрылғы орнату жолымен және қосымша өтім беру мақсатында құмқойыртпаққа тік құбыршаны жанама орнату арқылы қол жеткізіледі [5].

Ұсынылып отырған құрылғы - құмқойыртпақтан және бойлық саңылаулы тесіктерден тұратын галерея түріндегі тасынды тұтуға арналған құрылғыдан тұрады, ол құмқойыртпақтан кейін канал осіне параллель орналасқан, яғни төменгі бьефте және құмқойыртпаққа төмен жағынан түйіскен, және құмқойыртпақ ішінде құйынды қозғалыс тудыру үшін құм шығарғыш құбырға тік құбырша жанама ендірілген.

Жер каналдарда орнатылатын бойлық саңылаулы тесіктері төменгі бьеф жағындағы тасындытұтқыш галереялы құрылғы, бойлық саңылаулар бітелмейтіндей ірілеу тасындыларды өткізуге мүмкіндік береді, ал құмқойыртпаққа тангенциал тік құбыршаны орнату, судың жанама кіруі есебінен, тасындытұтқыш галереядан бір бағытта түсетін негізгі ағынды қосымша құйынды ағысқа келтіреді. Құмқойыртпақтың бастапқы бөлігінде және бүкіл ұзындығы бойыментасындылар шөгуі орын алмайды және бүкіл тосқындар су тастау каналына шығады және одан ары қарай өзенге немесе жергіліктің табиғи ойыстарына қайта ағызылады.

Құмшағалтұтқыштың конструкциясын одан ары жетілдіру үшін, біз бірнеше тәжірибелер топтамасын жасадық және құмтұтқыштың жаңа конструкциясына өтінім бердік. Бұл өнертабыс та, алдыңғы айтылған құрылғылар сияқты тасындытұтқыш құрылымдарға жатады және құмқойыртпақтарда тасынды шөгуін тоқтату және олардың тасымалдау қабілетін арттыру үшін мақсатталған. Салыстыру үшін екі нұсқа алынып, кемшіліктері анықталды [3,4].

Ұсынылатын өнертабыстың мақсаты,құмтұтқыш жұмысы сенімділігін және құмқойыртпақтағы ағынның тосқын тасымалдау қабілетін көтеру болып табылады.

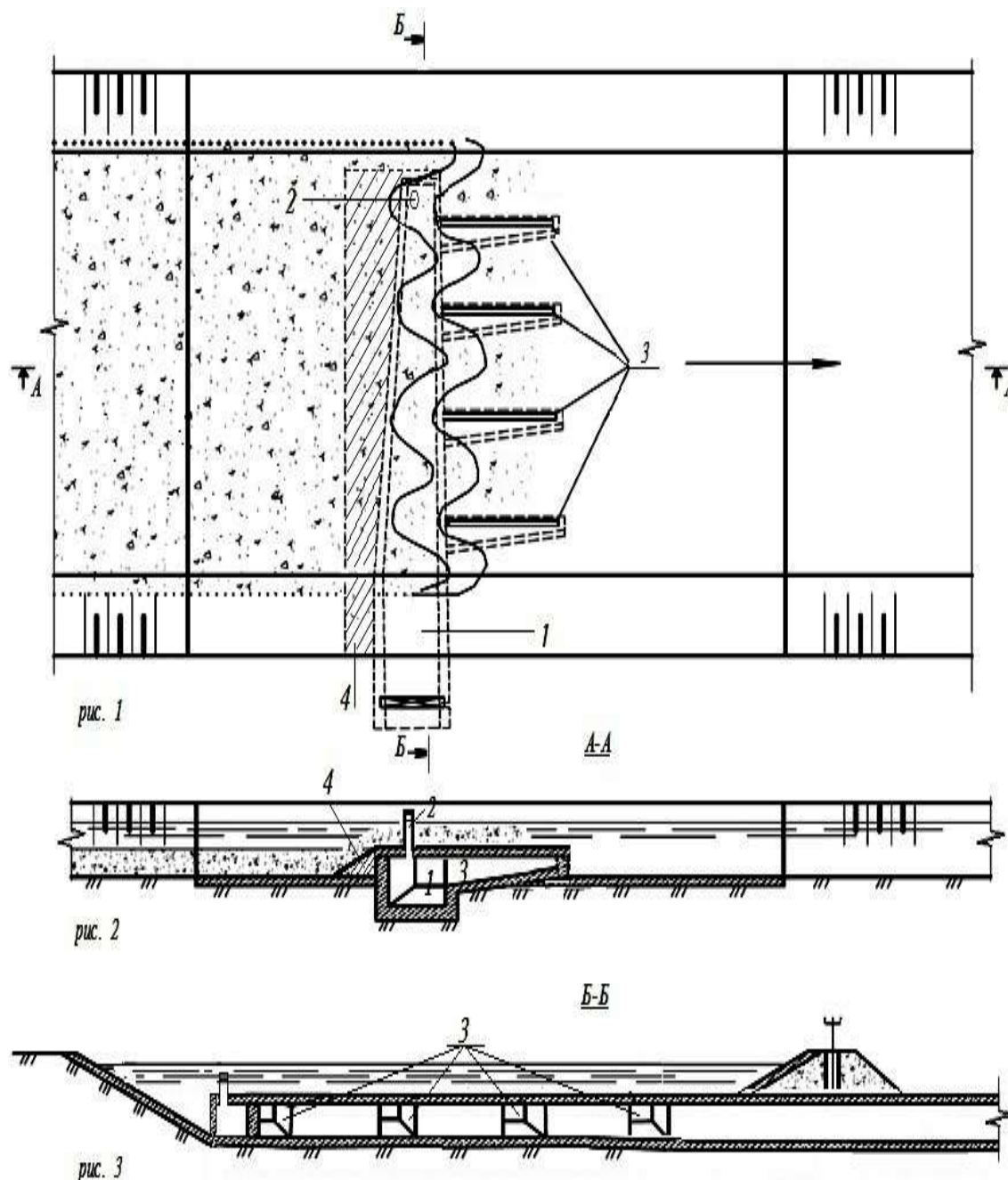
Ұсынылатын құмтұтқыш құмқойыртпақтан және бойлық саңылаулы тесіктерден тұратын галерея түріндегі тасынды тұтуға арналған құрылғыдан тұрады, ол құмқойыртпақтан кейін канал осіне параллель орналасқан, яғни төменгі бьефте және құмқойыртпаққа төмен жағынан түйіскен [6-8].

Қажетті нәтижеге, құмқойыртпаққа төмен жағынан түйіскен және төменгі бьеф жағында орналасқан, бойлық саңылаулы тесіктері бар галерея түріндегі тасынды тұтуға арналған құрылғыны және құмқойыртпақ құбыры астына әртүрлі мөлшердегі тасындылар түсуінің алдын алу үшін жер бетінен құмқойыртпақ жотасына дейін жақтама түріндегі темірбетон плитаныорнату арқылы қол жеткізіледі.

1-суретте құмшағалтұтқыштың жоспардағы көрінісі, 2-суретте 1-суреттегі А-А қимасы, 3-суретте 1-суреттегі Б-Б қимасы берілген.

Бойлық саңылаулы тесіктері бар құмшағалтұтқыш - құмқойыртпақтан 1, құмқойыртпақтың бастапқы бөлігінде оған тангенциал дәнекерленген дөңгелек немесе тікбұрышты қималы тік құбыршадан 2 және төменгі бьеф жағынан канал осіне параллель орналасқан және құмқойыртпаққа төменгі жағынан түйіскен бойлық тесікті саңылаулы галереядан 3 және де құмқойыртпақ алдына жер бетінен құбыр жотасына дейін (құбыр осімен) орнатылған жақтау түріндегі темірбетон плитадан тұрады.

Топырақ арналы каналдардағы төменгі бьеф жағынан орнатылған бойлық саңылаулы тесікті тасындытұтқыш галереялы 3 құрылғы бойлық тесіктерді көмбей, ірілеу тасындыларды өткізуге мүмкіндік береді, ал құмқойыртпаққа 1 тангенциалды тік құбыршаны 2 орнату, судың тангенциал түсуі есебінен, тасындытұтқыш галереядан бір бағытта түсетін негізгі ағынды қосымша құйынды ағысқа келтіруге мүмкіндік береді. Құмқойыртпақ алдында жер бетінен (арна түбінен) құбыр жотасына (құбыр осімен) дейін орнатылған жақтама түріндегі темірбетонды плитаның құрылымға толықтырылуы, құмқойыртпақ құбыры алдындағы түпкі және ілеспе тасындылардың түсуі мен шөгуінің алдын алады, бұл құмшағалтұтқышты ұзақ мерзім пайдалану кезінде негізгі шарттардың бірі. Құмқойыртпақтың бастапқы бөлігінде және бүкіл ұзындығы бойымен тасындылар шөгуі орын алмайды және бүкіл тосқындар су тастау каналына шығады және одан ары қарай өзенге немесе жергіліктің табиғи ойыстарына қайта ағызылады.



Сурет 1- Бойлық саңылаулы құмшағалтұтқыш

Қазіргі уақытта халық шаруашылығында пайдаланылатын, жер арналарда өтетін каналдардың басым бөлігінің түптеріне (табанына) өте көп мөлшерде тасындылар жиналуы есебінен, олардың көбісі істен шыққан, немесе көлденең қимасы кішеруімен жобалық өтімнің (расход) жарты мөлшерінде өткізе алмайды. Жыл сайын арналарды тасындылардан тазалау жұмыстары, адам күші мен механизмдерді көп қажет етеді, бұл бір жағынан уақытты алса және екінші жағынан көп қаржылай шығынға ұшыратады. Оның тағы да, экологиялық зардаптары мен табиғатқа тигізетін зиянды әсерлері бар. Бұл мәселе, ғалымдардың ұсынып отырған экономикалық та, экологиялық та тиімді және конструкциясы қарапайым құрылғыларды пайдалану, жалпыхалықтық іс екенін көрсетеді [9-12].

Лабораторияда жүргізілген көптеген зерттеулерді талдаумен мыналар анықталды, құрылымға, яғни су ағыны көпорлы құмшағалтұтқыштарға таяну бөлігінде құлау қисығы қалыптасады. Бұл кезде, бірінші ордың жоғарғы табалдырығында ағынның салыстырмалы

тереңдігі, каналдағы ағынның Фруд санына Fr және бірінші ордағы бөліну өтімі коэффициентіне k_1 байланысты өзгереді және де төменде осы жағдайға келтірілген байланыстылықпен анықталуы мүмкін

$$\eta_1 = \frac{H_1}{H} = 1 - \frac{5}{8} k_1^a \quad (1)$$

бұл жерде H_1 – ордың жоғарғы табалдырығындағы ағынның тереңдігі; H – каналдағы су ағынының тереңдігі; a – төмендегі шамаға тең параметр:

$$a = 1/4 + 2/5 Fr \quad (2)$$

$$k_1 = \frac{Q_T}{Q} \quad (3)$$

Q_T - бірінші ордың шаю өтімі;

Q - каналдағы су өтімі.

Көпорлы құмшағалтұтқыш маңындағы су ағынының бетінің пішіні өте күрделі болып келеді. Орлар, бір-бірінен $(4-5)H$ алыстаған кезде, ағынының қозғалысы салыстырмалы бірқалыпты режимдегі өзара бөлектенген телімдерден тұратын оның еркін беті бірқатар жеке аймақтарға бөлінеді. Бұл жағдайда, құмшағалтұтқыштың орларының құрамына енетін әрбір табалдырықтың жоғарғы бөлігінде η_1 шамасы (1) байланыстылықпен анықталады, ол жерде, тиісінше: $H=H_{i(opm)} - i-1$ және i –ші орлардың арасындағы бірқалыпты ағынның орташа тереңдігі; $Fr=Fr_i - i-1$ және i –ші орлардың арасындағы Фруд саны.

Егер орлар арасындағы арақашықтық $4H$ -тан кем болса, орлардың әсер ету аймақтары бір-бірінің үстіне келеді. Осы жағдай үшін көпорлы құмшағалтұтқыштың төңірегіндегі транзиттік ағынның еркін бетінің қисығының келесі теңдеуі алынды:

$$\frac{dH}{dx} = \frac{i_k - i_{mp} + \frac{v_y}{v} Fr}{1 - Fr} \quad (4)$$

бұл жерде i_k - канал түбінің еңістігі; i_{mp} - үйкеліс бетінің еңістігі; v - транзиттік ағынның жылдамдығы; v_y - орлардың кіру тесігі жазықтығына нормаль, бөлініп шығатын өтімнің орташа жылдамдығы, ол есептік жағдайларда келесідей анықталады:

$$v_y = \frac{kQ}{L_0 b_k} \quad (5)$$

мұнда k - көпорлы құмшағалтұтқыштың өтімінің бөліну коэффициенті; L_0 - көпорлы құмшағалтұтқыштың жалпы ұзындығы; b_k - каналдың түбінің ені.

Осы теңдеу бойынша тереңдіктерді есептеу, соңғы айырмашылықтар әдісімен жүргізіледі. (5) өрнек жақындатылған есептеулер үшін ұсынылады және өтімнің бөліну коэффициенті $k \leq 0,15$ кезінде тәжірибелік деректермен жақсы ұқсастық береді.

Бірқатар ғалымдардың зерттеу нәтижелері төмендегідей деректер көрсетті, орлардың санын ұлғайту, тасындылардың жеке фракцияларын тұту коэффициентін 2-3,5 есе

көтеруге мүмкіндік беретін факторлардың бірі болып табылады [13-15]. Сонымен бірге, транзиттік ағынның Фруд санының шамасы 1,0-ден асқан кезде ұсақ тасынды түйіршіктерін (тәжірибелерде мөлшері 0,5 мм-ден кіші) тұту кезінде, орлардың санын ұлғайтудан ең үлкен тиімділікке қол жеткізіледі. Бұл жағдайларда, ұсақ тасындылардың негізгі массасы ($\omega/\nu < 0.05 - 0.03$) бірінші ордан кейін тұтылады, олардың үлесіне құрылыммен тұтылған жалпы тасынды мөлшерінің 70-75% келеді. Бірінші орға іс жүзінде $\omega/\nu > 0.10$ мөлшердегі тасындылардың барлығы дерлік түседі.

Бірақ, тәжірибелер көрсеткендей, каналда төрт орды орнату, орлар санын ұлғайту есебінен құрылыммен тасындыларды тұту коэффициентін көтеру мүмкіндігін іс жүзінде жояды, сондықтан көпорлы құмшағалтұтқыштарда орлар санын төрттен артық емес етіп жобалау керек.

Көптеген зерттеу нәтижелері көрсеткендей, әртүрлі тасынды түйіршіктерін құрылым құрамындағы ордың ұтымды ең ауқымды тұту шамасының ені 0,8-1,0 м аралығында жатыр (болмыстық жағдайларда). Ордың ені көрсетілгеннен төмен болса, тасындыларды тұтудың күрт төмендейтіні байқалады. Тәжірибелердің негізінде, ор ішінде бір тұрақты бұрандалы ағыс түзілуі мен тасындылардың ең көп тұтылуын қамтамасыз ететін, ордың тереңдігі мен ені арасындағы ең ұтымды қатынас $h_T / b_T = 0.8 - 1.4$ алынды.

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ГИДРОЛОГИЧЕСКОЕ ОБОСНОВАНИЕ СТРОИТЕЛЬСТВА ЕСИЛЬСКОГО КОНТРЕГУЛЯТОРА

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Водный режим и условия формирования стока.

Территория Акмолинской области относится к районам резко выраженного недостаточного увлажнения, накладывающего свой отпечаток на формирование поверхностного стока.

Поверхностный сток в пределах области формируется почти исключительно за счёт таяния снеговых вод. Дождевые осадки в условиях жаркого лета и большой сухости почво-грунтов в своей подавляющей части теряются на испарение и в стоке рек и временных водотоков области практического значения не имеют. Грунтовое питание водотоков крайне не велико, а зачастую и вообще отсутствует, что связано с глубоким залеганием подземных вод, слабым врезом речных долин и малой мощностью сезонной верховодки. В научной статье были использованы такие труды [1-7].

Согласно таблице 1, доля грунтовых вод в стоке р.Есиль составляет 7-11%-тов. Таким образом, в связи с исключительной ролью снега в процессе формирования поверхностного стока, объём годового стока рек и временных водотоков Акмолинской области почти полностью определяется объёмом весеннего стока. Для р.Есиль доля весеннего стока составляет в разных створах 89-93%-тов (таблица 1).

Таблица 1 - Соотношение доли различных источников питания в годовом стоке реки Есиль и его притока Жабай

Река	Пункт	Площадь водосбора, км ²	Удельный вес различных источников питания (в %-тах от годового стока)		
			снеговое	грунтовое	дождевое
Есиль	с. Передовик	202	90	9	1
Есиль	г. Нур-Султан	7 400	93	7	0
Есиль	с. Каменный Карьер	86 200	89	11	0
Жабай	г. Атбасар	8 530	90	10	0

Основным фактором формирования весеннего стока на территории Акмолинской области является снежный покров. Однако в ряде случаев величина весеннего стока не в меньшей степени определяется другими факторами, в частности потерями воды на фильтрацию в почву, зависящими от состояния почвы к началу снеготаяния (её увлажнения

и промерзания) и, отчасти, интенсивности снеготаяния. Величина потерь при этом от года к году изменяется в довольно больших пределах по сравнению с величиной снегозапасов. Этим объясняются существенная роль потерь в формировании весеннего стока и резкие колебания последнего во времени.

Особенностями условий формирования стока на территории Северного Казахстана являются большие потери талых вод на поверхностную аккумуляцию в пределах бессточных площадей водосбора, а также задержание части весеннего стока, затем расходующееся на испарение в речных плёсах. Относительная величина этого задержания меняется в зависимости от водности года и достигает значительных величин в маловодные годы.

Площади бессточных областей, а соответственно и потери на поверхностную аккумуляцию и испарение, большей частью возрастают с увеличением общей площади бассейна.

Наряду с перечисленными переменными факторами, на величину поверхностного стока оказывает влияние также ряд постоянно действующих факторов (строение поверхности, высотное положение и уклоны водосборов, экспозиция склонов, почво-грунты), обуславливающих особенности распределения по территории снегозапасов, потерь талых вод и объёмов весеннего стока.

Главная особенность формирования водного режима водотоков обширного Казахского мелкосопочника - это, прежде всего, сравнительно равнинный рельеф. Отсутствие вертикальной поясности в распределении климатических элементов, обычно свойственной горным территориям, здесь, например, проявляется в отсутствии градиента распределения температур, величин осадков и установления снежного покрова по высоте, существенно изменяющихся значений испарения по территории. Равнинный рельеф обуславливает равный приток солнечной радиации в пределах больших пространств. В связи с этим весеннее снеготаяние происходит обычно одновременно по всему водосбору даже крупных рек. Это и обусловило прохождение высоких половодий в сравнительно краткие сроки. Практическое отсутствие летнего поверхностного стока и глубокая межень обусловлена так же тем, что за весенние месяцы успевает сойти весь снежный покров. Несмотря на то, что осадки за тёплый период года в два и более раз превышают величину осадков холодного периода, поверхностного стока они не дают. Летние осадки пропитывают сухую почву или заполняют большое множество озёр, которые переливаются только при очень больших осадках года. В обычные же годы осадки аккумулируются в этих озерах, и затем испаряются, не участвуя в питании основного водотока, в бассейне которого они расположены.

На водный режим реки Есиль в значительной степени оказывает влияние водохозяйственная деятельность на территории бассейна. В бассейне расположено около 45 водохранилищ, однако многолетнее глубокое регулирование стока р. Есиль осуществляется только двумя водохранилищами: Астанинским (Вячеславским) ($W_{\text{полез.}} = 375.4$ млн. м³) и Сергеевским ($W_{\text{полез.}} = 635$ млн. м³).

Годовой сток и его внутригодовое распределение.

Для оценки годового стока р. Есиль в расчётном створе использованы материалы наблюдений Гидрометцентра РК по гидрологическому посту у с. Каменный Карьер за период с 1947 по 2018 год. Несмотря на достаточно длительный период наблюдений, данные по стоку изобилуют пропусками, поэтому осуществлялось восстановление годового стока по зависимостям между значениями стока и соответственным уровням воды (рисунок 1).

При полном отсутствии наблюдений на посту у с. Каменный Карьер, что имело место в 1998-2002 годах, пропуски восстанавливались с привлечением стоковых характеристик по г/п. – аналогу у с.Сергеевка (рисунок 2).

Для определения параметров годового стока р.Есиль в расчётном створе использованы характеристики годового стока по материалам гидрологического поста у с.Каменный карьер за период с1971 по 2018гг. в условиях зарегулированного стока (после ввода в строй Вячеславского водохранилища 1969-70).

На рисунке 3 показана хронология распределения годового стока р. Есиль у с.Каменный карьер за период наблюдений с 1971 по 2018гг. Подвергнутый статистической обработке принятый ряд (с 1971-2018 годы) предварительно проверен на однородность. При рассмотрении выборок данных годового стока р. Есиль у с.Каменный карьер гипотеза однородности ряда (при уровне значимости 5%) по десяти критериям Диксона и по двум критериям Смирнова – Граббса подтвердилась. Стационарность ряда (при уровне значимости 5%) по его среднему значению и дисперсии, контролируемая соответственно критериями Стьюдента и Фишера подтвердилась. Таким образом, все вычисленные значения при принятом 5%-ном уровне значимости меньше критических значений (таблица 1) и принятый ряд годового стока может быть подвергнут статистической обработке.

На клетчатке вероятностей показаны эмпирическая и теоретическая кривые обеспеченности. Основные параметры кривой распределения и годовые значения стока расчётных обеспеченностей представлены в таблице 2.

Максимальный сток и расчётные гидрографы весеннего половодья.

Весеннее половодье является главной фазой водного режима любой реки. В этот период обычно проходит основной объём годового стока. Однако на территории Казахского мелкосопочника этот фактор особенно выражен. Равнинный рельеф здесь способствует исключительно дружному поступлению солнечной радиации на территорию речных бассейнов, что в свою очередь обеспечивает такое же, исключительно дружное таяние снежного покрова. И это главное условие, способствующее формированию непродолжительных, но очень высоких половодий. Наблюденные максимумы превышают средние многолетние годовые расходы воды в 100-200 раз.

В частности, на р.Есиль у с.Каменный карьер за весь период наблюдений (1947-2018гг) с учётом наибольшего расхода воды (4690 м³/с), наблюдавшегося 30 апреля 1948 года, это соотношение составило: $(4690/39,4 = 119 \text{ раз})$.

Имеющийся ряд наблюдений за максимальным стоком изобилует пропусками. Восстановление максимальных расходов воды пропущенных лет выполнены по зависимости между наибольшими расходами воды и соответствующими им наивысшими уровнями воды на р.Есиль у г/п Каменный Карьер (рисунок 1).

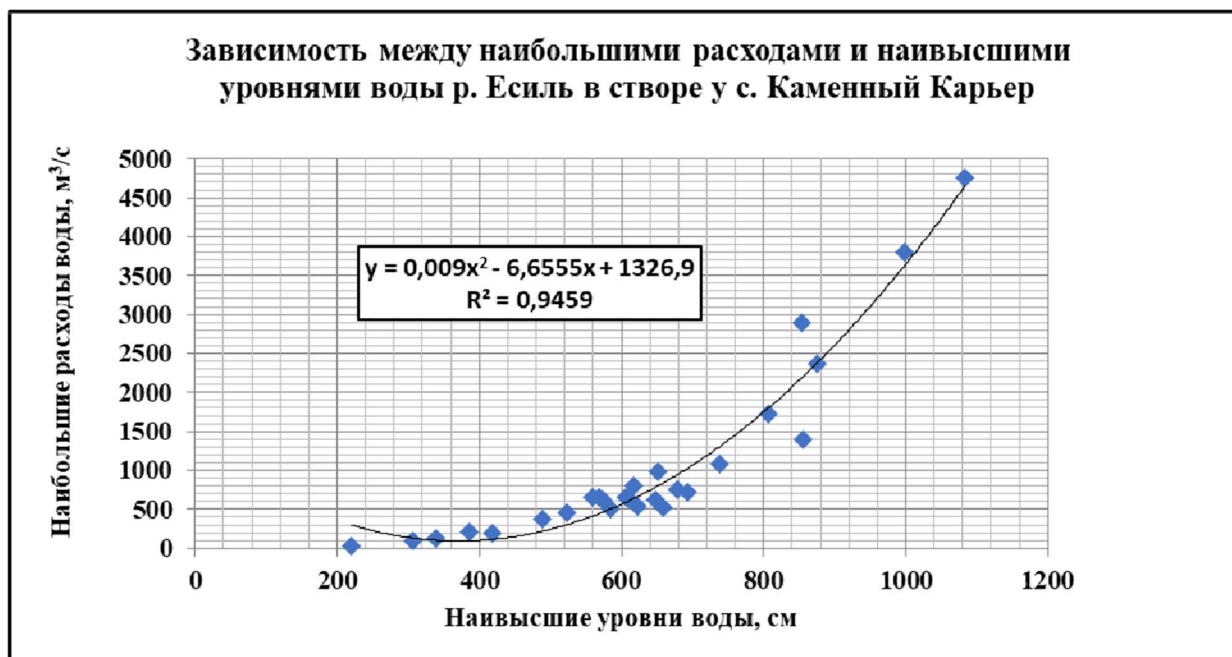


Рисунок 1 – Зависимость расхода от уровня воды

Для периода, когда г/п Каменный Карьер был закрыт и наблюдения были полностью прекращены (1998-2002годы), максимальные значения расходов воды были восстановлены с привлечением данных наблюдений г\поста аналога у с.Сергеевка (рисунок 2).

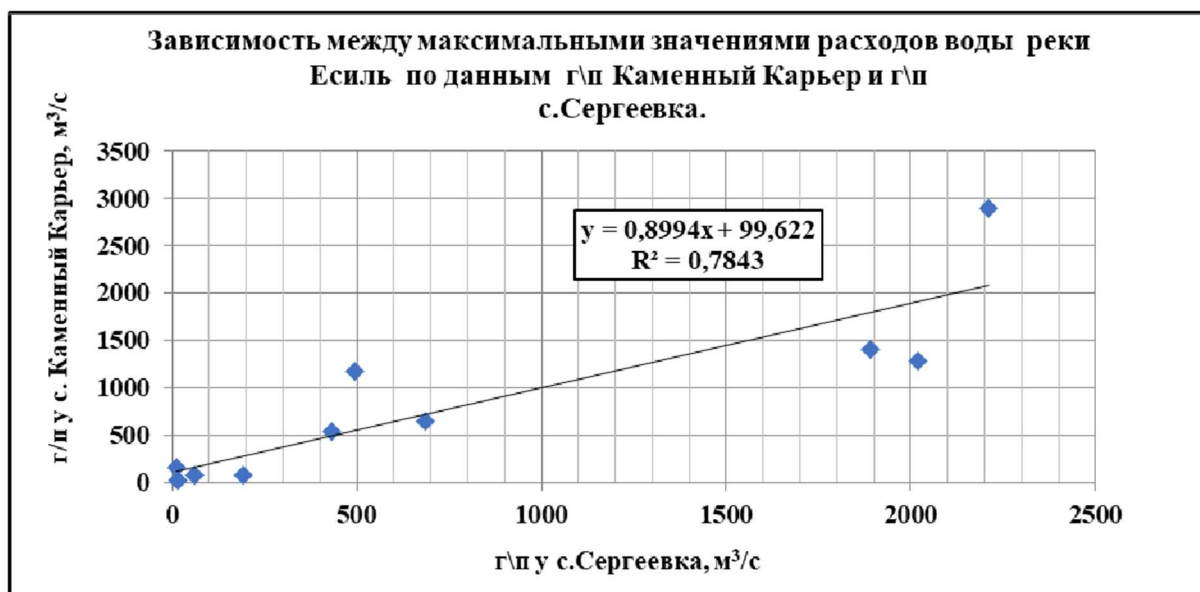


Рисунок 2 – Зависимость максимальных расходов реки

Хронология колебаний максимальных расходов воды р.Есиль у с.Каменный карьер показан на рисунке 3.

Статистической обработке восстановленного ряда наблюдений за максимальным стоком предшествовала его оценка на однородность и случайность формирования с помощью 10 критериев Диксона, двух критериев Смирнова – Граббса, Стьюдента и Фишера. Все названные вычисленные критерии оказались в зонах доверительной вероятности (таблица 1). Последнее указывает на то, что рассматриваемый ряд однороден и может быть

подвергнут статистической обработке с целью получения вероятностных значений максимального стока.

На клетчатке вероятностей (рисунок 3) показаны эмпирическая и подобранные к ней теоретические кривые распределения. В качестве расчётного принята кривая трехпараметрического гамма распределения Крицкого и Менкеля.

Основные параметры кривой распределения максимального стока и его значения расчётных обеспеченностей р.Есиль в заданном створе представлены в таблице 2.

Минимальный сток

С окончанием половодья на реке начинается летне-осенняя межень, а в очень маловодные годы она начинается практически с июля. Затем она плавно переходит в зимнюю межень. Наименьшие среднемесячные значения стока отмечаются в феврале-марте или в период за 30 дней перед началом половодья. В основном расходы воды в зимнюю межень ниже, чем в летне-осеннюю.

Для определения статистических параметров минимального стока и значений расчётных обеспеченностей использованы наблюдения за стоком в период межени на р. Есиль в створе поста Каменный карьер за период с 1950 по 2018 годы, с пропусками. Расчётный ряд сначала был подвергнут оценке на однородность десятью критериями Диксона, двумя критериями Смирнова- Граббса, Стьюдента и Фишера. Все поверочные критерии попали в зону допустимых значений (таблица 2).

На клетчатке вероятности (рисунок 1) показаны эмпирическая кривая и подобранная к ней теоретическая кривая трехпараметрического гамма- распределения Крицкого-Менкеля. Основные параметры минимального стока и их обеспеченные значения приведены в таблице 2.

Таблица 2 - Основные параметры минимального стока и их обеспеченные значения

Река- створ	Площадь водосбора , км ²	Параметры минимального стока			Минимальные расходы воды (м ³ /с) расчётной обеспеченности, (%)			
		Q _{мин. ср} , м ³ /с	C _v	C _s	80%	90%	95%	99%
1	2	3	4	5	6	7	8	9
Есиль	86200	1.62	0.59	0.4	0.7	0.39	0.217	0.055

Твёрдый сток

Для характеристики твёрдого стока р.Есиль в исследуемом створе использованы материалы наблюдений за взвешенными наносами на посту у с.Каменный карьер. По среднемесячным данным наблюдений за жидким и твердым стоком построена зависимость (рисунок 3). По месячным значениям расходов воды среднемноголетнего года и построенной зависимости на рисунке 3 определены средние месячные и средний годовой расходы взвешенных наносов (таблица 3).

$R_{\text{ср. мес.}} = f(Q_{\text{ср.мес.}})$

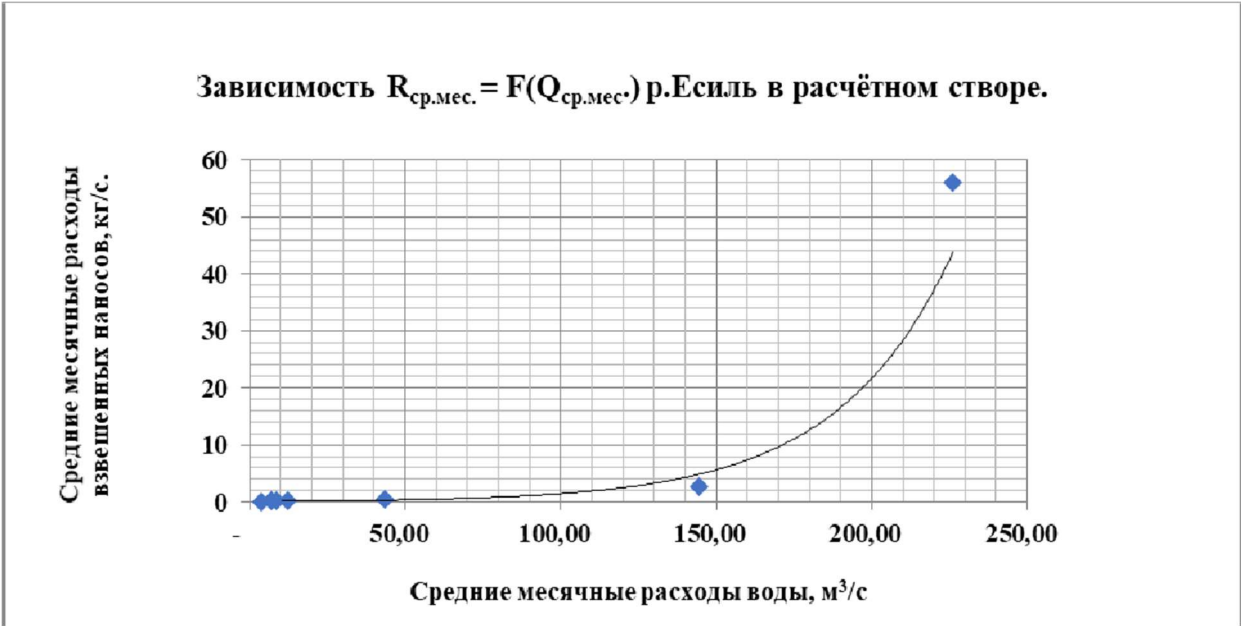


Рисунок 3 – Зависимость среднемесячных расходов воды от взвешенных наносов

Таблица 3 - Внутригодоевое распределение расходов воды (м3/с) и расходов взвешенных наносов (кг/с)

месяцы	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	год
$Q_{\text{ср.}}/\text{мес.}$	3.5	3.17	3.88	226	145	43.7	12.3	8.79	7.04	6.9	6.62	5.96	39.4
$R_{\text{ср.}}/\text{мес.}$			0.01	56	2.7	0,49	0.33	0.23	0.19	0.18			5.01

Тогда годовая масса стока взвешенных наносов составит: $W_{\text{год.}} = 5.01 \cdot 31.54 \cdot 1000 = 158\,154$ тонн/год.

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Logistical Foundations of Operational and Effective Supply Chain Management and Optimization Approaches

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Abstract

The operational and efficient management of the supply chain is of significant importance from both scientific and practical perspectives, as it enhances the competitiveness of enterprises, ensures the efficient use of resources, and optimizes logistics processes. In the modern era, the dynamic nature of global markets, demand uncertainty, and the rapid development of digital technologies have made it essential to manage supply chains in a more flexible and efficient manner. In this context, the application of logistics-based management approaches plays a crucial role in the strategic activities of enterprises. The main objective of this study is to examine the theoretical foundations of operational and efficient supply chain management and to systematically analyze the opportunities for optimizing these processes through logistics approaches. The research employs a combination of qualitative and quantitative methods, including the analysis of scientific literature and evaluation based on statistical data. The findings indicate that the proper implementation of logistics planning, demand forecasting, inventory management, and transportation optimization contributes to reducing operational costs, improving service levels, and increasing customer satisfaction. Additionally, the integration of information technologies into supply chain processes enables more flexible and accurate decision-making. The study concludes that effective supply chain management allows enterprises to respond more rapidly to market changes, minimize risks, and ensure sustainable development. Therefore, it is recommended that enterprises integrate modern technologies into their logistics strategies, improve planning and forecasting processes, and adopt innovative management approaches. These practices serve as key factors in achieving competitive advantage and ensuring long-term growth in a rapidly evolving business environment.

Keywords : supply chain, logistics, operational management, efficient management, transportation optimization, supply chain performance, digital logistics

Introduction

In the modern era, the rapid development of the global economy, the expansion of technological progress, and the increasing level of competition in the market environment have fundamentally transformed approaches to supply chain management. In particular, the development of logistics and digital technologies has necessitated the implementation of more flexible, optimized, and efficient management mechanisms in enterprise operations. In this context, the operational and effective management of the supply chain serves as one of the key factors that directly influence enterprises' strategic decision-making processes, operational activities, and overall performance. The application of logistics-based approaches in supply chain management holds strategic importance in enhancing competitiveness, ensuring efficient use of resources, and reducing operational costs. Under modern conditions, characterized by demand uncertainty, market volatility, and the acceleration of information flows, enterprises are compelled to use more accurate planning and optimization methods. In this regard, the topic is highly relevant both from theoretical and practical perspectives.

The scientific significance of the research lies in the systematization of existing theoretical approaches related to the operational and effective management of the supply chain, as well as in the comprehensive analysis of the application possibilities of logistics methods. At the same time, the study examines the practical aspects of applying these approaches in the modern business environment and evaluates their effectiveness.

The main objective of the research is to study the theoretical foundations of operational and effective supply chain management, to identify the application directions of logistics approaches, and to propose scientifically grounded recommendations for optimizing these processes.

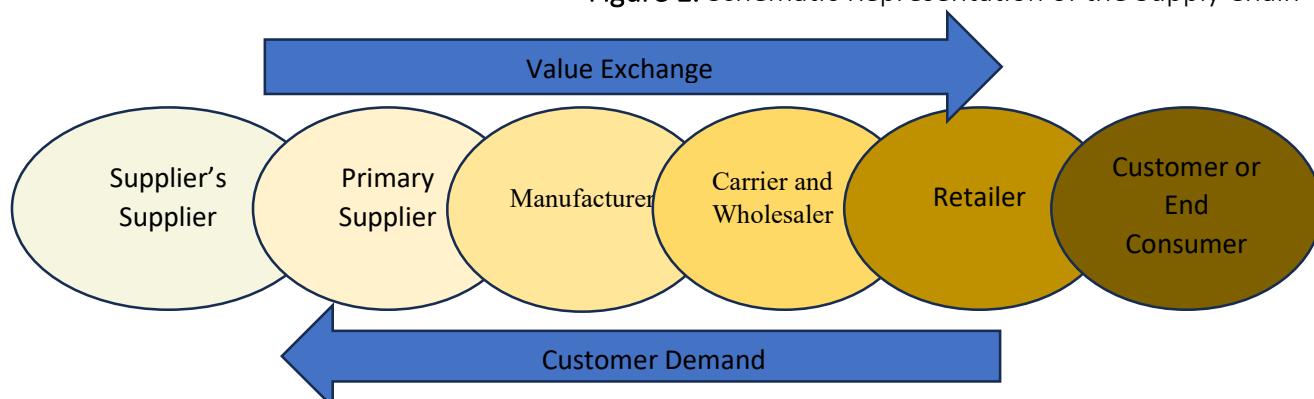
The tasks of the research include analyzing the essence of supply chain and logistics concepts, examining the principles of operational and effective management, evaluating logistics planning and demand forecasting methods, as well as analyzing directions of inventory and transportation optimization. From a methodological perspective, the study employs a combination of qualitative and quantitative methods, including the analysis of scientific literature, a comparative approach, and the interpretation of statistical data.

The information base of the research consists of international and local scientific sources, analytical reports, statistical indicators, and open information resources. The main limitations of the study are related to the limited accessibility of certain statistical data and the insufficient availability of empirical data regarding practical applications.

The practical significance of the research lies in the fact that the effective application of logistics approaches in supply chain management enables enterprises to improve management processes, reduce costs, and gain a competitive advantage.

The Essence of Supply Chain and Logistics. In the modern economic system, the concept of the supply chain has become an integral part of enterprise operations and is characterized as a set of complex processes that cover the movement of a product from the initial stage to the final consumer. Within this chain, various economic actors—such as suppliers, manufacturers, distributors, and retail enterprises—interact with each other and participate in the value creation process of the product. The supply chain is not limited only to the physical flow of goods; it also encompasses the coordination of information and financial flows (Dawei Lu, 2011).

Figure 1. Schematic Representation of the Supply Chain



Source : Dawei Lu, 2011.

Logistics acts as the main management mechanism in organizing these processes. The essence of logistics lies in the planning, organization, and control of material and information flows, aiming to ensure that products are delivered at the right time, in the right place, and with minimal costs. In modern approaches, logistics is considered not only as a function of transportation and warehousing, but also as a comprehensive system that includes planning, coordination, and optimization processes.

Although the concepts of supply chain and logistics are closely related, their functional directions differ to some extent. While logistics mainly focuses on managing processes at the operational level, supply chain management encompasses a broader approach by ensuring the integration of the activities of all participants. From this perspective, the effective functioning of the supply chain directly depends on the proper design of logistics systems.

In the modern business environment, the role of supply chains has increased significantly. The development of global markets, the organization of production on an international scale, and the intensification of competition force enterprises to manage their supply chains more efficiently. Under such conditions, competition arises not only between individual enterprises but also between entire supply chains. As a result, the success of enterprises depends on the effectiveness of the supply chain to which they belong.

Key Principles of Operational and Effective Management. The proper application of operational and effective management principles is essential for ensuring the efficient functioning of the supply chain. In the modern business environment, the acceleration of market changes and the increase in competition require enterprises to make not only strategic decisions but also flexible decisions at the operational level. In this regard, operational management ensures the coordination of daily activities and real-time decision-making, while effective management focuses on the optimal use of resources and the achievement of long-term results.

One of the main principles of operational and effective management is the principle of strategic alignment. According to this principle, all operational decisions made within an enterprise must be aligned with the organization's overall strategic objectives. Otherwise, short-term successes may lead to negative outcomes in the long term. Therefore, supply chain planning, inventory management, and transportation processes should be organized in accordance with the overall strategy of the enterprise (Chopra & Meindl, 2019).

Another important principle is the optimization of resources. Enterprises must utilize available resources—financial, material, human, and technological—with maximum efficiency. Within this principle, excess inventory, unnecessary costs, and time losses are minimized. In particular, in logistics systems, this approach contributes to reducing operational costs and increasing overall efficiency. The integration and coordination of processes are also key components of operational and effective management. Since the supply chain consists of multiple stages, it is essential to ensure the proper coordination of information and material flows between these stages. In modern conditions, the application of information technologies further strengthens this integration, enhancing the speed and accuracy of decision-making processes (Heizer, Render, & Munson, 2020).

The principle of flexibility and adaptability is an integral part of modern management systems. The instability of market conditions requires enterprises to quickly adapt to changes. In accordance with this principle, the supply chain must be able to respond promptly to demand fluctuations, supply disruptions, and other external factors. Flexible management approaches enable enterprises to reduce risks and ensure the sustainability of their operations.

The principle of performance measurement and continuous improvement is also of particular importance. Various indicators are used to evaluate the effectiveness of supply chain activities. Based on these indicators, processes are analyzed, shortcomings are identified, and measures are taken to eliminate them. This approach allows enterprises to continuously improve their performance. In addition, the principle of information and communication is one of the key factors determining management effectiveness. The proper establishment of information exchange among all participants in the supply chain ensures timely and accurate decision-making. Delays or inaccuracies in information flow, however, can negatively affect operational processes.

Supply Chain Performance Indicators and Modern Logistics Management Models.

Effective supply chain management depends not only on the organization of processes but also on the accurate measurement and evaluation of their outcomes. In this regard, performance indicators are considered one of the main tools for analyzing supply chain efficiency and optimizing management decisions. In the modern business environment, enterprises are not limited to producing goods; they also strive to evaluate how effectively all operations are carried out in terms of speed, quality, and cost (Mammadov, 2021, pp. 45–58).

The evaluation of supply chain performance is generally conducted based on three main dimensions: time, cost, and quality. Time indicators cover the period from order receipt to delivery to the final customer and determine the speed of logistics processes. Cost indicators include transportation, warehousing, production, and other operational expenses, reflecting how efficiently resources are utilized. Quality indicators assess the compliance of products and services with customer requirements, delivery accuracy, and service level. Based on these indicators, enterprises can identify existing problems within the supply chain and take appropriate measures to eliminate them. Performance measurement not only evaluates the current state but also provides an important information base for future planning and strategic decision-making. This approach enables enterprises to allocate resources effectively, optimize operations, and improve overall efficiency (Bayraktar, 2020, pp. 233–250).

In the modern era, various logistics management models are widely applied in supply chain management. These models are aimed at organizing processes in a more systematic and efficient manner. One of them is the “Just-in-Time” (JIT) model. According to this model, products are produced only when demand arises, and inventory levels are kept to a minimum. This approach reduces warehousing costs and ensures more efficient use of resources.

Another important approach is the Lean logistics model. The main objective of this model is to minimize waste in processes and prioritize value-creating activities. Through the Lean approach, enterprises simplify operational processes, reduce time losses, and ensure faster delivery of products to the market.

The Total Quality Management (TQM) model, on the other hand, is focused on ensuring quality at all stages of the supply chain. This approach provides quality control from the production stage to delivery to the final consumer and serves to increase customer satisfaction. In addition, modern information technology-based systems such as ERP and SCM also play an important role in supply chain management. Through these systems, data are collected and processed in a centralized manner and used in decision-making processes. This enables management processes to be carried out in a more transparent, faster, and more accurate way (Acar, 2014, pp. 123–140).

Logistics Approaches to Operational and Effective Supply Chain Management.

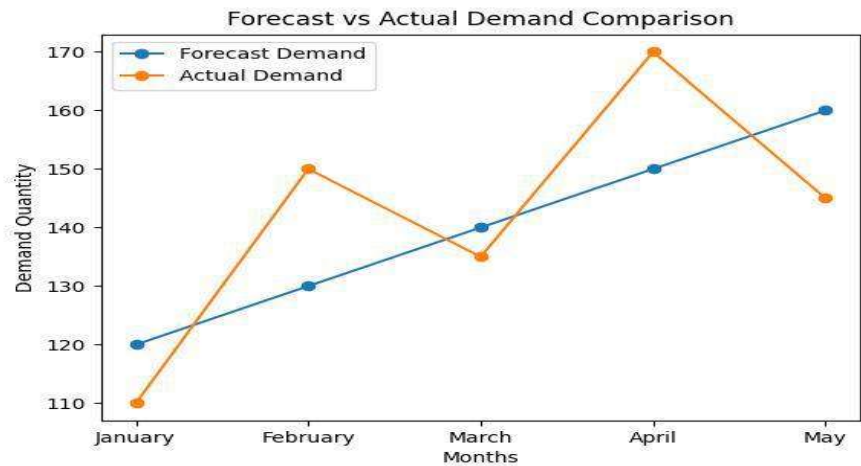
Logistics planning and demand forecasting play a crucial role in the effective management of the supply chain. These processes enable enterprises to anticipate market demand, optimize production and inventory levels, and organize logistics activities more efficiently. However, in practice, the implementation of these processes is accompanied by several challenges. One of the main problems in the supply chain is demand uncertainty. Changes in consumer behavior, seasonal fluctuations, and economic factors affect the stability of demand in market conditions. This leads to increased complexity in the planning process. When demand is not accurately forecasted, enterprises face either product shortages or excess inventory problems (Ibrahimov, 2019, pp. 101–120). In the first case, customer demand is not fully met, while in the second case, additional warehousing costs arise.

Table 1. Example of Demand Uncertainty

Month	Forecasted Demand	Actual Demand
January	120	110
February	130	150
March	140	135
April	150	170
May	160	145

Source: Prepared by the author based on Christopher (2016).

Figure 1. Graph of Demand Uncertainty



These indicators show that in certain periods, actual demand significantly differs from the forecasted demand. This confirms the presence of uncertainty factors in logistics planning. Another important problem in the supply chain is the inaccuracy of data. Effective management of logistics processes requires accurate and timely information. However, in practice, manual data entry, lack of system integration, and weak information exchange negatively affect this process.

The Bullwhip Effect and Its Impact on the Supply Chain. One of the major problems encountered in supply chains is the phenomenon known as the bullwhip effect, which refers to demand fluctuations. This effect is characterized by the amplification of small changes in demand at the end-consumer level as they move upstream through the supply chain. In other words, minor changes in the market can lead to exaggerated order volumes at the production and supply levels. The main causes of the bullwhip effect include delays in information transmission, placing additional orders to maintain safety stock, and the use of different forecasting methods at various stages of the supply chain. For example, a retailer may place larger orders anticipating an increase in demand for a certain product. The distributor, interpreting this as a continuous upward trend, places even larger orders with the manufacturer. As a result, at the production level, demand appears significantly higher than the actual market demand. This process leads to several negative consequences within the logistics system. The most common problems include excess inventory, disruption of production plans, and increased transportation costs (Lee, Padmanabhan, & Whang, 1997, pp. 93–102). In addition, demand fluctuations negatively affect financial planning in enterprises and increase the level of risk. The impact of the bullwhip effect can be more clearly illustrated through the following table.

Table 2. Example Statistics of the Bullwhip Effect in the Supply Chain (Model Based on the Azerbaijan Distribution Market)

Supply Chain Stage	Demand Variation (%)
Customer	5
Retailer	10
Distributor	18
Importer	25
Manufacturer	35

Source: Lee, H., Padmanabhan, V., & Whang, S. (1997). The Bullwhip Effect in Supply Chains. *Sloan Management Review*

As can be seen from the table, small changes at the end-consumer level increase along the supply chain and lead to larger fluctuations at the manufacturer level. This clearly demonstrates the main characteristic of the bullwhip effect, namely the amplified propagation of demand changes throughout the chain.

In the Azerbaijani market, this effect is more frequently observed, especially for products that are dependent on imports. Long delivery times and advance ordering often result in excess inventory when market demand changes. In addition, the lack of full sharing of sales data among supply chain participants further exacerbates this problem. Strengthening information exchange within the supply chain is considered essential for reducing the bullwhip effect. The sharing of real-time sales data enables more accurate order planning and helps prevent fluctuations. On the other hand, optimizing ordering policies and properly determining inventory levels also play a significant role in addressing this issue. Furthermore, the implementation of modern digital logistics systems serves as an effective tool in reducing the bullwhip effect. Through these systems, data flow among all participants in the supply chain is ensured on a unified platform, and the decision-making process becomes more transparent and efficient. Thus, while the bullwhip effect is one of the key factors affecting supply chain efficiency, its proper management plays an important role in optimizing logistics operations within enterprises.

Coordination Problems in the Supply Chain and Their Solutions. The supply chain is a complex system that operates through the interaction of various economic entities. In this system, manufacturers, suppliers, logistics companies, distributors, and retail enterprises function within a unified mechanism. Therefore, effective coordination and collaboration among participants are crucial for the efficient functioning of the chain. However, in practice, the failure to fully ensure these relationships negatively affects the efficiency of logistics processes.

One of the main causes of coordination problems is the insufficient level of information exchange. Delays or inaccuracies in the flow of information among different participants lead to inconsistencies in the planning process. In some cases, enterprises make decisions based solely on their own interests, which can negatively impact the overall performance of the supply chain. As a result, problems such as order delays, uneven distribution of inventory, and increased logistics costs arise.

In the Azerbaijani logistics sector, coordination challenges are particularly evident among small and medium-sized enterprises. In many cases, the absence of integrated information systems between enterprises complicates data exchange. In addition, the involvement of different entities in transportation, warehousing, and distribution processes leads to inconsistencies in management. Although certain progress has been made in the development of logistics infrastructure in recent years, the adoption of digital logistics systems is still not widespread. This

situation maintains the relevance of coordination problems. The current situation can be more clearly evaluated based on the following indicators.

Table 3. Key Indicators of Logistics and Supply Chain Coordination in Azerbaijan

Logistics Coordination Area	Indicator
Infrastructure	2.71
Customs Coordination	2.57
Delivery Time	2.57
Quality of Logistics Services	2.14
Overall Logistics Performance	2.44

Source ¹ : World Bank. (2023). *Logistics Performance Index: Connecting to Compete – Trade Logistics in the Global Economy*. Washington, DC: World Bank.

Source ²: Hasanli, P. (2018). *Azerbaijan's position in the East–West transport corridor and logistics performance index analysis*.

As can be seen from the indicators presented in the table, although logistics infrastructure is relatively well developed compared to other areas, service quality and the overall level of coordination remain lower. This indicates the need to improve management and coordination mechanisms in the logistics sector. To overcome coordination problems, it is essential to strengthen cooperation among all participants in the supply chain. For this purpose, modern logistics management models, particularly SCM (Supply Chain Management) systems, are widely used. Through these systems, all processes within the supply chain are managed on a unified platform, and information exchange is carried out more efficiently. In addition, the application of digital technologies plays a significant role in enhancing coordination levels. GPS and IoT technologies enable real-time monitoring of transportation processes and ensure more transparent management of logistics operations. Through these technologies, accurate information about cargo location, delivery time, and operational status can be obtained. In recent years, significant projects have been implemented in Azerbaijan to strengthen coordination in the logistics sector. Projects such as the Baku International Sea Trade Port and the Alat Free Economic Zone have had a positive impact on the development of logistics connections. At the same time, the wider implementation of digital information systems and the improvement of data exchange among enterprises are considered key directions for future development. Thus, strengthening coordination within the supply chain is of great importance in increasing the efficiency of logistics processes, reducing costs, and improving overall performance.

The Essence of Transportation and Route Optimization. Transportation and route optimization are among the key areas that play an important role in the effective management of the supply chain. The main objective of this process is to ensure that products are delivered from the point of origin to the final consumer via the most suitable route, with minimal time and cost. Properly planned routes contribute to reducing transportation costs, optimizing fuel consumption, and shortening delivery times. While traditional approaches to route selection were mainly based on experience and simple methods, modern logistics systems rely on mathematical models and optimization algorithms. In particular, methods such as the shortest path model, the traveling salesman problem, and vehicle routing techniques enable more efficient organization of logistics processes. In the modern era, the application of digital technologies has created new opportunities in this field. GPS systems, real-time traffic data, and artificial intelligence–based software allow routes to be adjusted dynamically. These technologies make logistics processes

more flexible and enable rapid adaptation to changing conditions. At the same time, transportation optimization is not only a technical issue but is also directly related to economic efficiency. Through this process, enterprises can use resources more effectively, reduce overall logistics costs, and improve the quality of customer service. However, challenges such as infrastructure limitations, lack of data, and limited technological capabilities still exist. Particularly in developing countries, these factors hinder the full optimization of logistics processes. Thus, transportation and route optimization, as one of the key elements of modern supply chain management, plays a significant role in enhancing the competitiveness of enterprises (Toth & Vigo, 2014, p. 220).

Conclusion and Recommendations. The conducted research shows that the operational and effective management of the supply chain plays a decisive role in ensuring enterprise competitiveness and sustainable development. In the modern business environment, demand volatility, global economic uncertainty, and the rapid development of digital technologies necessitate more flexible and optimized management of supply chains. The study indicates that logistics planning and demand forecasting are among the main factors determining supply chain efficiency. However, the presence of uncertainty creates significant challenges in the planning process. At the same time, problems such as the bullwhip effect lead to the amplification of demand fluctuations throughout the chain, negatively affecting proper inventory management.

Coordination problems in the supply chain have also been identified as one of the main factors reducing the effectiveness of logistics activities. Weak information exchange, insufficient interaction among participants, and the absence of integrated systems lead to inconsistencies in the decision-making process. Analyses conducted in the Azerbaijani logistics sector show that although certain progress has been achieved in infrastructure development, there is still a need for improvement in service quality, coordination, and digitalization. At the same time, transportation and route optimization play a crucial role in increasing the efficiency of the supply chain. The application of modern technologies enables more accurate planning of logistics processes and helps reduce costs. However, infrastructure limitations and the uneven development of technological capabilities create certain obstacles to the full optimization of these processes.

Based on the above-mentioned findings, the following recommendations are proposed:

- Information exchange among all participants in the supply chain should be strengthened, and real-time data sharing should be ensured.
- The implementation of integrated management systems such as ERP and SCM should be expanded within enterprises.
- The use of modern analytical methods and digital technologies in demand forecasting processes should be increased.
- To reduce the bullwhip effect, ordering policies should be optimized, and inventory levels should be calculated more accurately.
- The application of GPS, IoT, and other digital technologies in transportation and logistics processes should be expanded.
- Institutional measures should be implemented to improve service quality and enhance coordination levels in the Azerbaijani logistics sector.
- The digitalization of small and medium-sized enterprises in the field of logistics should be supported.

Thus, the operational and effective management of the supply chain is not limited only to the improvement of logistics processes but also directly influences the overall strategic

development of enterprises and the formation of competitive advantage. In this regard, the application of modern logistics approaches serves as one of the key conditions for the sustainable development of business structures in the future.

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İstehsalat təlimi və texniki baxımda artırılmış reallıq texnologiyalarının tətbiqi və effektivliyinin qiymətləndirilməsi

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Xülasə

Bu tədqiqatda artırılmış reallıq (AR) texnologiyalarının istehsalat təlimi və texniki baxım sahələrində tətbiqi və effektivliyi araşdırılmışdır. Müasir sənaye mühitində Sənaye 4.0 konsepsiyası çərçivəsində rəqəmsal texnologiyaların rolu artdıqca, ənənəvi təlim və texniki xidmət üsulları öz effektivliyini qismən itirir. Bu baxımdan, AR texnologiyası real mühitə rəqəmsal məlumatların inteqrasiyası vasitəsilə işçilərin təlim prosesini sadələşdirir, əməliyyatların dəqiqliyini artırır və səhv risklərini azaldır. Tədqiqat çərçivəsində kəmiyyət və keyfiyyət metodlarını birləşdirən qarışıq metodoloji yanaşmadan istifadə edilmişdir. Kəmiyyət analizində iş vaxtına qənaət, tapşırıqların yerinə yetirilmə sürəti və səhv göstəriciləri qiymətləndirilmiş, keyfiyyət analizində isə istifadəçilərin texnologiyaya münasibəti, məmnunluq səviyyəsi və öyrənmə təcrübəsi araşdırılmışdır. Əldə olunan nəticələr göstərir ki, AR texnologiyasının tətbiqi istehsalat proseslərində operativliyi artırır, texniki baxım işlərini daha effektiv edir və işçi performansına müsbət təsir göstərir. Eyni zamanda, araşdırma nəticəsində müəyyən edilmişdir ki, AR sistemlərinin tətbiqi zamanı texniki infrastrukturun çatışmazlığı, yüksək ilkin investisiya tələbi və istifadəçilərin uyğunlaşma problemləri kimi çətinliklər mövcuddur. Buna baxmayaraq, uzunmüddətli perspektivdə bu texnologiyanın tətbiqi müəssisələr üçün strateji üstünlük yaradır və rəqabət qabiliyyətini artırır.

Açar sözlər : Artırılmış reallıq (AR), istehsalat təlimi, texniki baxım, Sənaye 4.0, Digital Twin, kəmiyyət və keyfiyyət analizləri

Evaluation of the Application and Effectiveness of Augmented Reality Technologies in Industrial Training and Maintenance

Abstract

This study examines the application and effectiveness of Augmented Reality (AR) technologies in industrial training and maintenance. As the role of digital technologies continues to expand within the framework of the Industry 4.0 concept, traditional training and maintenance methods are gradually losing their effectiveness. In this context, AR technology enhances the real environment by integrating digital information, thereby simplifying training processes, increasing operational accuracy, and reducing the risk of errors. Within the scope of the research, a mixed methodological approach combining quantitative and qualitative methods was employed. The quantitative analysis evaluated indicators such as time savings, task completion speed, and error rates, while the qualitative analysis focused on user perceptions, satisfaction levels, and learning experiences. The findings indicate that the implementation of AR technology improves operational efficiency in industrial processes, enhances the effectiveness of maintenance activities, and positively impacts employee performance. At the same time, the study identifies several challenges associated with AR implementation, including insufficient technical infrastructure, high initial investment costs, and user adaptation issues. Nevertheless, in the long term, the adoption

of this technology provides strategic advantages for enterprises and strengthens their competitiveness.

Keywords : Augmented Reality (AR), industrial training, maintenance, Industry 4.0, Digital Twin, quantitative and qualitative analysis

Giriş

Müasir dövrdə sənaye sektorunda baş verən texnoloji transformasiya istehsalat proseslərinin təşkilinə, idarə olunmasına və işçi hazırlığına ciddi təsir göstərir. Sənaye 4.0 konsepsiyasının inkişafı ilə birlikdə rəqəmsal texnologiyalar, xüsusilə süni intellekt, Əşyaların İnterneti (IoT) və artırılmış reallıq (AR) kimi innovativ həllər istehsalat mühitində geniş tətbiq olunmağa başlamışdır. Bu texnologiyalar müəssisələrə daha çevik, səmərəli və dəqiq fəaliyyət göstərmək imkanı yaradır. Ənənəvi istehsalat təlimi və texniki baxım üsulları uzun müddət sənaye müəssisələrində əsas yanaşma kimi istifadə olunsa da, bu metodlar bir sıra məhdudiyyətlərə malikdir. Bu məhdudiyyətlərə uzun təlim müddəti, yüksək səhv ehtimalı, real vaxt dəstəyin olmaması və insan faktorundan asılılıq daxildir. Bu səbəbdən müasir sənaye mühitində daha interaktiv və effektiv texnologiyalara ehtiyac yaranmışdır.

Artırılmış reallıq (AR) texnologiyası real mühitə rəqəmsal məlumatların əlavə olunması vasitəsilə istifadəçilərə vizual və interaktiv təcrübə təqdim edir. Bu texnologiya istehsalat təlimində işçilərə addım-addım vizual göstərişlər verməyə, texniki baxım prosesində işə avadanlıqların vəziyyətini real vaxtda izləməyə imkan yaradır. Nəticədə, AR tətbiqləri iş proseslərini sadələşdirir, səhv risklərini azaldır və əməliyyatların ümumi səmərəliliyini artırır.

Bu tədqiqatın əsas məqsədi artırılmış reallıq texnologiyalarının istehsalat təlimi və texniki baxım sahələrində tətbiqinin effektivliyini qiymətləndirməkdir. Tədqiqat çərçivəsində AR texnologiyasının ənənəvi metodlarla müqayisədə üstünlükləri, işçi performansına təsiri və tətbiq zamanı qarşıya çıxan əsas problemlər araşdırılmışdır. Eyni zamanda, kəmiyyət və keyfiyyət analizlərini birləşdirən metodoloji yanaşma vasitəsilə əldə olunan nəticələrin daha obyektiv və etibarlı şəkildə qiymətləndirilməsi təmin edilmişdir.

Mövcud ədəbiyyatın icmalı. Artırılmış reallıq (Augmented Reality – AR) texnologiyası müasir dövrdə sürətlə inkişaf edən və müxtəlif sahələrdə tətbiq olunan innovativ həllərdən biridir. Bu texnologiyanın əsas mahiyyəti real mühitin üzərinə rəqəmsal elementlərin əlavə olunmasıdır ki, bu da istifadəçiyə həm real, həm də virtual məlumatları eyni anda qavramağa imkan verir. Elmi ədəbiyyatda qeyd olunur ki, AR texnologiyası ilk dəfə sənaye mühitində tətbiq olunmuş və zamanla daha geniş sahələrdə istifadə edilməyə başlanmışdır. AR texnologiyasının inkişafı onun texniki imkanlarının genişlənməsi ilə sıx bağlıdır. İlk dövrlərdə bu texnologiya əsasən iri və mürəkkəb avadanlıqlar vasitəsilə həyata keçirilirdi. Bu baxımdan, AR sahəsində mühüm mərhələlərdən biri ilk başa taxılan display sistemlərinin yaradılması olmuşdur.



Şəkil 1. “Damokl qılıncı” (Sword of Damocles)

Yuxarıdakı şəkildə göstərilən “Damokl qılıncı” sistemi artırılmış reallığın ilk nümunələrindən biri hesab olunur. Bu sistem istifadəçinin baş hərəkətlərinə uyğun olaraq vizual məlumatların təqdim edilməsini təmin edirdi. Qurğunun böyük və ağır olması onun geniş tətbiqinə mane olsa da, AR texnologiyasının inkişafı üçün mühüm əsas yaratmışdır. Sonrakı mərhələdə AR texnologiyası daha praktik və istifadəçi yönümlü cihazlara keçid etmişdir. Xüsusilə geyilə bilən texnologiyaların inkişafı AR-ın gündəlik həyatda və sənayedə tətbiq imkanlarını genişləndirmişdir.



Şəkil 2. Google Glass 2013

Google Glass kimi cihazlar AR texnologiyasını geniş istifadəçi kütləsinə təqdim edən ilk nümunələrdəndir. Bu cihazlar vasitəsilə istifadəçilər real mühit üzərində əlavə məlumatları görərək müxtəlif əməliyyatları daha rahat yerinə yetirə bilirlər. Bu cür texnologiyalar xüsusilə təlim və texniki xidmət sahələrində effektiv istifadə olunur. AR texnologiyasının inkişafında növbəti mühüm mərhələ daha inkişaf etmiş və sənaye yönümlü cihazların yaradılması olmuşdur. Bu baxımdan Microsoft tərəfindən hazırlanmış HoloLens cihazı xüsusi əhəmiyyət kəsb edir.



Şəkil 3. HoloLens

HoloLens cihazı artırılmış reallıq texnologiyasını daha interaktiv və funksional şəkildə təqdim edir. Bu cihaz istifadəçilərə 3D obyektlərlə real mühitdə qarşılıqlı əlaqə yaratmağa imkan verir. Xüsusilə istehsalat, təlim və texniki baxım sahələrində bu cür cihazlar iş proseslərinin optimallaşdırılmasına və səhvlərin azalmasına kömək edir. Artırılmış reallıq texnologiyası tez-tez virtual reallıq (VR) ilə müqayisə olunur. Lakin bu iki texnologiya arasında əsas fərq onların istifadəçi təcrübəsində özünü göstərir. VR istifadəçini tam virtual mühitə daxil etdiyi halda, AR real mühiti qoruyaraq onu rəqəmsal məlumatlarla zənginləşdirir. Bu xüsusiyyət AR-ı sənaye mühitində daha praktik və funksional edir. Müasir dövrdə AR texnologiyalarının inkişafı müxtəlif proqram platformaları ilə dəstəklənir. ARKit və ARCore kimi platformalar mobil cihazlarda AR tətbiqlərinin hazırlanmasını mümkün edir. Bundan əlavə, Unity və Vuforia kimi proqram mühitləri AR sistemlərinin inkişafında geniş istifadə olunur. Bu platformalar sensorlar və digər texnoloji komponentlərlə integrasiya olunaraq real vaxt məlumatlarının vizuallaşdırılmasını təmin edir. AR texnologiyasının tətbiqi Sənaye 4.0 konsepsiyası ilə sıx əlaqəlidir. Bu konsepsiya istehsalat proseslərinin rəqəmsallaşdırılması və avtomatlaşdırılmasını nəzərdə tutur. AR texnologiyası bu çərçivədə işçilərə real vaxt məlumat təqdim etməklə onların fəaliyyətini daha effektiv edir. Xüsusilə Rəqəmsal Əkiz (Digital Twin) texnologiyası ilə birlikdə AR sistemləri fiziki obyektlərin virtual modellərinin izlənməsinə və idarə olunmasına imkan yaradır. Nəticə etibarilə, mövcud elmi ədəbiyyat göstərir ki, artırılmış reallıq texnologiyası istehsalat təlimi və texniki baxım sahələrində yüksək potensiala malikdir. Bu texnologiya həm işçi performansını artırır, həm də əməliyyat proseslərini daha səmərəli və təhlükəsiz edir.

Sənaye 4.0 konsepsiyasında AR texnologiyalarının rolu və sənaye tətbiqləri. Müasir sənaye mühitində texnologiyanın sürətli inkişafı istehsalat proseslərinin strukturunu köklü şəkildə dəyişdirmişdir. Bu dəyişikliklər əsasən Sənaye 4.0 konsepsiyası ilə izah olunur. Sənaye 4.0 istehsalatın yalnız avtomatlaşdırılması ilə məhdudlaşmır, eyni zamanda məlumat əsaslı idarəetmə, real vaxt monitorinqi və müxtəlif sistemlərin integrasiyası kimi xüsusiyyətləri özündə birləşdirir. Bu yanaşma müəssisələrə daha çevik, adaptiv və effektiv fəaliyyət göstərmək imkanı yaradır. Sənaye 4.0 çərçivəsində tətbiq olunan əsas texnologiyalara Əşyaların İnterneti (IoT), böyük məlumat analitikası, süni intellekt, kiber-fiziki sistemlər (CPS) və bulud texnologiyaları daxildir. Bu texnologiyalar bir-biri ilə integrasiya olunaraq istehsalat proseslərinin optimallaşdırılmasına, risklərin azaldılmasına və qərar qəbul etmə prosesinin sürətləndirilməsinə imkan yaradır.

Artırılmış reallıq (AR) bu sistemlər arasında xüsusi yer tutur. AR texnologiyası fiziki mühitlə rəqəmsal məlumatların birləşdirilməsini təmin edərək operatorlara real vaxt rejimində vizual məlumat təqdim edir. Bu xüsusiyyət istehsalat təlimi, montaj və texniki baxım proseslərində AR-ı olduqca effektiv alətə çevirir. İşçilər avadanlıqlarla işləyərkən əlavə təlimatları birbaşa görərək daha az səhv edir və tapşırıqları daha sürətli yerinə yetirirlər. Sənaye 4.0 mühitində AR texnologiyası xüsusilə Rəqəmsal Əkiz (Digital Twin) konsepsiyası ilə birlikdə daha böyük əhəmiyyət kəsb edir. Rəqəmsal Əkiz fiziki obyektin virtual modelini yaradaraq onun real vaxt rejimində izlənməsinə və analiz edilməsinə imkan verir. AR texnologiyası bu modeli vizual şəkildə təqdim edərək istifadəçilərə daha aydın və interaktiv məlumat əldə etməyə şərait yaradır. Bu yanaşma istehsalat proseslərində nasazlıqların əvvəlcədən aşkar edilməsinə və qərarların daha dəqiq qəbul olunmasına kömək edir. İnkişaf etmiş ölkələrdə aparıcı sənaye şirkətləri AR və Sənaye 4.0 texnologiyalarını artıq geniş şəkildə tətbiq edirlər. Bu baxımdan Almaniya, Yaponiya və ABŞ kimi ölkələrdəki müəssisələr qabaqcıl nümunə kimi çıxış edir.

Siemens şirkəti Sənaye 4.0 texnologiyalarının tətbiqində lider mövqedədir. Şirkət ağıllı fabrik konsepsiyasını tətbiq edərək istehsalat proseslərini sensorlar və real vaxt monitorinq sistemləri vasitəsilə idarə edir. Siemens həmçinin Rəqəmsal Əkiz texnologiyasından istifadə edərək fiziki avadanlıqların virtual modellərini yaradır və onların fəaliyyətini əvvəlcədən simulyasiya edir.

Bu yanaşma istehsal xətalının azalmasına, enerji səmərəliliyinin artmasına və ümumi məhsuldarlığın yüksəlməsinə səbəb olur.

BMW şirkəti isə Sənaye 4.0 konsepsiyasını avtomobil istehsalında uğurla tətbiq edən müəssisələrdən biridir. BMW zavodlarında kollaborativ robotlar və insan operatorları birlikdə fəaliyyət göstərir. Bu əməkdaşlıq həm işçi təhlükəsizliyini artırır, həm də istehsalat proseslərinin sürətini yüksəldir. AR texnologiyası burada əsasən montaj və təlim proseslərində istifadə olunur. İşçilər AR vasitəsilə komponentlərin düzgün yerləşdirilməsini vizual şəkildə görür və bu da səhvlərin minimuma enməsinə gətirib çıxarır.

Bosch şirkəti də AR və digər rəqəmsal texnologiyaları istehsalat proseslərinə inteqrasiya edən qabaqcıl şirkətlərdəndir. Bosch ağıllı sensorlar və kiber-fiziki sistemlərdən istifadə edərək istehsalatın real vaxt monitorinqini həyata keçirir. AR texnologiyası isə texniki baxım və diaqnostika proseslərində tətbiq olunur. Bu yanaşma avadanlıqların nasazlıqlarını daha tez aşkar etməyə və texniki xidmət xərclərini azaltmağa imkan verir.

ABŞ-da fəaliyyət göstərən **Boeing** şirkəti isə AR və Rəqəmsal Əkiz texnologiyalarını aviasiya sənayesində geniş tətbiq edir. Şirkət istehsalat proseslərində virtual simulyasiya və optimallaşdırma alətlərindən istifadə edərək məhsul keyfiyyətini artırır və riskləri minimuma endirir. AR texnologiyası texniki xidmət və montaj proseslərində işçilərə real vaxt vizual dəstək təqdim edərək onların işini asanlaşdırır. Bu şirkətlərin təcrübəsi göstərir ki, AR texnologiyasının tətbiqi yalnız istehsalat proseslərini sürətləndirmir, eyni zamanda işçi təhlükəsizliyini artırır, səhv risklərini azaldır və ümumi əməliyyat səmərəliliyini yüksəldir. Bununla belə, AR sistemlərinin tətbiqi müəyyən çətinliklərlə də müşayiət olunur. Bu çətinliklərə yüksək ilkin investisiya xərcləri, texniki infrastrukturun yetərsizliyi və işçilərin yeni texnologiyaya uyğunlaşma problemləri daxildir. Ümumilikdə, aparılan təhlil göstərir ki, artırılmış reallıq texnologiyası Sənaye 4.0 konsepsiyasının ayrılmaz hissəsidir və istehsalat təlimi, montaj və texniki baxım sahələrində geniş tətbiq potensialına malikdir. Gələcəkdə bu texnologiyanın daha da inkişaf edəcəyi və sənaye müəssisələrində daha geniş istifadə olunacağı gözlənilir.

Metodologiya. Bu tədqiqatın metodoloji əsasını artırılmış reallıq (AR) texnologiyalarının istehsalat təlimi və texniki baxım sahələrində effektivliyinin obyektiv və hərtərəfli qiymətləndirilməsi təşkil edir. Mövzunun həm texniki, həm də insan amilləri ilə sıx bağlı olması səbəbindən yalnız bir metoddan istifadə etmək kifayət etmir. Buna görə də tədqiqatda qarışıq metodoloji yanaşma (mixed-method) seçilmişdir. Bu yanaşma kəmiyyət və keyfiyyət metodlarının birgə tətbiqini nəzərdə tutur və nəticələrin daha dolğun və etibarlı olmasına imkan yaradır. Tədqiqatın əsas ideyası ondan ibarətdir ki, AR texnologiyasının effektivliyi yalnız ölçülə bilən göstəricilərlə deyil, eyni zamanda istifadəçi təcrübəsi və texnologiyanın qəbul səviyyəsi ilə də müəyyən edilməlidir. Bu səbəbdən metodologiya iki əsas istiqamət üzrə qurulmuşdur: kəmiyyət təhlili və keyfiyyət təhlili.

Kəmiyyət təhlili çərçivəsində AR texnologiyasının tətbiqindən əvvəl və sonra əldə olunan nəticələr müqayisə edilmişdir. Bu mərhələdə əsas məqsəd AR texnologiyasının istehsalat proseslərinə təsirini konkret göstəricilər vasitəsilə ölçmək olmuşdur. Təhlil zamanı tapşırıqların yerinə yetirilmə müddəti, səhv göstəricilərinin səviyyəsi, işin icra sürəti və ümumi məhsuldarlıq kimi indikatorlar əsas götürülmüşdür. Məsələn, AR tətbiq olunmadan əvvəl müəyyən texniki əməliyyatın yerinə yetirilməsinə sərf olunan vaxt ilə AR istifadə edildikdən sonra əldə olunan nəticələr müqayisə edilmişdir. Eyni zamanda, səhv sayında baş verən dəyişikliklər də analiz edilmişdir. Bu cür müqayisə AR texnologiyasının praktiki faydasını konkret rəqəmlərlə göstərməyə imkan verir.

Keyfiyyət təhlili isə tədqiqatın insan yönümlü tərəfini əhatə edir. Bu mərhələdə istifadəçilərin AR texnologiyasına münasibəti, onun istifadəsinin rahatlığı, öyrənmə prosesinə təsiri və ümumi məmnunluq səviyyəsi araşdırılmışdır. Keyfiyyət məlumatları əsasən sorğular və yarı-strukturlaşdırılmış intervyular vasitəsilə toplanmışdır. Sorğular vasitəsilə istifadəçilərin texnologiya

haqqında ümumi fikirləri, üstün və zəif tərəflər barədə düşüncələri öyrənilmişdir. Intervyular isə daha dərin məlumat əldə etməyə imkan verərək istifadəçilərin real təcrübələrini və qarşılaşdıqları problemləri daha geniş şəkildə analiz etməyə şərait yaratmışdır. Tədqiqatın həyata keçirilməsi zamanı bir neçə metod paralel şəkildə tətbiq olunmuşdur. İlk növbədə müqayisəli analiz metodu istifadə edilmişdir. Bu metod vasitəsilə ənənəvi təlim və texniki baxım üsulları ilə AR əsaslı yanaşma müqayisə olunmuşdur. Müqayisə zamanı həm vaxt, həm də keyfiyyət göstəriciləri nəzərə alınmışdır. Nəticədə AR texnologiyasının hansı aspektlərdə üstünlük təşkil etdiyi müəyyən edilmişdir.

Digər mühüm metod nümunəvi sınaq (pilot test) olmuşdur. Bu metod çərçivəsində AR texnologiyası real və ya simulyasiya olunmuş istehsalat mühitində tətbiq edilmiş və onun nəticələri müşahidə olunmuşdur. Pilot testlər AR sistemlərinin praktik tətbiq imkanlarını yoxlamağa və potensial problemləri əvvəlcədən müəyyən etməyə imkan verir. Bu yanaşma xüsusilə texnologiyanın real şəraitdə necə işlədiyini anlamaq baxımından əhəmiyyətlidir.

Sorğu və intervyu metodları isə keyfiyyət məlumatlarının toplanmasında əsas rol oynamışdır. Sorğular strukturlaşdırılmış formada hazırlanaraq istifadəçilərə təqdim edilmiş, onların cavabları statistik olaraq ümumiləşdirilmişdir. Intervyular isə daha çevik formada aparılmış və istifadəçilərin fərdi təcrübələri, texnologiyaya uyğunlaşma səviyyəsi və qarşılaşdıqları çətinliklər daha dərinlənən araşdırılmışdır. Seçilmiş metodoloji yanaşmanın əsas üstünlüyü ondan ibarətdir ki, bu yanaşma həm obyektiv (rəqəmsal) nəticələri, həm də subyektiv (insan təcrübəsi) faktorları bir arada nəzərə almağa imkan verir. Bu isə AR texnologiyasının real təsirinin daha dəqiq qiymətləndirilməsini təmin edir. Tədqiqat nəticələrinin etibarlılığını artırmaq məqsədilə müxtəlif mənbələrdən əldə olunan məlumatlar müqayisə edilmiş və analiz olunmuşdur. Nəticə etibarilə onu qeyd edə bilərik ki, tətbiq olunan metodologiya artırılmış reallıq texnologiyalarının istehsalat təlimi və texniki baxım sahələrində effektivliyini kompleks şəkildə araşdırmağa imkan vermişdir. Bu yanaşma yalnız texnologiyanın texniki üstünlüklərini deyil, eyni zamanda onun praktik tətbiq imkanlarını və istifadəçi tərəfindən qəbul səviyyəsini də üzə çıxarmışdır.

Nəticə və təhlil. Bu tədqiqat çərçivəsində artırılmış reallıq (AR) texnologiyalarının istehsalat təlimi və texniki baxım sahələrində tətbiqinin effektivliyi həm kəmiyyət, həm də keyfiyyət göstəriciləri əsasında qiymətləndirilmişdir. Əldə olunan nəticələr göstərir ki, AR texnologiyası ənənəvi metodlarla müqayisədə daha yüksək səmərəlilik və operativlik təmin edir. Kəmiyyət təhlili nəticəsində müəyyən edilmişdir ki, AR texnologiyasının tətbiqi tapşırıqların yerinə yetirilmə müddətinin azalmasına səbəb olmuşdur. İşçilər real vaxt rejimində təqdim olunan vizual təlimatlar vasitəsilə əməliyyatları daha sürətli və ardıcıl şəkildə icra edə bilmişlər. Eyni zamanda, səhv göstəricilərində əhəmiyyətli azalma müşahidə olunmuşdur. Bu, əsasən AR sistemlərinin istifadəçiyə addım-addım yönləndirmə təqdim etməsi və kritik mərhələlərdə xəbərdarlıq funksiyalarının mövcud olması ilə izah olunur. Məhsuldarlıq göstəricilərində də artım qeydə alınmışdır ki, bu da texnologiyanın ümumi əməliyyat səmərəliliyinə müsbət təsir etdiyini göstərir.

Keyfiyyət təhlili isə istifadəçilərin AR texnologiyasına münasibətini və praktiki təcrübəsini əks etdirir. Sorğu və intervyuların nəticələri göstərir ki, istifadəçilərin əksəriyyəti AR texnologiyasını müsbət qiymətləndirir və onun təlim prosesini daha aydın və anlaşıqlı etdiyini bildirir. Xüsusilə vizual təqdimatın olması öyrənmə prosesini sürətləndirir və məlumatların daha yaxşı mənimsənilməsinə şərait yaradır. İstifadə rahatlığı və interaktiv mühit işçilərin texnologiyaya marağını artırmış və onların iş prosesinə adaptasiyasını asanlaşdırmışdır. Bununla yanaşı, təhlil nəticəsində müəyyən çətinliklər də aşkar olunmuşdur. Bəzi hallarda istifadəçilər ilkin mərhələdə yeni texnologiyaya uyğunlaşmaqda çətinlik çəkmişlər. Bundan əlavə, texniki infrastrukturun kifayət qədər inkişaf etməməsi və AR sistemlərinin tətbiqi üçün tələb olunan yüksək ilkin investisiya xərcləri də məhdudlaşdırıcı amillər kimi çıxış edir. Bu problemlər qısa müddətdə tətbiqi çətinləşdirsə də, uzunmüddətli perspektivdə əldə olunan faydalar bu çətinlikləri kompensasiya edir. Əldə olunan nəticələr göstərir ki, AR texnologiyası istehsalat mühitində yalnız təlim vasitəsi

kimi deyil, həm də əməliyyatların optimallaşdırılması üçün effektiv alət kimi çıxış edir. Texnologiyanın tətbiqi işçi performansının yüksəlməsinə, səhvlərin azalmasına və iş proseslərinin daha sistemli şəkildə həyata keçirilməsinə imkan yaradır. Bu işə müəssisələrin ümumi rəqabət qabiliyyətinin artmasına birbaşa təsir göstərir.

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РУДНИЧНЫЕ ГЭС-1 И ГЭС-2 НА ТЕРРИТОРИИ АЛМАТИНСКОЙ ОБЛАСТИ

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Рудничные ГЭС-1 и ГЭС-2 будут работать на территории Алматинской области, которая входит в Южную зону Единой Энергетической Системы (ЕЭС) Казахстана. Южная зона, кроме Алматинской, включает Южно-Казахстанскую, Жамбылскую и Кызылординскую области и связана электрическими сетями с Северной зоной и ОЭС Центральной Азии (Кыргызстаном и Узбекистаном) по электрическим сетям напряжением 220÷500 кВт.

Для надежного электроснабжения и покрытия дефицита электроэнергии южных регионов Казахстана в сентябре 2009 года введена вторая линия электропередачи 500 кВ транзита Север-Юг Казахстана.

Таблица 1 - Электропотребление и максимальная нагрузка по Южной зоне и Алматинской области

Наименование	2000	2005	2006	2007	2008	2009	2010	2011	2024
Южная зона									
Электропотребление, млрд. кВт.ч	9,3	13,7	14,3	15,5	16,4	15	16,2	17,97	19
Темп прироста, %		47,3	4,4	8,4	5,8	-8,5	8	10,9	5,7
Максимум электрической нагрузки (совм),МВт	1815	2596	2643	2805	2887	2658	2938	3231	3325
Алматинская область									
Электропотребление, млрд. кВт.ч	4,83	7,09	7,7	8,3	8,6	8,44	8,8	9,34	9,85
Темп прироста, %		46,8	8,6	7,8	3,6	-1,9	4,3	6,1	5,5
Максимум электрической нагрузки (совм),МВт	955	1404	1397	1555	1589	1483	1576	1749	1844

Реализация проекта с вводом Рудничных ГЭС-1 и ГЭС-2 в 2020 году позволили уменьшить дефицит энергии в Алматинской области на 191 ГВтч., повысит качество электроэнергии, снизит выбросы парниковых газов.

Таблица 2 - Техничко-экономические показатели Рудничных ГЭС-1 и ГЭС-2.

№№	Наименование показателей	Един. изм.	ГЭС-1	ГЭС-2
1	Установленная мощность ГЭС	МВт	19,0	23,0
2	Гарантированная мощность	МВт	2,35	2,76
3	Среднегогодовая выработка электроэнергии	ГВтч	86,86	104,28
4	Расчетный напор ГЭС	М	49,5	61
5	Расчетный расход ГЭС	м³/с	44	44
6	Число агрегатов	шт.	3	3

В Алматинской области с 2000 по 2008 год отмечен рост электропотребления на 78%. В 2009 году снижение электропотребления в Алматинской области произошло в меньшей степени, чем по Югу, электропотребление уменьшилось на 1,9% по сравнению с 2008г. Дальнейшее восстановление экономики показало прирост электропотребления в 2012г. на 14,5% по сравнению с 2008г.

С 2000 года по 2008 год максимальная нагрузка по Южной зоне увеличилась на 59%. В 2009г. произошло снижение максимальной нагрузки на 7.9% по сравнению с предыдущим годом, в 2010г. - увеличение на 10.5% к 2009г., в 2011г. – увеличение на 10% к 2010 году, в 2024г. – прирост составил 2.9%.

Максимальная нагрузка по Алматинской области с 2000 года по 2008 год увеличилась на 66%. В 2009 году максимум нагрузки уменьшился на 6.7% по отношению к 2008г., в 2010 году увеличился на 6.3% к 2009г., в 2024г. увеличился на 11% к 2010г., в 2024г. рост составил 5.4% к 2018г.

Развитие электропотребления Талдыкорганского региона - непосредственной зоны влияния ГЭС-1 за последние три года представлено в таблице 3.

Таблица 3 - Развитие электропотребления Талдыкорганского региона

Наименование	2010	2018	2024
Электропотребление, млрд. кВт.ч	806,5	838,6	920,6
Темп прироста, %		4	9,8
Максимум электрической нагрузки (совм.),МВт	146	167	198

В последние годы наблюдается стабильный рост электропотребления и максимальной нагрузки в Талдыкорганском регионе.

В структуре электропотребления преобладающую долю составляет промышленность и коммунально-бытовое потребление. Доля промышленности в структуре Южного Казахстана снизилась по сравнению с 1990 годом в связи со снижением электропотребления наиболее крупного потребителя – предприятий ТОО «Казфосфат».

Структура электропотребления Южного Казахстана и Алматинской области представлена в таблице 4.

Таблица 4 - Структура электропотребления Южного Казахстана и Алматинской области

Наименование потребителя	Южная зона	Алматинская область
Промышленность, %	28,5	21
Коммунально - бытовое, %	39,1	43
Строительство, %	2,1	2,1
Транспорт, %	6,3	5,7
Сельское хозяйство, %	3,4	4,6
Собственные нужды электростанций, %	7,3	9,8
Потери в сетях, %	13,3	13,8
Всего, %	100	100

В таблице 5 приведены установленная и располагаемая мощности электростанций Южной зоны и Алматинской области по состоянию на 01.01.2010г. и 01.01.2024г.

Таблица 5 - Основные показатели по действующим электростанциям Южной зоны и Алматинской области, МВт

Наименование	На 01.01.2010г.		На 01.01.2024г.	
	Установленная мощность	Располагаемая мощность	Установленная мощность	Располагаемая мощность
Южная зона				
Всего:	2 987	2 249	3 007,10	2 320
в том числе: ТЭС	2 399	1 967	2 416	2 037
ГТЭС	46	46	46	46
ГЭС	542	236	545,1	237
Алматинская область				
Всего:	1 294	774	1 297,10	853
в том числе: ТЭС	852	628	852	696
ГЭС	442	146	445,1	157

Как видно из приведенных данных, ТЭС по установленной мощности в Южной зоне составляют 80,3%, по располагаемой – 87,8%. Доля ГЭС по установленной мощности составляет 18,1%, по располагаемой – 10,2%. Доля ГТЭС по установленной мощности 1,6%, по располагаемой – 2%.

На 01.01.2011г. в Алматинской области ТЭС по установленной мощности составляли 65,7%, по располагаемой – 81,6%. Доля ГЭС по установленной мощности составляла 34,3%, по располагаемой – 18,4%.

При общей установленной мощности электростанций Юга Казахстана превышающей собственный максимум электрических нагрузок, баланс по мощности за последние годы складывается с дефицитом.

Как следует из приведенных данных, собственные электростанции Алматинской области осуществляли частичное покрытие электрической нагрузки. Баланс мощности складывался с нарастающим дефицитом, который покрывался за счет получения мощности по сетям 220÷500 кВ из Северного Казахстана и стран Центральной Азии. В таблице 6 приведен баланс электроэнергии по Алматинской области за отчетные 2000÷2012гг.

Таблица 6 - Баланс электроэнергии по Алматинской области, млрд.кВтч

Наименование	2000	2005	2006	2007	2008	2009	2010	2018	2024
Потребность									
Электропотребление	4,83	7,09	7,7	8,3	8,6	8,4	8,76	9,34	9,85
Покрытие									
Выработка э/электроэнергии	4,4	4,79	4,8	4,6	5,1	4,8	5,77	5,78	6,15
Дефицит энергии	0,43	2,3	2,9	3,7	3,5	3,6	2,99	3,56	3,7
Получение электроэнергии по транзиту Север-Юг и ЦА	0,43	2,3	2,9	3,7	3,5	3,6	2,99	3,56	3,7

Из таблицы 6 видно, что баланс за весь период сводился с дефицитом. Выработка на собственных электростанциях нестабильна за счет морально и физически устаревших тепловых мощностей. Существующее оборудование электростанций достигло предельных сроков наработки, что требует его техперевооружения и реконструкции.

Увеличение мощности и выработки электроэнергии в 2012 году по Южной зоне и Алматинской области произошло за счет ввода Мойнакской ГЭС установленной мощностью 300 МВт.

Баланс мощности и электроэнергии по Талдыкорганскому региону за 2010÷2024 гг. приведен в таблице 7.

Таблица 7 - Баланс мощности и электроэнергии по Талдыкорганскому региону

Наименование	2010	2018	2024
Потребность			
Максимум нагрузки, МВт	146	167	198
Покрытие			
Участие электростанций, МВт	33	41	36
Дефицит мощности, МВт	113	126	162
Электропотребление, млн. кВтч	806,5	838,6	920,6
Покрытие			
Выработка эл. энергии, млн. кВтч	307,4	320	315,5
Дефицит энергии, млн.кВтч	499,1	518,6	605,1

Покрытие баланса мощности собственными электростанциями в Талдыкорганском регионе снизилось за последние годы с 27% до 18%.

Основным производителем электроэнергии Алматинской области является АО «АлЭС», на долю которого приходится 94.3% всей производимой электро – энергии региона. В составе АО «АлЭС» находятся ТЭЦ-1, ТЭЦ-2, ТЭЦ-3 в городе Алматы, Капшагайская ГЭС в Алматинской области и каскад малых ГЭС в г. Алматы. В Талдыкорганском регионе действует Текелийская ТЭЦ и ряд малых ГЭС.

С вводом второй линии электропередачи Север-Юг в 2009г. электро -снабжение южного региона улучшилось. Пропускная способность линии составляет 1 350 МВт. Но проблема с покрытием пиковой части суточного графика нагрузки остается и после ввода

второй линии электропередачи. Мойнакская ГЭС, введенная в 2011г, позволит лишь частично решить проблему дефицита маневренной мощности Юга Казахстана.

Прогноз электропотребления и электрических нагрузок до 2030г.

Прогноз электропотребления и электрических нагрузок до 2030 года был выполнен в 2017 году в работе института АО КазНИПИИТЭС «Энергия» - «Технико-экономические исследования вариантов покрытия перспективных электронагрузок...», (далее «ТЭИ...»). В 2011г. в работах «Энергии» были уточнены данные по перспективному электропотреблению и максимальным нагрузкам на 2015г., что отражено в представленном ниже прогнозе.

В таблицах 8 и 9 приведены электропотребление и электрические нагрузки на перспективу до 2030г. по Южной зоне Казахстана и Алматинской области по минимальному варианту развития отрасли.

Таблица 8 - Электропотребление и электрические нагрузки по Южной зоне Казахстана на период до 2030г.

Наименование	2012г.	2015г.	2020г.	2030г.
	отчет	мин.	мин.	мин.
Электропотребление, млрд.кВтч	19	20,7	25,5	31,9
Максимум нагрузки (совм), МВт	3 325	3 800	4 620	6 040

Таблица 9 - Электропотребление и электрические нагрузки по Алматинской области на период до 2030г.

Наименование	2012г.	2015г.	2020г.	2030г.
	отчет	мин.	мин.	мин.
Электропотребление, млрд.кВтч	9,85	11,8	14,8	20
Максимум нагрузки (совм), МВт	1 844	2100	2 620	3 580

Географическое местонахождение проекта

Место строительства Рудничных ГЭС расположено на реке Коксу, в Кербулакском районе Алматинской области Республики Казахстан. Река Коксу берет свое начало в горах Джунгарского Алатау и является основным притоком реки Каратал. Диапазон географических координат: восточная долгота 76°7.4'-79°51.5', северная широта 44°2.7'-45°8.8'.

Площадка строительства находится на расстоянии 80км от города Талдыкорган, вблизи поселка Рудничный. Проектом предусматривается строительство ГЭС-1 и ГЭС-2. Расход воды, подаваемой на ГЭС составляет 44м³/с, установленная мощность ГЭС-1 –19МВт, установленная мощность ГЭС-2–23МВт. Суммарная установленная мощность обеих ГЭС – 42МВт. Средне-многолетняя выработка электроэнергии ГЭС-1 - 86.86 млн.кВтч., ГЭС-2-104.28 млн. кВтч. Суммарная выработка электроэнергии - 191.14 млн. квт.ч.

Район строительства Рудничных ГЭС расположен в бассейне реки Коксу, климат района умеренно континентальный. Лето относительно влажное и мягкое, со значительным количеством осадков, преобладают небольшие морозы, температура быстро повышается весной и снижается осенью.

В целом на территории бассейна с запада на восток: температура постепенно снижается, количество осадков увеличивается, объем испарения уменьшается.

Многолетние данные, фактически измеренные на метеорологической станции Талдыкорган, показывают:

Температура воздуха: среднемноголетняя температура воздуха 7.7°C, средне-многолетняя температура воздуха самого холодного месяца (январь) -9.6°C, средне-

многолетняя температура воздуха самого жаркого месяца (июль) (Т) 23.6°C, минимальная температура воздуха -42°C, максимальная температура воздуха +44°C.

Осадки: среднемноголетнее количество осадков (Р) 394мм, распределение их не равномерно в течение года, наибольшее количество осадков (Р) приходится на апрель-май и октябрь-ноябрь, а летом (июнь-август) количество осадков небольшое. Максимальное суточное количество осадков составляет 45мм. Количество осадков в горах больше количества осадков на равнинах, по мере увеличения высоты годовое количество осадков колеблется в диапазоне 179-800мм. Ветер: средне -многолетняя скорость ветра 2,1м/с, максимальная скорость ветра 29 м/с. Снежный покров: максимальная толщина снежного покрова 16 см. Максимальная глубина промерзания составляет 80см.

Безморозный период: средняя многолетняя продолжительность безморозного периода составляет 178 дней.

Сток

Река Коксу берет свое начало в ледниках гор и вечных снегах Джунгарского Алатау. Питание реки Коксу смешанное: таяние ледников, снега, сток от атмосферных осадков, а также подпитка грунтовыми водами.

По статистическим данным гидропоста Коксу: средне-многолетний расход 38.48м³/сек., средний объём стока 12,14×108м³. (1,214млрд.м³/год)

Внизу в таблице 10, показаны внутригодовое распределение стока течений в различной обеспеченности в створе водозабора Рудничной ГЭС-1 в течение года.

Паводок

Река Коксу, образуется от слияния двух рек Карабулак и Казан, берущих свое начало в горах Джунгарского Алатау, покрытых вечными снегами. Половодье на реке Коксу длится в течении 4 месяцев: (май, июнь, июль и август)

Рудничные ГЭС-1 и ГЭС-2 деривационного типа, с подводящими каналами без регулирования стока.

Для Рудничных ГЭС ранее не составлялись проекты строительства водозаборного узлов и водохранилищ. Объем паводковых вод, фактически измеренный на гидропосту Коксу, даёт представление о естественном состоянии стока в т.ч. половодья, и поэтому допускается применения данных о паводковых расходах для получения расчётных максимальных расходов.

Таблица 10 - Максимальные расходы в створе водозаборного узла

Наименование	Расчетная обеспеченность стока (%)						
	0,5	1	2	3	5	10	20
Расход (м ³ /с)	526	440	396	364	338	292	244

Во время выполнения работ в сезон дождей, паводок в течение года (один раз в 5 лет и один раз в 10 лет) может быть прямо получен из графика зависимости пикового паводка от частоты

Таблица 11 - Строительный период

Строительный период	Единица измерения	Обеспеченность стока	
		20%	10%
В течение года	м ³ /с	247	293
Август-апрель	м ³ /с	100	120

Задача проекта

Рудничные ГЭС деривационного типа представляют собой каскад из двух ГЭС, использующих в гидроэнергетических целях средний участок реки Коксу. После завершения строительства, ГЭС предназначены для передачи электроэнергии в энергосети юга Казахстана.

Необходимость строительства проекта

Место расположения Рудничных ГЭС выбрано с учетом ближайших потребителей электроэнергии (г. Талдыкорган, г. Текели и т.д.) и к нему ведут имеющиеся коммуникации (дороги ВЛ и ЛС), что будет способствовать их скорейшему строительству. Строительство Рудничных ГЭС играет важную роль для экономического развития Алматинской области, особенно города Талдыкорган, что потребует улучшения строительства электросетей, а также соответствует требованиям объективных законов рынка электрической энергии.

Экономика Республики Казахстана развивается быстрыми темпами, по мере развития экономики нередко проявляются недостаток капиталовложений в строительство инфраструктуры. Освоение минеральных ресурсов за последние несколько лет и быстрое развитие отрасли по выплавке металлов увеличивается потребность в электроэнергии, а недостаток электроэнергии ограничивает экономическое развитие.

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AZƏRBAYCAN TƏHSİL SİSTEMİNDƏ DÖVLƏT İNFORMASIYA TƏHLÜKƏSİZLİYİNİN TƏŞKİLİ VƏ TEXNOLOJİ PROBLEMLƏRİ

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XÜLASƏ

Rəqəmsal transformasiya təhsil mühiti üçün geniş imkanlar yaratsa da, məlumatların məxfiliyi və bütövlüyünün pozulması riski də artır. Məqalədə Azərbaycanın təhsil sistemində dövlət informasiya təhlükəsizliyinin təşkili araşdırılır və bu sahədəki texnoloji problemlər təhlil olunur. Araşdırma mövcud normativ bazaya, e-təhsilin inkişaf meyllərinə və beynəlxalq təcrübəyə əsaslanır. Azərbaycanın milli strategiyaları İKT-nin təhsildə tətbiqini prioritet kimi müəyyən etsə də, təhsil müəssisələrinin informasiya resurslarını qorumaq üçün müstəqil təhlükəsizlik sistemləri və səlahiyyət bölgüsü çatışmazlıqları qalmaqdadır. Məlumat bazalarının genişlənməsi kibertəhdidlərin hədəfi olur; tələbə və əməkdaşların fərdi məlumatlarının qanunsuz ələ keçirilməsi riski vardır. Təhsil sektorunda informasiya təhlükəsizliyi fənninin məcburi tədrisi və mütəxəssislərin hazırlanması, normativ-hüquqi bazanın gücləndirilməsi və universitetlərin risk idarəetmə strukturlarının formalaşdırılması təklif olunur. Məqalə dövlət qurumlarının və təhsil müəssisələrinin rolunu qiymətləndirir və kibermühitdə səmərəli müdafiə üçün tədbirlər paketi irəli sürür.

Açar sözlər: *informasiya təhlükəsizliyi, təhsil sistemi, kiberhücumlar, məlumatların qorunması, normativ baza, risklərin idarə edilməsi, mütəxəssis hazırlığı*

ОРГАНИЗАЦИЯ ГОСУДАРСТВЕННОЙ ИНФОРМАЦИОННОЙ БЕЗОПАСНОСТИ И ТЕХНОЛОГИЧЕСКИЕ ПРОБЛЕМЫ В СИСТЕМЕ ОБРАЗОВАНИЯ АЗЕРБАЙДЖАНА.

РЕЗЮМЕ

Цифровая трансформация создает для образовательной среды новые возможности, но одновременно повышает риск нарушения конфиденциальности и целостности данных. В статье исследуется организация государственной информационной безопасности в образовательной системе Азербайджана и анализируются технологические проблемы в этой сфере. Исследование опирается на существующую нормативную базу, тенденции развития электронного образования и международный опыт. Национальные стратегии Азербайджана определяют внедрение ИКТ в образование как приоритет, однако в образовательных учреждениях сохраняются недостатки в создании автономных систем безопасности и распределении ответственности. Расширение баз данных делает их мишенью киберугроз; существует риск незаконного получения персональных данных студентов и сотрудников. Предлагается обязательное преподавание дисциплины «Информационная безопасность» в учебных заведениях и подготовка специалистов, усиление нормативно-правовой базы и создание структур управления рисками. Работа оценивает роль государственных органов и образовательных учреждений и выдвигает пакет мер для эффективной защиты в киберсреде.

Ключевые слова: *информационная безопасность, образовательная система, кибератаки, защита данных, нормативная база, управление рисками, подготовка специалистов*

ORGANIZATION OF STATE INFORMATION SECURITY AND TECHNOLOGICAL PROBLEMS IN AZERBAIJAN'S EDUCATION SYSTEM SUMMARY

Digital transformation provides new opportunities for education but also increases the risk of breaches of confidentiality and integrity. This article examines how state information security is organized in Azerbaijan's education system and analyzes the technological challenges facing this field. The study draws on the existing regulatory framework, e-education development trends, and international experience. Although Azerbaijan's national strategies prioritize the application of ICT in education, educational institutions still lack autonomous security systems and clear responsibility allocation. The expansion of educational databases makes them targets for cyber-threats; there is a risk of unauthorized acquisition of students' and staff's personal data. The article proposes compulsory teaching of an "information security" course and specialist training, strengthening the legal framework, and forming risk-management structures in universities. It evaluates the roles of state bodies and educational institutions and offers a set of measures for effective defence in cyberspace.

Keywords: *information security, education system, cyberattacks, data protection, regulatory framework, risk management, specialist training*

GİRİŞ

Mövzunun aktuallığı və məqsədi: İnformasiya-kommunikasiya texnologiyalarının (İKT) sürətli inkişafı təhsil sistemində bütün prosesləri kəskin dəyişdirir. Rəqəmsal resurslar tədrisin effektivliyini artırsa da, elektron sənəd dövriyyəsi, onlayn dərs platformaları və təhsil məlumat bazalarının genişlənməsi yeni kibertəhlükələr yaradır. Təhsil müəssisələri artıq yalnız akademik mərkəzlər deyil, həm də böyük həcmdə fərdi, maliyyə və inzibati məlumatların saxlandığı strateji obyektlərdir. Bu şəraitdə informasiya təhlükəsizliyi siyasətinin formalaşdırılması dövlət üçün vacibdir. Məqalənin məqsədi Azərbaycan təhsil sistemində informasiya təhlükəsizliyinin təşkilini və texnoloji problemlərini elmi baxımdan təhlil etmək, mövcud boşluqları müəyyənləşdirmək və onların aradan qaldırılması üçün tövsiyələr verməkdir.

Mövzunun tədqiqat obyekti və predmeti: Tədqiqatın obyekti Azərbaycanın təhsil sistemində informasiya təhlükəsizliyidir; predmeti isə bu sahədə dövlətin və təhsil müəssisələrinin həyata keçirdiyi idarəetmə mexanizmləri, normativ baza və texnoloji həllərdir. İnformasiya təhlükəsizliyinin idarəedilməsi üzrə tədqiqatlar nisbətən yeni olsa da, problem dinamikdir və mütəmadi yenilənməni tələb edir. Bu səbəbdən, araşdırma həm mövcud təcrübəni, həm də yeni metodoloji yanaşmaları nəzərdən keçirir.

İnformasiya təhlükəsizliyinin mahiyyəti və əhəmiyyəti: İnformasiya təhlükəsizliyi informasiya ehtiyatlarının məxfilik, bütövlük və əlçatanlığını təmin edən tədbirlər kompleksidir. İnformasiya təhlükəsizliyi dərsləri bu sahənin əsas anlayışlarını və təhdidlərini izah edir, təhlükəsizlik siyasəti və kriptografik üsullar kimi alətləri təqdim edir. Cəmiyyətin və dövlətin dayanıqlığı informasiyanın qorunmasına bilavasitə bağlıdır: şəxsi məlumatların yayılması və saxtalaşdırılması, təhsil prosesinin pozulması, elmi araşdırmaların oğurlanması kimi hallar həm fərdlərin, həm də dövlətin maraqlarına zərər vurur. Buna görə də informasiya təhlükəsizliyi məsələləri yalnız texniki deyil, həm də hüquqi, təşkilati və mədəni aspektləri əhatə edir.

Təhsil sistemində informasiya təhlükəsizliyinin qorunmasının vacibliyi: Azərbaycanda təhsilin informasiyalaşdırılması üzrə dövlət proqramları bir neçə onillikdir həyata keçirilir. 2003-2012-ci illəri əhatə edən milli strategiya və 2008-2012-ci illər üçün təhsil sisteminin informasiyalaşdırılması proqramı təhsil sahəsində İKT tətbiqinin prioritet olduğunu vurğulayır. Bu proqramların çərçivəsində "Xalq Kompüter" kimi layihələr icra olunmuş və tədrisin elektron formatda təşkili genişlənməmişdir. Lakin rəqəmsallaşmanın dərinləşməsi ilə yanaşı, universitetlərin

böyük və strateji məlumat bankına çevrilməsi onları kibercinayətkarların hədəfinə çevirir. Təhsildə elektron xidmətlərin genişlənməsi fonunda məlumatların məxfiliyinin və bütövlüyünün qorunması mütləqdir.

Dövlət siyasəti və mövcud normativ-hüquqi baza: Azərbaycan dövləti informasiya təhlükəsizliyini milli təhlükəsizlik siyasətinin mühüm tərkib hissəsi kimi qəbul etmişdir. 2012-ci il 26 sentyabr tarixli Prezident Fərmanı ilə Xüsusi Rabitə və İnformasiya Təhlükəsizliyi Dövlət Agentliyi yaradılmış, kibertəhlükəsizlik risklərinin qiymətləndirilməsi, informasiya ehtiyatlarının qorunması və dövlət qurumlarının fəaliyyətinin əlaqələndirilməsi agentliyin əsas funksiyaları kimi müəyyənləşdirilmişdir. Həmin fərman Nəqliyyat, Rabitə və Yüksək Texnologiyalar Nazirliyinə kibertəhlükəsizlik üzrə vəziyyətin mütəmadi təhlilini, əhalinin və qurumların maarifləndirilməsini və qabaqlayıcı tədbirlərin görülməsini tapşırır. 2016-2020-ci illər üçün informasiya cəmiyyətinin inkişafı üzrə dövlət proqramında informasiya cəmiyyətinin formalaşdırılması və İKT istifadə səviyyəsinin yüksəldilməsi məqsədi ilə təhsil, səhiyyə və digər sosial sahələrdə müasir texnoloji yeniliklərin tətbiqi, yüksək ixtisaslı kadr hazırlığı və elektron hökumət xidmətləri nəzərdə tutulur. E-dövlətin informasiya təhlükəsizliyinin idarə edilməsi üzrə elmi araşdırmalar da normativ bazanın təkmilləşdirilməsi, təşkilati strukturun formalaşdırılması və kadr hazırlığı məsələlərinin dövlət qurumları tərəfindən sistemli şəkildə həyata keçirildiyini qeyd edir. Bütün bu sənədlər Azərbaycan təhsil sistemində informasiya təhlükəsizliyinin qorunması üçün hüquqi baza yaratsa da, təcrübədə tətbiqi və koordinasiya mexanizmlərinin gücləndirilməsi zəruridir.

Əsas hissə

Azərbaycan təhsil sistemində informasiya təhlükəsizliyinin cari vəziyyəti

Təhsil sisteminin rəqəmsallaşması bütün səviyyələrdə (məktəb, kollec, universitet) onlayn tədris platformaları, elektron gündəliklər və məsafədən idarəetmə sistemlərinin geniş tətbiqi ilə müşayiət olunur. Dövlət proqramları nəticəsində təhsil müəssisələrinin İKT infrastrukturunu sürətlə inkişaf etmiş, internetə çıxış genişlənməmişdir [2].

Lakin rəqəmsal resursların artması ilə onların müdafiəsi arasında uyğunsuzluq müşahidə olunur. Bir çox təhsil müəssisələri informasiya təhlükəsizliyi üzrə tam bir siyasətə malik deyil, serverlərdə və lokal şəbəkələrdə köhnəlmiş proqram təminatı istifadə edilir. E-universitetlər barədə tədqiqatlar göstərir ki, hesablama şəbəkələri və məlumat bazaları xüsusi təhlükəsizlik sistemləri olmadan işlədikdə kənar qüvvələrin və hətta daxildə narazı qalmış tələbələrin hədəfinə çevrilir. Bununla yanaşı, təhsil bazalarının genişlənməsi fərdi məlumatların kütləvi sızması riskini artırır; bəzi xarici nümunələr tələbə və əməkdaşların şəxsi məlumatlarının oğurlanması ilə nəticələnmişdir. Azərbaycanda belə hadisələrin qarşısının alınması üçün vahid təhlükəsizlik standartlarına uyğunluq və risklərin qiymətləndirilməsi mexanizmləri formalaşdırılmalıdır [8, s.129].

Mövcud elmi yanaşmalarda informasiya təhlükəsizliyi getdikcə daha çox kompleks idarəetmə problemi kimi qiymətləndirilir və bu sahənin yalnız texniki vasitələr vasitəsilə tənzimlənməsinin kifayət etmədiyi qəbul olunur. Dövlət informasiya sistemlərinin dayanıqlı və etibarlı fəaliyyəti təşkilati mexanizmlərin formalaşdırılmasını, normativ-hüquqi çərçivənin dəqiq müəyyənləşdirilməsini və ixtisaslı insan resurslarının hazırlanmasını paralel şəkildə tələb edir. Bu kontekstdə təhlükəsizlik risklərinin sistemli şəkildə qiymətləndirilməsi, məsuliyyət bölgüsünün aydın müəyyən edilməsi və davamlı maarifləndirmə tədbirlərinin həyata keçirilməsi əsas şərt kimi çıxış edir. Sözügedən yanaşmanın təhsil sistemində tətbiqi xüsusilə əhəmiyyətlidir, çünki bu sahədə informasiya resurslarının miqyası və istifadəçi sayı sürətlə artır. Təhsil müəssisələrində belə integrasiya olunmuş idarəetmə modelinin formalaşdırılması həm texnoloji boşluqların, həm də idarəetmə zəifliklərinin aradan qaldırılmasına imkan verə, informasiya təhlükəsizliyinin ümumi səviyyəsini yüksəldə bilər [6].

Təşkilati idarəetmə və məsuliyyət bölgüsü problemləri

İnformasiya təhlükəsizliyinin təmin edilməsi dövlət, təhsil və xüsusi sektorların koordinasiya fəaliyyəti ilə mümkün olur. Normativ sənədlərdə bu sahədə bir neçə qurumun məsul olduğu göstərilir: Xüsusi Rabitə və İnformasiya Təhlükəsizliyi Dövlət Agentliyi dövlət rabitəsi və informasiya-telekommunikasiya sistemlərinin təhlükəsizliyinin təşkilinə cavabdehdir. Nəqliyyat, Rabitə və Yüksək Texnologiyalar Nazirliyi kibertəhlükəsizlik vəziyyətini təhlil etməli, elektron təhlükələr barədə cəmiyyəti məlumatlandırmalı və qabaqlayıcı tədbirlər görməlidir [1].

Elm və Təhsil Nazirliyi isə təhsil sahəsində innovasiya və rəqəmsallaşma proseslərini idarə edir. Lakin praktiki səviyyədə bu qurumlar arasında informasiya mübadiləsinin və səlahiyyət bölgüsünün tam aydın olmaması risklərin vaxtında aşkarlanmasına mane olur. E-dövlətin informasiya təhlükəsizliyinin idarə edilməsi üzrə dissertasiya işində normativ-hüquqi bazanın təkmilləşdirilməsinin və təşkilati strukturun formalaşdırılmasının vacibliyi vurğulanır [6].

Təhsil müəssisələrinin öz daxilində də informasiya təhlükəsizliyi üzrə məsul şəxslərin təyin olunmaması və daxili siyasətlərin olmaması problemdir. Tədbirlərin parçalanması, hesabatlılığın zəifliyi və resurs çatışmazlığı nəticəsində təhlükəsizlik boşluqları yaranır. Məsuliyyət bölgüsünün aydınlaşdırılması və koordinasiya mexanizmlərinin gücləndirilməsi üçün normativ aktların praktiki təlimatlarla tamamlanması və təhsil sektorunda risklərin idarəedilməsi üzrə mərkəzi koordinasiya qurumunun yaradılması təklif olunur.

Təhsil müəssisələrində məlumatların qorunması mexanizmləri

Məlumatların qorunması texniki, inzibati və hüquqi tədbirlərin kompleksini tələb edir. Təhsil sektorunda istifadə edilən mühafizə mexanizmlərinə şəbəkə təhlükəsizlik sistemləri (firewall və müdaxilənin aşkarlanması sistemləri), kriptografik vasitələr, identifikasiya və autentifikasiya sistemləri, ehtiyat nüsxələrin hazırlanması və fiziki mühafizə daxildir. İnformasiya təhlükəsizliyi dərslərlərində təhlükəsizlik siyasətinin əsas anlayışları, kriptografik üsullar və modellər geniş təsvir edilir [5, s.2]

E-universitetlər üzrə tədqiqatlar göstərir ki, hesablama şəbəkələrinin xüsusi təhlükəsizlik sistemi olmadıqda kompüter sabotajı, spam, gizli qapılar və log-faylların manipulyasiyası kimi risklər artır. Müəlliflər təhsil müəssisələrində “İnformasiya təhlükəsizliyi” fənninin tədrisini və proqram təminatının yerli mütəxəssislər tərəfindən hazırlanmasını mühüm hesab edirlər, çünki bu, gizli girişlərin qarşısını alır. Bundan əlavə, məlumatların məxfilik səviyyəsinə görə kateqoriyalara bölünməsi, məhdudlaşdırılmış resurslara giriş üçün yalnız səlahiyyətli istifadəçilərin seçilməsi və hər giriş zamanı IP və MAC ünvanlarının yoxlanması kimi tədbirlər təklif edilir. Azərbaycan təhsil müəssisələrinin beynəlxalq standartlara uyğun informasiya təhlükəsizliyi idarəetmə sistemləri (məsələn, ISO/IEC 27001) tətbiq etməsi, müntəzəm risk analizi aparması və insidentlərin monitorinqi üzrə mərkəzi qeydiyyat sisteminə qoşulması məqsədəuyğundur [8, s.129].

Təhlükəsizlik sahəsində mütəxəssis hazırlığı və maarifləndirmə tədbirləri

adr hazırlığı və maarifləndirmə informasiya təhlükəsizliyinin ən vacib komponentlərindəndir. Rəqəmsal mədəniyyətin formalaşdırılması, şagirdlərin, tələbələrin və təhsil işçilərinin kibermühitdə təhlükəli davranışlardan xəbərdar edilməsini tələb edir. “Cəmiyyətdə informasiya təhlükəsizliyi mədəniyyətinin formalaşdırılması” mövzusunda aparılan tədqiqatda qeyd olunur ki, informasiya mənbələrinin artması və elektron xidmətlərin genişlənməsi insanlar arasında manipulyasiya və sosial mühəndislik risklərini artırır; buna görə də mütəxəssislərin, vətəndaşların, təhsil işçilərinin və gənclərin informasiya təhlükəsizliyi mədəniyyətinin yüksəldilməsi aktual məsələ kimi qiymətləndirilir [7]

E-universitetlər barədə konfrans materialında təklif edilir ki, digər məcburi fənnilərlə yanaşı “informasiya təhlükəsizliyi” fənni bütün ixtisaslarda tədris edilsin. Bu kurs təhlükə mənbələri və qorunma üsullarını öyrədərək gələcək mütəxəssislərin kibertəhdidlərə qarşı hazırlığını artırır [8, s.129]. Prezidentin 2012-ci il tarixli fərmanı kriptoloji fəaliyyətin təkmilləşdirilməsi və tədris işinin gücləndirilməsi üçün Xüsusi Rabitə və İnformasiya Təhlükəsizliyi Dövlət Agentliyinə konkret

tapşırıqlar verir. Eyni zamanda, 2016–2020-ci illəri əhatə edən dövlət proqramında yüksəkixtisaslı kadr hazırlığı informasiya təhlükəsizliyi siyasətinin prioritet istiqamətlərindən biri kimi müəyyən edilmişdir [2].

Buna baxmayaraq, təhsil müəssisələrində informasiya təhlükəsizliyi üzrə ixtisaslı kadrların çatışmazlığı mövcuddur. Mütəxəssis hazırlığı üçün ali təhsil proqramlarının müasir tələblərə uyğun yenilənməsi, praktiki laboratoriyaların yaradılması və beynəlxalq sertifikatlı təlimlərin təşkili zəruridir. Tədris prosesinə informasiya təhlükəsizliyi mədəniyyətinin elementlərinin daxil edilməsi və maarifləndirmə tədbirlərinin məktəb pilləsindən başlaması kibertəhdidlərə qarşı davamlılıq yaradar.

Nəticə

Mövcud problemlərin ümumiləşdirilməsi

Araşdırma göstərir ki, Azərbaycan təhsil sistemində informasiya təhlükəsizliyi sahəsində mühüm irəliləyişlərə baxmayaraq, bir sıra problemlər mövcuddur. Rəqəmsal resursların sürətli artımı ilə müqayisədə məlumatların mühafizəsi mexanizmləri geridə qalır; təhsil müəssisələrinin bir çoxu təhlükəsizlik siyasətini və insident idarəetmə planlarını işləməyib. Normativ sənədlərdə dövlət qurumlarının funksiyaları müəyyən edilsə də, səlahiyyət bölgüsü və koordinasiya praktiki səviyyədə tam işləməyir. İnfrastrukturun modernləşdirilməsi ləng gedir, yerli proqram təminatının olmaması və kadr çatışmazlığı təhlil olunan əsas problemlərdəndir.

Təklif olunan həll yolları

Problemlərin həlli üçün kompleks yanaşma tələb olunur. İlk olaraq, təhsil müəssisələrində informasiya təhlükəsizliyi idarəetmə sistemləri tətbiq edilməli, risk analizi və insidentlərin monitorinqi üzrə standart prosedurlar hazırlanmalıdır. Məlumatların məxfilik səviyyəsinə görə kateqoriyalasdırılması və kritik resurslara girişin çoxsəviyyəli autentifikasiya ilə məhdudlaşdırılması təklif olunur. Tədris proqramlarına informasiya təhlükəsizliyi fənninin daxil edilməsi və bütün ixtisaslarda tədrisi vacibdir. Dövlət qurumları arasında koordinasiya mexanizmləri təkmilləşdirilməli, eyni zamanda təhsil müəssisələrində informasiya təhlükəsizliyi üzrə məsul şəxslər təyin edilməlidir. Normativ-hüquqi baza texnoloji yenilikləri nəzərə alaraq mütəmadi yenilənməli, risklərin idarəedilməsi üzrə metodik göstərişlər hazırlanmalıdır. Yerli proqram təminatı və kriptografik həllərin hazırlanması üçün startapların və universitet laboratoriyalarının dəstəklənməsi məqsədilə dövlət və özəl sektorun əməkdaşlığı genişləndirilməlidir.

Dövlət və təhsil müəssisələrinin rolu

Dövlət informasiya təhlükəsizliyinin təminatçısı kimi normativ sənədlər qəbul edir, mərkəzi koordinasiya qurumları yaradır və maliyyə dəstəyini təşkil edir. Prezident fərmanları və dövlət proqramları kibertəhlükəsizlik risklərinin idarə olunmasını, maarifləndirmə tədbirlərini və kadr hazırlığını prioritet kimi göstərir. Lakin təhlükəsizliyin praktik təminatı təhsil müəssisələrinin üzərinə düşür. Universitetlər və məktəblər öz şəbəkələrinin və məlumat bazalarının təhlükəsizliyini təmin etməli, daxili normativ sənədlər hazırlamalı və əməkdaşların mütəmadi təlimini təşkil etməlidirlər. Eyni zamanda, təhsil müəssisələri dövlət qurumları ilə əməkdaşlıq edərək kibertəhlükə insidentləri haqqında məlumat mübadiləsi aparmalı, beynəlxalq təcrübədən yararlanmalı və tələbə və əməkdaşların məlumatlandırılması üçün proqramlar həyata keçirməlidirlər. Yalnız dövlət və təhsil sektorunun birgə, koordinasiyalı fəaliyyəti nəticəsində Azərbaycanın təhsil sistemində informasiya təhlükəsizliyi yüksək səviyyədə təmin edilə bilər.

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БІЛІМ БЕРУДЕГІ ЖАСАНДЫ ИНТЕЛЛЕКТ: МҮМКІНДІКТЕРІ МЕН БОЛАШАҒЫ

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Аңдатпа: Бұл мақалада білім беру жүйесінде жасанды интеллекттің (ЖИ) қолданылу мүмкіндіктері мен оның болашағы қарастырылады. ЖИ-дің оқыту процесін жекелендірудегі, білім сапасын арттырудағы, мұғалімдердің жұмысын жеңілдетудегі рөлі талданады. Сонымен қатар, интеллектуалды платформалар, автоматты бағалау жүйелері, виртуалды ассистенттер сияқты технологиялардың тиімділігі көрсетіледі. Мақалада жасанды интеллекттің артықшылықтарымен қатар, деректер қауіпсіздігі, технологияға тәуелділік сияқты мәселелер де қозғалады.

Кілттік сөздер: жасанды интеллект, білім беру, цифрлық технология, жекелендірілген оқыту, интеллектуалды жүйе, онлайн платформа, автоматты бағалау, виртуалды ассистент, цифрлық трансформация, білім сапасы

Қазіргі заманда технология қарқынды дамып, адам өмірінің барлық саласына еніп келеді. Соның ішінде білім беру жүйесі де бұл өзгерістерден тыс қалған жоқ. Жасанды интеллект (ЖИ) білім беру саласына жаңа серпін беріп, оқыту әдістерін жетілдіруге және білім сапасын арттыруға үлкен мүмкіндік туғызуда. Ғылым мен технологияның қарқынды дамуы білім беру жүйесіне жаңа мүмкіндіктер ұсынып, оқыту әдістерін түбегейлі өзгертуде. Кейінгі жылдары жасанды интеллект білім саласында ерекше рөл атқарып, оқушылардың оқу процесін жекешелендіруге, мұғалімдердің жұмысын жеңілдетуге және оқыту сапасын арттыруға ықпал етіп отыр. Жасанды интеллект тек автоматтандырылған жүйе емес, ол – адамның ойлау қабілетін жетілдіретін, жаңа білім көзін ашатын құрал. Белгілі ғалым Альберт Эйнштейн «Білім – мектепте алған білімнің жиынтығы емес, ол – өмір бойы үйрену қабілеті» деп айтқан. Жасанды интеллект дәл осы қағиданы қолдай отырып, білім алудың шексіз мүмкіндіктерін ашуда.

Жасанды интеллект білім беру саласында ең алдымен оқытуды жекешелендіру бағытында үлкен рөл атқарады. Себебі әрбір оқушының білім деңгейі мен оқу қарқыны әртүрлі болғандықтан, ЖИ олардың жеке ерекшеліктеріне сәйкес келетін оқу бағдарламаларын ұсына алады. Мысалы, Google компаниясы әзірлеген Google Classroom платформасы мұғалімдерге оқушылардың үлгерімін талдауға және әрқайсысына жеке тапсырмалар беруге мүмкіндік береді. Мұндай тәсіл білім сапасын арттырып, оқушылардың өз деңгейіне сай тиімді білім алуына жағдай жасайды.

Сонымен қатар, жасанды интеллект білім беру жүйесінде бағалау процесін автоматтандыруда да маңызды орын алады. Дәстүрлі түрде тесттер мен жазбаша жұмыстарды тексеру мұғалімдерге көп уақыт пен күш жұмсауды талап етеді. Ал ЖИ негізіндегі жүйелер бұл процесті жылдам әрі тиімді жүзеге асырып, оқушылардың қай тұста қиналатынын және қай бағытта жақсы нәтиже көрсететінін анықтауға көмектеседі. Осындай жүйелердің бірі – Turnitin. Бұл платформа тек плагиатты анықтап қана қоймай, студенттердің жазу дағдыларын жақсартуға арналған ұсыныстар да береді.

Жасанды интеллект – бұл компьютерлік жүйелердің адамға тән ойлау, талдау, үйрену қабілеттерін имитациялауы. Білім беру саласында ЖИ оқушылардың жеке ерекшеліктерін

ескеріп, білім беруді жекелендіруге мүмкіндік береді. Мысалы, интеллектуалды оқу платформалары әр оқушының деңгейіне сай тапсырмалар ұсынып, олардың әлсіз тұстарын анықтап, сол бағытта жұмыс жасауға көмектеседі.

Сонымен қатар, ЖИ мұғалімдердің жұмысын жеңілдетеді. Автоматты бағалау жүйелері тесттер мен жазбаша жұмыстарды жылдам тексеріп, уақытты үнемдейді. Бұл мұғалімдерге шығармашылық және әдістемелік жұмыстарға көбірек көңіл бөлуге жағдай жасайды. Сондай-ақ, виртуалды ассистенттер оқушылардың сұрақтарына тәулік бойы жауап беріп, қосымша түсіндіру жұмыстарын жүргізе алады.

Жасанды интеллекттің тағы бір артықшылығы – білімге қолжетімділікті арттыру. Онлайн платформалар мен интеллектуалды жүйелер арқылы әлемнің кез келген нүктесіндегі адам сапалы білім ала алады. Бұл әсіресе ауылдық немесе шалғай аймақтар үшін маңызды.

Дегенмен, ЖИ қолданудың кейбір қиындықтары да бар. Мысалы, деректердің қауіпсіздігі мен құпиялылығы мәселелері, сондай-ақ технологияға тәуелділіктің артуы алаңдаушылық тудырады. Сонымен қатар, мұғалім мен оқушы арасындағы тірі қарым-қатынастың азаюы да маңызды мәселе болып табылады.

Қазіргі таңда білім беру жүйесі цифрлық трансформация кезеңін бастан өткеруде. Осы үдерістің ең маңызды элементтерінің бірі – жасанды интеллект (ЖИ). ЖИ тек технологиялық құрал ғана емес, ол оқыту тәсілдерін өзгертіп, білім беру сапасын жаңа деңгейге көтеруге ықпал ететін күшке айналды. Бүгінгі күні білім берусаласында қолданылатын жасанды интеллект түрлері мен олардың қызметін қарастыру аса маңызды.

Ең алдымен, білім беруде кеңінен қолданылатын ЖИ түрлерінің бірі – адаптивті оқыту жүйелері. Бұл жүйелер әр оқушының білім деңгейін, қабілетін және оқу қарқынын талдай отырып, жеке оқу бағдарламасын ұсынады. Мысалы, оқушы белгілі бір тақырыпты түсінуде қиналса, жүйе оған қосымша тапсырмалар мен түсіндірмелер береді. Ал тақырыпты жақсы меңгерген оқушыға күрделірек материалдар ұсынылады. Бұл тәсіл білімді жекелендіруге мүмкіндік береді.

Екінші маңызды бағыт – интеллектуалды оқыту платформалары. Мұндай платформаларда ЖИ оқушылардың әрекеттерін бақылап, олардың оқу барысындағы қателіктерін анықтайды және ұсыныстар береді. Сонымен қатар, бұл жүйелер мұғалімдерге оқушылардың үлгерімі туралы толық талдау жасап, оқу процесін тиімді жоспарлауға көмектеседі.

Үшінші бағыт – виртуалды ассистенттер мен чат-боттар. Олар оқушылардың сұрақтарына жауап беріп, оқу материалын түсіндіруге көмектеседі. Мұндай ассистенттер тәулік бойы жұмыс істей алады және оқушыға кез келген уақытта қолдау көрсетеді. Бұл әсіресе қашықтан оқыту жағдайында өте тиімді.

Тағы бір маңызды құрал – автоматты бағалау жүйелері. ЖИ көмегімен тесттер, эсселер және басқа да жазбаша жұмыстар тез әрі объективті түрде бағаланады. Бұл мұғалімдердің уақытын үнемдеп, бағалаудың әділдігін арттырады.

Сонымен қатар, білім беруде сөйлеуді тану және мәтінді өңдеу технологиялары да кеңінен қолданылуда. Бұл технологиялар тіл үйренуде, диктант жазуда және ауызша жауаптарды бағалауда тиімді. Мысалы, оқушының сөйлеу дағдысын бағалап, қателерін автоматты түрде анықтауға болады.

ЖИ-дің тағы бір қызықты қолдану саласы – виртуалды және толықтырылған шындық (VR/AR) технологияларымен бірігуі. Бұл тәсіл арқылы оқушылар күрделі тақырыптарды визуалды түрде түсініп, тәжірибелік білім алады. Мысалы, тарих сабағында ежелгі қалаларды «аралау» немесе биологияда адам ағзасын 3D форматта зерттеу мүмкіндігі пайда болады.

Қорытындылай келе, жасанды интеллект білім беру саласына үлкен өзгерістер әкелуде. Ол оқыту үдерісін тиімдірек, қолжетімді әрі жекелендірілген етеді. Алайда, бұл

технологияны тиімді пайдалану үшін оның артықшылықтары мен кемшіліктерін ескере отырып, теңгерімді түрде енгізу қажет. Болашақта ЖИ білім беру жүйесінің ажырамас бөлігіне айналатыны сөзсіз.

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Бет-әлпетінің биометриялық эталондарын генерациялаудағы Privacy- preserving алгоритмдері

Ергеш Нұрсұлтан Сагитянұлы

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Аңдатпа. Бет-әлпет биометриясы заманауи аутентификация жүйелерінің негізгі компоненттерінің бірі болып табылады. Алайда биометриялық эталондарды (template) ашық түрде сақтау пайдаланушының жеке басының деректерін айтарлықтай қауіпке ұшыратады. Парольден айырмашылығы, ұрланған биометриялық деректі қайта шығаруға болмайды. Осыған байланысты эталондарды құпиялылықты сақтай отырып генерациялау (privacy-preserving template generation) -ақпараттық қауіпсіздіктің өзекті ғылыми мәселесіне айналды. Бұл мақалада бет-әлпет эталондарын қорғаудың үш негізгі тәсіл талданады: cancelable biometrics (BioHashing), fuzzy vault схемасы және гомоморфты шифрлау (CKKS). Әрбір әдістің математикалық негізі, тәжірибелік жүзеге асырылуы және әлсіз жақтары егжей-тегжейлі қарастырылады. Сонымен қатар осы әдістерді біріктіретін гибридіті схема ұсынылады, оның ArcFace эмбеддингтерімен бірге қолданылуы көрсетіледі. LFW (Labeled Faces in the Wild) деректер базасында жүргізілген эксперименттер ұсынылған әдістің EER көрсеткіші 0,82% деңгейінде екендігін, бұл қолданыстағы шешімдермен салыстыруға болатынын дәлелдейді.

Түйін сөздер: биометриялық эталон, бет-әлпетті тану, privacy-preserving, cancelable biometrics, BioHashing, fuzzy vault, гомоморфты шифрлау, ArcFace, ақпараттық қауіпсіздік.

Кіріспе

Соңғы онжылдықта бет-әлпетті автоматты түрде тану технологиялары қарқынды дамыды. Терең нейрондық желілерге негізделген заманауи алгоритмдер (FaceNet, ArcFace, AdaFace) LFW сияқты эталондық деректер базаларында 99,8%-дан астам дәлдікке қол жеткізді. Бұл биометрияны смартфондарды құлыптан шығарудан бастап халықаралық әуежай шекараларын бақылауға дейінгі ауқымды салаларда қолдануға мүмкіндік берді. Дүниежүзілік биометрия нарығы 2030 жылға қарай 68 миллиард АҚШ долларынан асады деп болжанады.

Алайда биометриялық идентификацияның кеңінен таралуы жеке деректерді қорғау проблемасын күрделендірді. Аутентификация процесінің жүрегінде «эталон» (биометриялық template) ұғымы тұрады - бұл адам бетінен алынған, оны қайта тану үшін пайдаланылатын математикалық сипаттама (әдетте 128-512 өлшемді нақты сандар векторы). Кәдімгі парольдерден айырмашылығы, биометриялық эталондар келесідей бірегей қасиеттерге ие:

- Олар қайтарылмайды - ұрланған саусақ ізін немесе бетті ауыстыруға болмайды;
- Олар бірегей - бір ғана адамға тиесілі;
- Олар тұрақты - өмір бойы өзгеріссіз қалады;
- Олар көрсетілмеуі керек - адамның ризалығынсыз ашық көрсету заңсыз.

Эталондарды ашық түрде сақтайтын дерекқорларға бірнеше ірі шабуыл орын алды. 2015 жылы АҚШ-тың OPM (Office of Personnel Management) дерекқорынан 5,6 миллион

саусақ ізі ұрланды. 2019 жылы Suprema BioStar 2 жүйесінен 27,8 миллион биометриялық жазба ағып кетті. 2023 жылы Ұлыбританияның Police National Database жүйесіне қатысты осындай оқиға тіркелді. Бұл инциденттер биометриялық эталондарды криптографиялық қорғаудың шұғыл қажеттілігін көрсетті.

Privacy-preserving (құпиялылықты сақтаушы) алгоритмдер - биометриялық эталондарды бастапқы (plaintext) күйде еш жерде сақтамай тұрып, аутентификация процесін орындауға мүмкіндік беретін криптографиялық әдістер тобы. ISO/IEC 24745:2022 халықаралық стандарты осындай схемаларға қойылатын төрт негізгі талапты белгілейді:

- 1) Қайтарылмастық (irreversibility) - қорғалған эталоннан бастапқы биометриялық деректерді қалпына келтіру есептеу тұрғысынан мүмкін болмауы керек;
- 2) Сабақтаспаушылық (unlinkability) - әртүрлі қызметтерде сақталатын бір адамның эталондары бір-бірімен байланыстырылмауы керек;
- 3) Жаңартылғыштық (renewability) - эталон бұзылған жағдайда оны жаңасымен ауыстыру мүмкіндігі болуы керек;
- 4) Өнімділік (performance) - қорғаныс схемасы тану дәлдігін айтарлықтай төмендетпеуі тиіс.

Бұл мақалада осы талаптарды қанағаттандыруға бағытталған үш негізгі privacy-preserving тәсіл қарастырылады: cancelable biometrics (атап айтқанда, BioHashing), fuzzy vault схемасы және гомоморфты шифрлау. Сонымен қатар қазіргі заманғы ArcFace эмбеддингтерін осы әдістермен біріктіру мүмкіндіктері талданады.

Зерттеулерге шолу

Биометриялық эталондарды қорғау мәселесіне қатысты алғашқы іргелі еңбектерді 1990-жылдардың аяғында кездестіруге болады. 1999 жылы Juels және Wattenberg ұсынған Fuzzy Commitment схемасы биометриялық деректі қате түзеуші кодпен біріктірудің алғашқы тәсілі болды. Кейіннен 2002 жылы Juels және Sudan фингер-принт типті деректер үшін Fuzzy Vault концепциясын кеңейтті. 2007 жылы Ratha және басқалары Cancelable Biometrics ұғымын ұсынып, ол бойынша биометриялық деректерге пайдаланушыға тән, қайтарылмайтын түрлендіру қолданылуы керектігін көрсетті.

Соңғы жылдары назар гомоморфты шифрлау (HE) бағытына аударылды. 2017 жылы Boddeti CKKS схемасын бет-әлпет векторларымен бірге қолданудың алғашқы практикалық мысалын ұсынды. 2020 жылы Engelsma және басқалары DeepBio атты ашық кодты кітапхананы жариялады, ол шифрленген эмбеддингтер арасында тікелей косинустық ұқсастықты есептеуге мүмкіндік берді. 2023 жылы NIST FIPS 203 стандартын қабылдады - пост-кванттық кілт алмасу үшін CRYSTALS-Kyber алгоритмі. Бұл биометриялық схемаларды кванттық қауіптерге қарсы дайындау бойынша жаңа зерттеу бағытын ашты.

Қазақстандық ғалымдар да осы салаға өз үлестерін қосуда. С. Бошанның тобы (КазҰУ) cancelable biometrics негізіндегі мобильді банкинг үшін аутентификация хаттамаларын зерттеді. М. Ыбыраймұратовтың (ЕНУ) еңбектерінде ұлттық eGov платформасына биометриялық қорғаныс енгізу мәселелері қарастырылды.

Әдеби шолу нәтижесінде келесі қорытынды жасауға болады: қолданыстағы privacy-preserving схемалардың әрқайсысының өзіндік артықшылықтары мен әлсіз жақтары бар, бірақ ешқайсысы жалғыз өзі қауіпсіздік, өнімділік және пост-кванттық төзімділік талаптарын толық қанағаттандырмайды. Сондықтан гибриді тәсілдер ерекше өзектілікке ие.

Бет-әлпетті танудың математикалық негізі

Заманауи бет-әлпетті тану жүйесі екі негізгі компоненттен тұрады: (1) эмбеддингтерді шығаратын терең нейрондық желі және (2) шығарылған векторларды салыстыратын метрикалық кеңістік. Эмбеддинг (embedding) - бұл адам бетінің суретін n -өлшемді нақты сандар векторымен ұсыну. ArcFace моделі үшін $n = 512$:

$$E = \text{CNN}(I), \text{ мұндағы } E \in \mathbb{R}^{512}, \|E\|_2 = 1$$

Бұл векторлар L_2 нормасы бойынша нормаланған -яғни 512-өлшемді бірлік сферада орналасады. Бұл құрылымның артықшылығы -ұқсас беттердің векторлары сферада жақын орналасады, ал басқа адамдардың беттері -алыс. Екі эмбеддинг арасындағы ұқсастық косинустық метрика арқылы есептеледі:

$$s(E_1, E_2) = (E_1 \cdot E_2) / (||E_1|| \cdot ||E_2||) = E_1 \cdot E_2$$

Себебі екі вектор бірлік ұзындықта болғандықтан, скаляр көбейтінді тікелей косинусқа тең болады. ArcFace үшін шектік мән $\tau = 0,36$ болғанда, FAR (False Accept Rate) шамамен 10^{-4} деңгейіне жетеді.

ArcFace (Deng et al., 2019) -бет-әлпетті танудағы ең танымал loss-функциялардың бірі. Оның негізгі идеясы -softmax функциясының ішіне «аддитивтік бұрыштық маржа» (additive angular margin) m қосу:

$$L = -\log(\exp(s \cdot \cos(\theta_y + m)) / (\exp(s \cdot \cos(\theta_y + m)) + \sum_{j \neq y} \exp(s \cdot \cos(\theta_j))))$$

Мұндағы θ_y -эмбеддинг пен дұрыс класс центроиды арасындағы бұрыш, $m = 0,5$ рад ($\approx 28,6^\circ$) -қосылатын бұрыштық маржа, $s = 64$ -масштабтаушы коэффициент. Бұл loss-функцияны қолдану әртүрлі адамдардың эмбеддингтері арасындағы дискриминативтілікті айтарлықтай арттырады.

Біршама эталондық сапаны қамтамасыз ету мақсатында тіркеу процесінде N үлгі қолданылады (әдетте $N = 3-7$). Әр үлгіден жеке эмбеддинг E_i алынады, содан кейін олардың орташа мәні есептеліп, қайтадан нормаланады:

$$T = (\sum_i E_i) / ||\sum_i E_i||_2$$

Алынған T векторы -бұл біз қорғауымыз керек эталон. Дәл осы мән privacy-preserving схеманың кірісі болады.

4. Cancelable Biometrics: BioHashing

Cancelable biometrics тұжырымдамасының негізгі идеясы -биометриялық эталонға пайдаланушыға тән кездейсоқ, бірақ қайтарылмайтын түрлендіру қолдану. Егер қорғалған эталон ашылса, пайдаланушының кілтін (token) ауыстыру арқылы жаңасы жасалады. Осылайша «жаңартылғыштық» (renewability) талабы орындалады.

BioHashing (Teoh et al., 2004) -cancelable схемалардың ішіндегі ең танымал әдістерінің бірі. Ол кездейсоқ матрица арқылы проекциялаудан және бинаризациядан тұрады.

BioHashing алгоритмі үш қадамды қамтиды:

- 5) Кездейсоқ ортогоналды матрица генерациясы. Әрбір пайдаланушы үшін salt деп аталатын құпия мән негізінде $W \in \mathbb{R}^{k \times n}$ матрицасы құрылады. Әдетте $n = 512$ (эмбеддинг өлшемі), $k = 256$ (нәтиже бит саны). Матрица бағандары Грам-Шмидт процесі арқылы ортогоналдандырылады.
- 6) Сызықтық проекция. Эмбеддинг T матрица арқылы k -өлшемді кеңістікке проекцияланады:

$$y = W \cdot T, y \in \mathbb{R}^k$$

- 7) Бинаризация. Әрбір y_i элементі белгісіне қарай битка түрлендіріледі:

$$b_i = 1, \text{ егер } y_i > 0; b_i = 0, \text{ егер } y_i \leq 0$$

Нәтижесінде $B \in \{0, 1\}^k$ бинарлық код алынады. ArcFace эмбеддинглері үшін $k = 256$ бит = 32 байт жеткілікті, өйткені төмендетілген өлшемге қарамастан, дискриминативтілік сақталады.

BioHashing қайтарылмастығының математикалық негізі $\text{sign}(\cdot)$ операциясының ақпарат жоғалтатын (lossy) сипатына негізделген. Әрбір y_i үшін шексіз көп оң (немесе теріс) мән сәйкес келеді -тек белгісі белгілі болады. Сонымен қатар, $k < n$ болған жағдайда, проекция 512-өлшемді кеңістіктен 256-өлшемдіге өтеді, бұл ақпараттың айтарлықтай жоғалуын білдіреді. Сондықтан b_i биттерінен бастапқы T -ны қалпына келтіру -толықтығы бар проблемалардың бірі.

Аутентификация кезінде жаңа эмбеддинг E_query сол W матрицасы арқылы B_query бинарлық кодына түрлендіріледі. Содан кейін сақталған B шаблонумен Hamming қашықтығы есептеледі:

$$HD(B, B\_query) = (1/k) \cdot \sum_i (b_i \oplus b\_query_i)$$

Шектік мән $HD < 0,35$ болғанда екі эмбеддинг бір адамға тиесілі деп саналады. LFW базасында жүргізілген эксперименттер BioHashing әдісі бастапқы ArcFace эмбеддингтерімен салыстырғанда EER шамасын тек 0,3%-ға арттыратынын көрсетеді ($0,42\% \rightarrow 0,76\%$), бұл қолайлы шығын болып табылады.

Fuzzy Vault схемасы

Fuzzy Vault (Juels & Sudan, 2002) -бұл реттелмеген элементтер жиынымен жұмыс істей алатын криптографиялық схема, бұл оны биометрияға (әсіресе minutiae жиындарына) қолданысты етеді. Эмбеддингтер үшін бұл әдіс модификацияланған түрде қолданылады: эмбеддинг алдын ала дискретизацияланады, содан кейін Vault-та сақталады.

Тіркеу процесі келесі қадамдардан тұрады:

- 8) Эталон T нүктелер жиынына түрленеді: $T \rightarrow A = \{a_1, a_2, \dots, a_n\}$ (мысалы, әрбір эмбеддинг компоненті дискретизацияланып, индекспен бірге сақталады);
- 9) Кездейсоқ S құпиясы (32 байт) генерацияланады. Оның негізінде d дәрежелі $p(x)$ көпмүшесі құрылады, мұндағы $p(x)$ коэффициенттері S -тен есептеледі;
- 10) Әрбір $a_i \in A$ үшін $(a_i, p(a_i))$ жұбы есептеледі -бұл «нағыз» нүктелер жиыны (genuine points);
- 11) M кездейсоқ «жалған» нүкте (chaff points) $(c_j, d_j) \in \mathbb{R}^2$ жасалады, мұндағы $d_j \neq p(c_j)$. Әдетте $M \approx 10 \cdot n$;
- 12) Vault $V = \text{«нағыз» } U \text{ «жалған» нүктелер жиынтығы ретінде анықталады. Жұптар Vault ішінде араластырылады.}$

Тану кезінде Vault-тан S құпиясын қалпына келтіру үшін Reed-Solomon декодтау алгоритмі қолданылады. Жаңа эмбеддинг E_query негізінде A_query жиыны құрылады. Vault-та A_query элементтеріне сәйкес нүктелер таңдалады. Егер таңдалған нүктелердің ішінде $d+1$ -ден көп «нағыз» нүкте болса, $p(x)$ көпмүшесін Лагранж интерполяциясы арқылы қалпына келтіруге болады, демек S құпиясы да анықталады.

Қауіпсіздік талдауы көрсеткендей, Vault-тан S -ті brute force арқылы табуға қажетті комбинациялар саны:

$$|V| \text{ choose } (d+1) \approx 2^{80} \text{ қауіпсіздік деңгейі}$$

Бұл әдістің артықшылығы -оның ақпараттық-теориялық қауіпсіздігі. Алайда нақты эмбеддингтер үшін дискретизация қателіктері және chaff нүктелерін генерациялау процедурасы практикалық қолдануды күрделендіреді. EER шамасы 1,12% деңгейіне көтеріледі, бұл BioHashing-тен жоғарырақ.

Гомоморфты шифрлау: CKKS схемасы

Гомоморфты шифрлау (Homomorphic Encryption, HE) -бұл шифрленген деректерді шешілмеген күйде есептеуге мүмкіндік беретін криптографиялық примитив. CKKS (Cheon-Kim-Kim-Song, 2017) схемасы -нақты сандармен жұмыс істеуге арналған толық емес гомоморфты схемалардың (Leveled HE) бір түрі. Оның негізгі қасиеті:

$$Enc(a) \oplus Enc(b) = Enc(a + b)$$

$$Enc(a) \otimes Enc(b) = Enc(a \cdot b)$$

Бұл шифр астында екі вектордың скаляр көбейтіндісін есептеу мүмкіндігін тікелей береді -яғни косинустық ұқсастықты эмбеддингтерді шешпестен есептеуге болады.

CKKS-ті бет-әлпет аутентификациясында қолдану келесі сценарий бойынша жүзеге асырылады. Тіркеу кезінде клиент жұп кілт (pk, sk) генерациялайды. Эмбеддинг T клиент жағында шифрленеді: $ct\_T = Enc(pk, T)$. Шифрленген ct_T серверге жіберіліп, базада сақталады. Клиент жасырын кілт sk -ні өзінде ұстайды -сервер оны ешқашан көрмейді.

Аутентификация кезінде клиент жаңа сұраныс эмбеддингі Q -ны шифрлейді: $ct\_Q = \text{Enc}(pk, Q)$. Сервер шифрленген күйде ұқсастықты есептейді:

$$ct\_s = ct\_T \otimes ct\_Q$$

$$ct\_total = \text{SumReduce}(ct\_s)$$

Сервер ct_total -ды клиентке қайтарады. Клиент оны шешеді: $s = \text{Dec}(sk, ct\_total)$. Егер $s \geq \tau$ болса -аутентификация сәтті болғаны. Бұл сценарийде сервер ешқандай мезетте плайтекст эмбеддингтерді көрмейді -бұл privacy-preserving сипаттамасының күшті дәлелі болып табылады.

СККС параметрлерін таңдау қауіпсіздік пен өнімділік арасындағы тепе-теңдікке байланысты. Стандартты конфигурация (NIST 128-биттік қауіпсіздікке тең):

- Көпмүше дәрежесі $N = 8192$;
- Координат модулі $q \approx 2^{218}$;
- Шкала факторы $\Delta = 2^{40}$;
- Гаусс шуыл $\sigma = 3,2$.

Бір шифрленген эмбеддингің көлемі шамамен 4–12 МБ-ты құрайды (бастапқы 2 КБ-ке қарсы). Косинустық ұқсастықты есептеу уақыты Intel Xeon Gold процессорында ~520 миллисекундты алады, бұл бастапқы plain-text есептеуден шамамен 1000 есе ұзақ. EER көрсеткіші 0,48%-ға жоғарылайды (0,42%-дан) -өте аз шығын. Бұл схеманың басты артықшылығы оның сақталу қауіпсіздігі болып табылады.

Ұсынылған гибриді схема

Қарастырылған әдістердің әрқайсысы өзінің күшті және әлсіз жақтарына ие. BioHashing өте жылдам әрі ықшам (32 байт), бірақ матрица W ұрланса, қайтару шабуылдарына осалдылықты арттырады. Fuzzy Vault ақпараттық-теориялық қауіпсіздік ұсынады, бірақ дискретизация эмбеддингтерге нашар сәйкеседі. СККС толық privacy береді, бірақ өте баяу. Бұл әлсіздіктерді бір-біріне қарама-қарсы орналастырып, артықшылықтарын біріктіретін гибриді схема ұсынылады.

Ұсынылған гибриді схема үш деңгейлі қорғанысты қамтиды:

- 13) Бірінші деңгей -BioHashing. Эмбеддинг T 256-биттік B кодына түрлендіріледі. Ол көп жадыны үнемдейді әрі қайтарылмастық алғашқы кепілдігін береді.
- 14) Екінші деңгей -AES-256-GCM шифрлау. B бинарлық код симметриялы шифрмен қорғалады. Кілт K HSM (Hardware Security Module) ішінде сақталады және плайтекст түрінде ешқашан шықпайды:

$$(C, IV, tag) = \text{AES\_GCM\_Enc}(K, IV, B)$$

- 15) Үшінші деңгей -пост-кванттық кілт алмасу. Клиент пен сервер арасындағы байланыс CRYSTALS-Kyber-768 KEM арқылы орнатылады, бұл болашақтағы кванттық компьютерлерден қорғаныс береді. Гибриді режимде Kyber X25519-мен бірге қолданылады:

$$\text{shared\_secret} = \text{KDF}(X25519(a, B) || \text{Kyber768}(\dots))$$

Толық аутентификация процесі келесі қадамдардан тұрады. Клиент бетті түсіріп, MTCNN арқылы ажыратады, ArcFace моделімен Q эмбеддингін есептейді. Содан кейін $B\_query = \text{BioHash}(W, Q)$ есептеледі. Клиент серверге сұраныс жібереді (Kyber-X25519 түнелі арқылы). Сервер шифрленген B -ны базадан алып, HSM-нен K кілтін сұрап, AES-GCM арқылы шешеді. Содан кейін Hamming қашықтығын есептеп, шектік мәнмен салыстырады. Шешім (accept/reject) JWT токен арқылы клиентке қайтарылады. Әр сәтті аутентификация әрекеттен кейін сервер EMA (Exponential Moving Average) арқылы шаблонды біртіндеп жаңартады:

$$T\_new = (1 - \alpha) \cdot T\_old + \alpha \cdot Q, \alpha = 0,1$$

Бұл механизм адамның қартаюы, шаш стилінің өзгеруі немесе жарықтандырудағы біртіндеп өзгерістерге автоматты бейімделуді қамтамасыз етеді.

Эксперименттік бағалау

Ұсынылған схеманың тиімділігін бағалау үшін халықаралық LFW (Labeled Faces in the Wild) деректер базасы қолданылды. Базада 13 233 сурет, 5 749 жеке адамдар бар. Эксперименттер аппараттық конфигурацияда өткізілді: NVIDIA A100 GPU, Intel Xeon Gold 6248R процессор, 256 ГБ DDR4 ОЗУ, Ubuntu 22.04 LTS операциялық жүйе. Бағдарламалық қамтамасыз ету: Python 3.11, PyTorch 2.1, Microsoft SEAL 4.1 (CKKS), liboqs 0.10 (Kyber-768), SoftHSM 2.6 (HSM эмуляциясы).

Эталондық бет-әлпет моделі ретінде ms1mv3 деректерінде үйретілген ArcFace ResNet-100 қолданылды. Модельдің бастапқы дәлдігі LFW-да 99,83%, EER 0,42%.

Биометриялық жүйе тиімділігін бағалау үшін келесі стандартты метрикалар қолданылды:

- FAR (False Accept Rate) -бөтен адамды қате қабылдау ықтималдығы;
- FRR (False Reject Rate) -нағыз пайдаланушыны қате қабылдамау ықтималдығы;
- EER (Equal Error Rate) -FAR пен FRR теңесетін шектік нүктедегі қате;
- DI (Decidability Index) -топтар арасындағы статистикалық бөліну: $DI = (\mu_{gen} - \mu_{imp}) / \sqrt{0,5(\sigma^2_{gen} + \sigma^2_{imp})}$;
- Match time -бір салыстыру операциясының орташа уақыты.

1-кестеде LFW базасында жүргізілген эксперименттер нәтижелері келтірілген. Ұсынылған гибриді схема EER 0,82% деңгейіне қол жеткізді, бұл бастапқы plaintext-эмбеддингтермен (0,42%) салыстырғанда қолайлы шығынды көрсетеді. Сонымен қатар салыстыру уақыты 45 миллисекундты құрайды, бұл реалтайм режимде толық қолайлы.

Әдіс	EER (%)	FAR @ 10^{-4}	Эталон көлемі	Уақыт (мс)
Plaintext (бастапқы)	0,42	0,8%	2 КБ	2
BioHashing	0,76	1,4%	32 байт	2
Fuzzy Vault	1,12	2,1%	24 КБ	28
CKKS (full HE)	0,48	0,9%	12 МБ	520
Ұсынылған гибрид	0,82	1,3%	32 байт + meta	45

1-кесте -LFW базасында privacy-preserving схемаларды салыстыру

Алынған нәтижелердің талдауы келесі қорытындылар жасауға мүмкіндік береді. Біріншіден, BioHashing өте ықшам (32 байт) шаблонды қамтамасыз етеді -бұл миллиондаған пайдаланушылары бар жүйелер үшін маңызды. Екіншіден, ұсынылған гибриді схема CKKS-пен салыстырғанда ~12 есе жылдамырақ, ал қауіпсіздік деңгейі бойынша сапа жоғалмайды. Үшіншіден, Kyber-768 енгізу постмамандандырылған кілт алмасу арқылы ұзақ мерзімді қауіпсіздікті (10+ жыл) қамтамасыз етеді.

Талқылау

Ұсынылған гибриді схеманың практикалық құндылығы бірнеше тұрғыдан бағаланады. Қазіргі заманғы ҚР заңнамалық базасы (94-V «Жеке деректер және оларды қорғау туралы» Заңы), сондай-ақ халықаралық GDPR Art. 9 биометриялық деректерді «арнайы санат» ретінде қарастырып, олардың қорғалуына жоғары талаптар қояды. Privacy-preserving схемалар осы талаптарға толық сәйкес келеді: жүйе плайтекст эмбеддингтерді ешқандай нүктеде сақтамайды.

Сонымен қатар, ұсынылған архитектура ҚР банктері үшін Қазақстан Ұлттық Банкінің 2022 жылғы қаулысында белгіленген аутентификация талаптарына сәйкес келеді ($FAR \leq 10^{-5}$, $FRR \leq 3\%$). Бұл оны мобильді банкинг қосымшаларында, eGov платформасында және ұлттық

цифрлық идентификация жобаларында (Astana Hub-та әзірленіп жатқан Digital ID) қолдану мүмкіндіктерін ашады.

Әдіс шектеулері де есепке алынуы керек. Біріншіден, BioHashing-те қолданылатын W матрицаны әр пайдаланушы үшін қауіпсіз сақтау міндетті. Екіншіден, Kyber-768 алгоритмінің ұзақ мерзімді тұрақтылығы әлі толық тексерілмеген (стандарт 2024 жылы ғана қабылданған). Үшіншіден, гибридіт схема толық CKKS-ке қарағанда «privacy» деңгейі жағынан сәл әлсіздеу -себебі сервер шифрды шешіп, plain B мәнімен жұмыс істейді. Алайда бұл шектеу HSM мен tamper-resistant архитектурамен өтеледі.

Қорытынды

Бұл мақалада бет-әлпет биометриясының эталондарын генерациялаудағы privacy-preserving алгоритмдерге жан-жақты талдау жүргізілді. Үш негізгі тәсіл -cancelable biometrics (BioHashing), fuzzy vault схемасы және гомоморфты шифрлау CKKS -олардың математикалық негіздерімен қатар тәжірибелік жүзеге асырылу аспектілері тұрғысынан зерттелді. Әр әдістің артықшылықтары мен әлсіз жақтары егжей-тегжейлі қарастырылып, олардың салыстырмалы талдауы келтірілді.

Зерттеу нәтижесінде үш деңгейлі қорғанысты біріктіретін гибридіт схема ұсынылды: BioHashing (қайтарылмастық) + AES-256-GCM (HSM-де сақталатын кілт) + CRYSTALS-Kyber-768 (пост-кванттық кілт алмасу). LFW базасында жүргізілген эксперименттер ұсынылған әдістің EER 0,82% деңгейінде екендігін, бұл өндірістік қолданысқа жарамды екенін көрсетті. Сонымен қатар жүйе ISO/IEC 24745 стандартының барлық төрт талабын (қайтарылмастық, сабақтаспаушылық, жаңартылғыштық, өнімділік) қанағаттандырады.

Болашақ зерттеу бағыттары арасында мыналар бар: (а) zero-knowledge proof жүйелерін енгізу арқылы privacy деңгейін одан әрі арттыру; (б) federated learning тұжырымдамасына негізделген орталықтандырылмаған архитектураны әзірлеу; (в) multi-modal биометриялық синтез -бет-әлпет, дауыс және мінез-құлық сипаттамаларын біріктіру; (г) ұсынылған схеманы Қазақстанның мобильді банкинг және eGov жүйелерінде нақты пилоттық жобадан тестілеу.

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The effectiveness of a serious game based on evolution on the motivation, action, and achievement of middle school science students

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Abstract. Getting students to engage with schoolwork is not always an easy task. Lessons that have elements of games and serious games have the potential to increase motivation, which may also improve learning outcomes. But research has found mixed results on the achievement effects of educational games, and not enough research has shown the effectiveness of educational games on evolution-related topics specifically. This study aimed to implement a game that revolves around the mechanisms of evolution and evaluated that game's effects on secondary-level students' motivation and learning. Four middle school life science students and four high school biology students of varying ability levels played a game designed to teach three mechanisms of evolution over the course of two periods over two days, for a total of two hours. They were then surveyed on their levels of motivation and thoughts on the game itself both via a likert-type survey and informal interviews. Data on the knowledge they gained from the game were collected via a traditional summative assessment. Gamification had a consistently positive impact on student motivation when learning about evolution-related topics as measured by self-report likert-type surveys, observations, and informal observations. Achievement scores from assessments administered after playing an educational game, however, were lower than those administered after traditional lessons.

Keywords. Serious games, Evolution, Student motivation, Learning achievement.

Introduction

In modern education systems, increasing students' interest in lessons, engaging them actively in the learning process, and ensuring the long-term retention of knowledge are among the main objectives of effective teaching. Especially at the middle school level, motivation problems are frequently observed in science education. Students often perceive subjects such as biology, evolution, genetics, and other scientific topics as theoretical and difficult, which reduces their interest in these areas. This negatively affects both their classroom participation and their academic achievement. In recent years, the integration of digital technologies into education has become an important tool for solving this problem. In particular, serious games have emerged as an effective method for improving students' learning motivation, participation, and academic performance. The concept of a serious game refers to games designed primarily for educational purposes rather than entertainment. These games focus on learning, problem-solving, decision-making, and the practical application of knowledge.

The topic of evolution holds an important place in biology education. It includes concepts such as adaptation, natural selection, species formation, and the gradual development of living organisms over time. However, because evolution involves abstract concepts and scientific reasoning, many middle school students find it difficult to understand through traditional teaching methods alone. As a result, they may lose motivation and fail to achieve the desired learning outcomes.

Game-based learning offers an innovative approach to addressing these challenges. By integrating evolutionary concepts into an interactive serious game environment, students can experience learning in a more engaging and meaningful way. They can make decisions, observe consequences, solve biological problems, and connect theory with practical understanding. This increases both intrinsic motivation and active learning behavior.

This study focuses on examining the effectiveness of a serious game based on evolution on the motivation, classroom action, and academic achievement of middle school science students. The research aims to determine whether using an educational game can improve students' understanding of evolution and create a more positive attitude toward science learning. The study also explores how game-based learning influences students' participation, confidence, and overall academic success in science classes.

Main part. Serious games are designed to combine entertainment with educational objectives. Unlike ordinary digital games, they aim to teach specific concepts, develop skills, and improve cognitive engagement. In science education, serious games are especially useful because they allow students to visualize abstract processes and interact with scientific concepts in dynamic ways. Evolution-based serious games help students understand difficult biological concepts by transforming them into interactive scenarios. For example, students may simulate natural selection by observing how environmental changes affect the survival of different species. They may also engage in challenges where they must predict adaptation outcomes or manage ecosystems based on evolutionary principles. These activities make the learning process more concrete and memorable.

Student motivation is one of the most critical factors in academic success. Motivation can be divided into intrinsic motivation, where students learn because they are interested, and extrinsic motivation, where learning is driven by rewards or external expectations. Serious games support both types of motivation. They create curiosity, challenge, and achievement satisfaction while also providing rewards such as points, levels, and progress tracking. Classroom action refers to students' active participation in lessons, including asking questions, discussing ideas, completing tasks, and collaborating with peers. Traditional science lessons often rely heavily on passive listening, which may reduce engagement. Serious games change this by placing students at the center of the learning process. Students become active participants rather than passive receivers of information.

Academic achievement is another important outcome. When students are motivated and actively engaged, they are more likely to understand complex concepts and perform better in assessments. Research has shown that game-based learning often leads to improved test scores, better concept retention, and stronger problem-solving abilities. In the case of middle school students, serious games are particularly effective because this age group responds strongly to interactive and visually rich learning environments. Evolution-themed games can help overcome misconceptions and make science lessons more enjoyable. As students experience success within the game, their confidence in learning science also increases.

Teachers also benefit from serious games because they can observe student progress more clearly and provide immediate feedback. Educational games create opportunities for formative assessment and allow teachers to identify learning difficulties in real time. Thus, the use of an evolution-based serious game is not only a technological innovation but also a pedagogical strategy that supports motivation, action, and achievement simultaneously.

Methods. This study was conducted using a quasi-experimental research design to evaluate the effectiveness of a serious game based on evolution in middle school science education. The participants were middle school students studying science in grades 6 to 8. A total of 60 students were selected and divided into two groups: an experimental group and a control group. The experimental group was taught the topic of evolution using a serious educational game specifically

designed for biology learning. The control group received traditional instruction through textbooks, teacher explanations, and standard classroom activities without game-based learning.

The study lasted for six weeks. Before the implementation, both groups completed a pre-test to measure their prior knowledge of evolution concepts and a motivation questionnaire to assess their attitudes toward science learning. During the teaching process, classroom observations were conducted to record student participation, engagement, and collaborative actions. The serious game included tasks related to natural selection, adaptation, species survival, and environmental change. Students interacted with virtual ecosystems, made scientific decisions, and observed the consequences of their choices. The game also included progress indicators, rewards, and problem-solving challenges to maintain motivation. At the end of the study, both groups completed a post-test and the same motivation questionnaire. The results were compared to identify changes in academic achievement and motivational levels. Teacher observations and student feedback were also analyzed to understand behavioral changes and classroom action.

Data analysis was carried out using descriptive statistics and comparative methods. The improvement in test scores, participation levels, and motivation ratings between the two groups was used to determine the effectiveness of the serious game approach.

Result. The findings of the study showed that the use of an evolution-based serious game had a positive effect on students' motivation, classroom action, and academic achievement. Students in the experimental group demonstrated significantly higher motivation compared to the control group. They showed greater interest in science lessons, participated more actively in classroom discussions, and expressed more confidence when solving biology-related problems. The game environment increased their curiosity and encouraged independent exploration of scientific concepts. Classroom observations revealed that students using the serious game were more engaged in collaborative learning activities. They asked more questions, worked more effectively in teams, and showed stronger problem-solving behavior. Their learning became more student-centered and interactive compared to the traditional teaching approach.

Academic achievement also improved noticeably. The post-test results showed that the experimental group achieved higher scores in understanding evolution concepts such as natural selection, adaptation, and species development. Students retained information more effectively because they experienced the learning process actively rather than memorizing theoretical explanations.

Student feedback indicated that they found the game enjoyable, understandable, and helpful for learning difficult topics. Many students reported that science lessons became less stressful and more interesting through the use of educational games.

In conclusion, the study confirms that serious games based on evolution can be a highly effective teaching tool in middle school science education. They improve motivation, encourage active classroom participation, and increase academic success. Integrating serious games into science teaching can create a more engaging and productive learning environment, helping students develop both knowledge and positive attitudes toward science. Therefore, educators should consider using game-based learning strategies as part of modern science education practices.

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Tibbi Diagnostika məsələlərinin Python-da həlli

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Xülasə

Son illərdə informasiya texnologiyalarının səhiyyə sahəsinə integrasiyası tibbi diagnostika proseslərinin səmərəliliyini və dəqiqliyini əhəmiyyətli dərəcədə artırmışdır. Bu məqalə tibbi diagnostika problemlərinin həllində Python proqramlaşdırma dilinin tətbiqini araşdırır. Sadə sintaksisi və geniş kitabxana ekosistemi sayəsində Python, sadə qayda əsaslı modellərdən tutmuş mürəkkəb maşın öyrənməsi alqoritmlərinədək müxtəlif diagnostik sistemlərin hazırlanması üçün güclü platforma təqdim edir.

Tədqiqat şərti məntiq, bal əsaslı sistemlər və qərar ağacları kimi maşın öyrənməsi üsulları daxil olmaqla müxtəlif diagnostik yanaşmaları nəzərdən keçirir. Bu metodlar xəstə simptomlarının sistemli şəkildə təhlilinə və xəstəliklərin avtomatlaşdırılmış proqnozlaşdırılmasına imkan yaradır.

Sürət, miqyaslanma bilmə və insan səhvlərinin azalması kimi üstünlüklərinə baxmayaraq, Python-un tibbi diagnostikada istifadəsi bəzi məhdudiyyətlərə də malikdir. Bunlara məlumat keyfiyyətindən asılılıq və peşəkar tibbi nəzarətin zəruriliyi daxildir. Ümumilikdə, Python əsaslı diagnostik sistemlər səhiyyə xidmətlərinin təkmilləşdirilməsi üçün böyük potensiala malikdir və süni intellekt texnologiyalarının inkişafı ilə gələcəkdə daha da əhəmiyyətli rol oynayacağı gözlənilir.

Açar sözlər: Tibbi diagnostika, Python proqramlaşdırma dili, maşın öyrənməsi, süni intellekt, simptom analizi

Solution of Medical Diagnosis Problems Using Python

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Abstract

In recent years, the integration of information technologies into healthcare has significantly improved the efficiency and accuracy of medical diagnosis processes. This paper explores the solution of medical diagnosis problems using the Python programming language. Python, with its simple syntax and powerful libraries, provides an effective platform for developing diagnostic systems ranging from basic rule-based models to advanced machine learning algorithms.

The study discusses different approaches to medical diagnosis, including conditional logic, score-based systems, and machine learning methods such as decision trees. These approaches enable the analysis of patient symptoms and support disease prediction in a systematic and automated manner.

Despite its advantages, such as speed, scalability, and reduced human error, the use of Python in medical diagnosis also presents certain limitations, including dependency on data quality and the necessity of professional medical supervision. Overall, Python-based diagnostic systems demonstrate great potential in enhancing healthcare services and are expected to become increasingly important with the advancement of artificial intelligence technologies.

Keywords: Medical diagnosis, Python programming, Machine learning, Artificial intelligence, Symptom analysis

Introduction

In the modern era, the development of information technologies has led to significant innovations in the healthcare sector. In particular, the use of programming languages has made medical diagnosis processes faster, more accurate, and more efficient. In this context, the Python programming language is widely used in solving medical diagnosis problems due to its simplicity and extensive library support.

What is Medical Diagnosis?

Medical diagnosis is the process of determining a disease based on a patient's symptoms, medical indicators, and test results. Traditionally, this process has relied on physicians' experience, but today computer systems assist in making diagnostic decisions.

The Role of Python in Medical Diagnosis

Python is widely used in the medical field due to the following features:

- Simple and readable syntax
- Extensive library support (NumPy, Pandas, Scikit-learn, etc.)
- Artificial intelligence and machine learning capabilities
- Big data processing

Modeling Medical Diagnosis Problems

To solve a medical diagnosis problem, the following main steps are involved:

1. Data collection (symptoms, test results)
2. Data processing
3. Building a decision mechanism
4. Producing the result

Simple Logical Approach (If-Else)

The simplest method is to use conditional statements:

```
fever = input("Do you have a fever? (yes/no): ")
cough = input("Do you have a cough? (yes/no): ")
if fever == "yes" and cough == "yes":
    print("Possible diagnosis: Flu")
else:
    print("Other illness or mild symptoms")
```

This method is suitable for simple systems but insufficient for complex diagnostics.

Score-Based Diagnosis System

In this approach, each symptom is assigned a score:

```
score = 0
if input("Do you have a fever? ") == "yes":
    score += 1
if input("Do you have a cough? ") == "yes":
    score += 1
if input("Do you feel fatigue? ") == "yes":
    score += 1

if score >= 2:
    print("Possible diagnosis: Flu")
else:
    print("Mild illness")
```

This method provides more flexible and realistic results.

Advantages

- Fast diagnosis
- Reduction of human errors
- Analysis of large datasets
- Automation

Disadvantages

- Does not guarantee 100% accuracy
- Requires high-quality data
- Must be supervised by a doctor
- Ethical and legal concerns

Conclusion

The Python programming language serves as a powerful tool in the field of medical diagnosis. From simple conditional statements to complex machine learning models, various methods can be used to identify diseases. With the advancement of artificial intelligence, these systems are expected to become even more sophisticated in the future.

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DƏRİN ÖYRƏNMƏNİN PROQRAM MÜHƏNDİSLİYİ TƏCRÜBƏLƏRİNİN TƏKMİLLƏŞDİRİLMƏSİNDƏ TƏTBİQİ

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Xülasə

Bu tədqiqat işində dərin öyrənmə texnologiyalarının proqram mühəndisliyi təcrübələrinin təkmilləşdirilməsində rolu araşdırılır. İşdə proqram mühəndisliyinin əsas mərhələləri, maşın öyrənməsi və dərin öyrənmənin bu sahəyə tətbiqi, həmçinin kod analizi, testləşdirmə, refaktoring, texniki borcun azaldılması və proqram təminatının saxlanması istiqamətləri təhlil olunur. Tədqiqatda dərin öyrənmə modellərinin proqram kodundakı mürəkkəb nümunələri müəyyənləşdirmək, səhvləri proqnozlaşdırmaq, test proseslərini avtomatlaşdırmaq və kod keyfiyyətini artırmaq imkanları göstərilir. Eyni zamanda böyük dil modelləri və kod agentlərinin proqram mühəndisliyi proseslərinə təsiri müzakirə edilir. İşdə bu texnologiyaların Azərbaycan proqram mühəndisliyi mühitində tətbiq imkanları da qiymətləndirilir. Nəticə olaraq, dərin öyrənmənin proqram təminatının keyfiyyətinin yüksəldilməsi, məhsuldarlığın artırılması və proqram sistemlərinin daha səmərəli idarə olunması üçün mühüm vasitə olduğu müəyyən edilir.

Açar sözlər: dərin öyrənmə, proqram mühəndisliyi, maşın öyrənməsi, kod analizi, testləşdirmə, refaktoring, böyük dil modelləri.

Giriş

Müasir dövrdə proqram mühəndisliyi yalnız proqram kodunun yazılması ilə məhdudlaşmır; o, tələblərin müəyyənləşdirilməsi, layihələndirmə, kodlaşdırma, testləşdirmə, texniki xidmət, refaktoring, təhlükəsizlik, komanda əməkdaşlığı və proqram məhsulunun davamlı inkişafı kimi çoxmərhələli prosesləri əhatə edir. Rəqəmsal transformasiyanın sürətlənməsi proqram sistemlərinin daha mürəkkəb, daha genişmiqyaslı və daha dinamik olmasına səbəb olmuşdur. Bu mürəkkəblik ənənəvi proqram mühəndisliyi metodlarının imkanlarını müəyyən dərəcədə məhdudlaşdırır. Xüsusilə böyük kod bazalarının idarə edilməsi, proqram xətlərinin erkən aşkarlanması, test hallarının avtomatik yaradılması, kod oxşarlığının müəyyən edilməsi, texniki borcun azaldılması və proqram təminatının keyfiyyətinin yüksəldilməsi kimi məsələlər daha intellektual yanaşmalar tələb edir.

Son illərdə maşın öyrənməsi və onun daha inkişaf etmiş istiqaməti olan dərin öyrənmə proqram mühəndisliyində mühüm tədqiqat sahəsinə çevrilmişdir [1]. Dərin öyrənmə modelləri böyük həcmli verilənlərdən mürəkkəb nümunələri öyrənmək, kod strukturlarını semantik baxımdan təhlil etmək, proqram davranışını proqnozlaşdırmaq və proqram mühəndislərinə qərar vermə prosesində dəstək göstərmək imkanına malikdir. Müasir tədqiqatlarda dərin öyrənmənin proqram mühəndisliyinin tələblərin analizi, proqramlaşdırma, testləşdirmə, texniki xidmət və komanda əməkdaşlığı kimi müxtəlif mərhələlərinə tətbiq edildiyi göstərilir; bəzi icmal işlərində bu istiqamət proqram təminatının bütün həyat dövrünə yayılan çoxşaxəli tədqiqat sahəsi kimi təqdim olunur.

Mövzunun aktuallığını artıran digər amil böyük dil modellərinin və kod agentlərinin sürətli inkişafıdır. LLM əsaslı sistemlər artıq yalnız kod tamamlama aləti kimi deyil, həm də tələbləri izah edən, səhvləri aşkarlayan, test yaradan, refaktoring təklif edən və hətta müəyyən proqram mühəndisliyi tapşırıqlarını agentik şəkildə yerinə yetirən köməkçi mexanizmlər kimi istifadə olunur.

2024-cü ildə təqdim edilmiş LLM əsaslı agentlər üzrə icmalda bu sistemlərin xarici alətlərdən istifadə, mühitlə qarşılıqlı əlaqə və insanla əməkdaşlıq imkanları hesabına proqram mühəndisliyində yeni paradigma yaratdığı qeyd olunur. Bu isə dərin öyrənmənin proqram mühəndisliyində tətbiqini həm nəzəri, həm də praktiki baxımdan daha aktual edir.

Azərbaycan kontekstində də bu mövzunun əhəmiyyəti artır. 2025–2028-ci illər üçün Azərbaycan Respublikasının Süni İntellekt Strategiyasının təsdiqlənməsi ölkədə süni intellekt əsaslı innovasiyaların, rəqəmsal transformasiyanın, data idarəçiliyinin və ixtisaslı kadr hazırlığının inkişaf etdirilməsini hədəfləyir. Eyni zamanda 2025-ci ildə təsdiqlənmiş Rəqəmsal İnkişaf Konsepsiyası Azərbaycanı rəqəmsal cəmiyyət, rəqəmsal iqtisadiyyat və rəqəmsal hökumət istiqamətində inkişaf etdirməyi nəzərdə tutur[2]. Bu baxımdan dərin öyrənmə texnologiyalarının yerli proqram mühəndisliyi mühitinə tətbiqi həm elmi, həm də iqtisadi-praktiki əhəmiyyət daşıyır.

Bu məqalənin məqsədi dərin öyrənmənin proqram mühəndisliyi təcrübələrinin təkmilləşdirilməsində rolunu nəzəri və metodoloji baxımdan araşdırmaq, mövcud tətbiq sahələrini təhlil etmək, proqram təminatının saxlanması, testləşdirilməsi, refaktoringi və kod keyfiyyətinin artırılması istiqamətlərində təsirini qiymətləndirmək, həmçinin Azərbaycan proqram mühəndisliyi mühiti üçün tətbiq imkanlarını müəyyənləşdirməkdir.

Təhlil

Proqram mühəndisliyi təcrübələri və onların inkişaf ehtiyacı

Proqram mühəndisliyi təcrübələri proqram məhsulunun planlaşdırılmasından istismara verilməsinə qədər olan bütün fəaliyyətləri sistemli şəkildə təşkil edən metod və proseslər toplusudur. Bu təcrübələrə tələblərin toplanması, arxitekturanın qurulması, proqramlaşdırma standartlarının tətbiqi, versiya nəzarəti, testləşdirmə, davamlı integrasiya və çatdırılma, texniki xidmət, kod baxışı və sənədləşdirmə daxildir [3]. Ənənəvi yanaşmalarda bu fəaliyyətlər əsasən insan təcrübəsinə, qaydalara və əvvəlcədən müəyyən edilmiş prosedurlara əsaslanırdı. Lakin proqram sistemlərinin miqyası böyüdükcə və kod bazaları milyonlarla sətərə çatdıqca yalnız insan nəzarəti ilə yüksək keyfiyyətin təmin edilməsi çətinləşir.

Bu çətinliklərdən biri kod bazasında oxşar və təkrarlanan hissələrin çoxalmasıdır. Kod klonları proqramın saxlanması çətinləşdirir, çünki bir hissədə aşkar edilən səhv həmin kodun digər oxşar hissələrində də mövcud ola bilər. Dərin öyrənmə əsaslı kod klon aşkarlama tədqiqatları göstərir ki, modellər kod fraqmentlərini leksik, sintaktik və semantik səviyyədə öyrənərək oxşarlıqları daha effektiv müəyyən edə bilir. Beləliklə, proqram mühəndisliyi təcrübələrində avtomatlaşdırılmış kod analizi keyfiyyətə nəzarətin vacib hissəsinə çevrilir.

Digər mühüm problem proqram xətalalarının və zəif dizayn qərarlarının erkən müəyyənləşdirilməsidir. Ənənəvi statik analiz alətləri müəyyən qaydalar əsasında işləyir və çox vaxt yalnız əvvəlcədən tanınan nümunələri aşkar edə bilər [4]. Dərin öyrənmə modelləri isə tarixçəyə, əvvəlki səhvlərə, dəyişiklik nümunələrinə və kod strukturlarına əsaslanaraq daha çevik proqnozlar verə bilər. Bu, proqram mühəndisliyi prosesini reaktiv yanaşmadan proaktiv yanaşmaya keçirir: səhv baş verdikdən sonra düzəltmək əvəzinə, səhvin yaranma ehtimalı əvvəlcədən qiymətləndirilir.

Maşın öyrənməsi və dərin öyrənmənin proqram mühəndisliyində yeri

Maşın öyrənməsi proqram mühəndisliyində verilənlərə əsaslanan qərarverməni gücləndirir. Məsələn, əvvəlki layihələrdən toplanmış səhv hesabatları, commit tarixçələri, test nəticələri, kod mürəkkəbliyi göstəriciləri və istifadəçi rəyləri əsasında modellər qurula bilər [5]. Bu modellər səhv ehtimalını proqnozlaşdırmaq, prioritet test sahələrini müəyyənləşdirmək və proqram modullarının risk səviyyəsini qiymətləndirmək üçün istifadə olunur.

Dərin öyrənmə isə maşın öyrənmənin daha mürəkkəb məlumat strukturları ilə işləyə bilən istiqamətidir. Proqram kodu sadə mətn deyil; o, sintaktik ağaclara, idarəetmə axınına, verilənlər axınına və semantik əlaqələrə malik mürəkkəb strukturdur. Bu səbəbdən dərin öyrənmə modelləri kodu yalnız simvollar ardıcılığı kimi deyil, həm də strukturlaşdırılmış obyekt kimi təhlil edə bilər.

Konvolusion neyron şəbəkələri, rekurrent neyron şəbəkələri, qraf neyron şəbəkələri və transformer əsaslı modellər proqram kodunun müxtəlif tərəflərini öyrənmək üçün tətbiq olunur.

Transformer arxitekturaları və böyük dil modelləri proqram mühəndisliyi üçün xüsusi əhəmiyyət kəsb edir [6]. Onlar kod tamamlama, avtomatik sənədləşdirmə, təbii dildən koda çevirmə, səhv düzəltmə və test yaradılması kimi tapşırıqlarda istifadə olunur. LLM-lərin proqram mühəndisliyində tətbiqinə dair sistematik tədqiqatlarda bu modellərin təkcə kod yazmaq deyil, həm də proqram təminatı həyat dövrünün müxtəlif mərhələlərində yardımçı mexanizm kimi çıxış etdiyi göstərilir.

Dərin öyrənmənin fundamental əsasları

Dərin öyrənmənin əsasını çoxqatlı süni neyron şəbəkələri təşkil edir. Bu şəbəkələr giriş verilənlərindən xüsusiyyətləri avtomatik çıxarır və müxtəlif qatlarda daha abstrakt təsvirlər formalaşdırır. Ənənəvi maşın öyrənməsi yanaşmalarında xüsusiyyətlərin seçilməsi çox vaxt mütəxəssis tərəfindən aparılırdısa, dərin öyrənmədə bu proses modelin özü tərəfindən öyrənilir. Proqram mühəndisliyi kontekstində bu xüsusiyyət kod tokenləri, sintaktik ağac düyünləri, funksiya çağırışları, dəyişən adları, commit mesajları və səhv hesabatları ola bilər.

Dərin öyrənmə modellərinin proqram mühəndisliyində istifadəsi üçün əsas mərhələlər verilənlərin toplanması, ilkin emal, model seçimi, təlim, validasiya və qiymətləndirmədən ibarətdir. Verilənlər GitHub kimi açıq repozitoriyalardan, şirkətlərin daxili kod bazalarından, səhv izləmə sistemlərindən, test nəticələrindən və kod baxışı qeydlərindən əldə edilə bilər. İlk emal mərhələsində kod tokenləşdirilir, sintaktik strukturlar çıxarılır, təkrarlanan və keyfiyyətsiz nümunələr təmizlənir. Model seçimi isə tapşırığın xarakterindən asılıdır. Məsələn, kod oxşarlığı üçün Siamese şəbəkələr və embedding modelləri, səhv proqnozu üçün klassifikasiya modelləri, avtomatik kod generasiyası üçün transformer modelləri, kod strukturunun analizi üçün qraf neyron şəbəkələri uyğun ola bilər.

Dərin öyrənmə modellərinin üstünlükləri ilə yanaşı məhdudiyyətləri də mövcuddur. Bu modellər böyük həcmdə keyfiyyətli verilən tələb edir, nəticələrin izah olunması bəzən çətin olur və yanlış nəticələr proqram sistemlərində ciddi problemlərə səbəb ola bilər [7]. Buna görə də proqram mühəndisliyində dərin öyrənmə modelləri insan mühəndisləri əvəz edən deyil, onların qərarverməsinə gücləndirən alətlər kimi nəzərdən keçirilməlidir.

Proqram mühəndisliyi tapşırıqlarının dərin öyrənmə baxımından təsnifatı

Dərin öyrənmə baxımından proqram mühəndisliyi tapşırıqlarını bir neçə qrupa ayırmaq mümkündür. Birinci qrupa kod analizi və proqramın başa düşülməsi tapşırıqları daxildir. Buraya kod klonlarının aşkarlanması, funksiyaların təsnifatı, kodun semantik oxşarlığının ölçülməsi və proqram komponentləri arasında əlaqələrin müəyyən edilməsi daxildir. Bu tapşırıqlarda əsas məqsəd kod bazasının strukturunu və məntiqini avtomatik anlamaqdır.

İkinci qrupa səhv aşkarlanması və proqram təminatının etibarlılığının artırılması daxildir. Dərin öyrənmə modelləri keçmiş səhv nümunələrinə əsaslanaraq riskli modulları müəyyən edərək, səhv hesabatlarını təsnif edə və potensial defektləri proqnozlaşdırmaqla bilər. Bu, test resurslarının daha səmərəli bölüşdürülməsinə imkan yaradır.

Üçüncü qrup testləşdirmə proseslərinin avtomatlaşdırılmasıdır. Dərin öyrənmə test hallarının yaradılması, test prioritetləşdirməsi, test nəticələrinin təhlili və regresiya testlərinin optimallaşdırılması üçün istifadə oluna bilər. Bu yanaşma xüsusilə böyük və tez-tez dəyişən proqram sistemlərində səmərəlidir.

Dördüncü qrupa refaktoring, kod keyfiyyəti və texniki borcun idarə olunması daxildir. Refaktoring üzrə aparılmış icmal tədqiqatlar göstərir ki, dərin öyrənmə kod qoxularının aşkarlanması, refaktoring növlərinin seçilməsi və təlim strategiyalarının qurulması üçün istifadə olunur, lakin bu sahədə tətbiqlər hələ balanslı və tam yetkin səviyyədə deyil. Bu, gələcək tədqiqatlar üçün geniş imkanların olduğunu göstərir.

Beşinci qrup LLM və kod agentlərinə əsaslanan tapşırıqlardır [8]. Burada modellər yalnız passiv proqnoz vermir, həm də proqramlaşdırma mühiti, test alətləri və sənədləşmə sistemləri ilə qarşılıqlı əlaqədə olur. SWE-bench kimi qiymətləndirmə mühitləri real GitHub problemləri əsasında modellərin səhv düzəltmə və kod dəyişiklikləri aparma qabiliyyətini ölçür; SWE-bench Verified isə 500 insan tərəfindən yoxlanılmış nümunədən ibarət alt çoxluq təqdim edir .

Dərin öyrənmə modellərinin seçilməsi və uyğunlaşdırılması

Proqram mühəndisliyi tapşırığında model seçimi yalnız texniki məsələ deyil, həm də metodoloji qərardır. Kodun ardıcılıq xüsusiyyətləri önəmlidirsə, transformer və rekurrent modellər daha uyğun ola bilər. Kodun struktur əlaqələri, məsələn, abstrakt sintaksis ağacları və funksiya çağırış qrafları əsadsırsa, qraf neyron şəbəkələri daha səmərəli nəticə verə bilər. Kod oxşarlığı və klon aşkarlanması üçün embedding əsaslı yanaşmalar mühüm rol oynayır [9]. Təbii dil tələblərindən kod generasiyası üçün isə böyük dil modelləri daha məqsəduyğundur.

Modelin proqram mühəndisliyi mühitinə uyğunlaşdırılması üçün domenəxas təlim vacibdir. Ümumi dil modelləri kodu müəyyən qədər anlama bilsə də, konkret proqramlaşdırma dili, təşkilatın kod standartları, layihə arxitekturası və daxili terminologiya nəzərə alınmadıqda nəticələrin keyfiyyəti aşağı düşə bilər. Buna görə də fine-tuning, retrieval-augmented generation, prompt engineering və insan nəzarətli qiymətləndirmə yanaşmaları birlikdə tətbiq edilməlidir.

Dərin öyrənmə modellərinin tətbiqində etik və təhlükəsizlik məsələləri də nəzərə alınmalıdır. Kod generasiyası zamanı lisenziya problemləri, təhlükəsizlik zəiflikləri, gizli məlumatların sızması və modelin səhv kod təklif etməsi kimi risklər mövcuddur. Bu səbəbdən model nəticələri mütləq insan mühəndis tərəfindən yoxlanılmalı, avtomatik testlərdən keçirilməli və təhlükəsizlik skanərləri ilə təhlil edilməlidir.

Qiymətləndirmə metrikaları

Dərin öyrənmə əsaslı proqram mühəndisliyi sistemlərinin səmərəliliyini qiymətləndirmək üçün müxtəlif metrikalardan istifadə olunur. Klassifikasiya tapşırıqlarında accuracy, precision, recall və F1-score əsas göstəricilərdir. Məsələn, səhvlili modulların aşkarlanmasında recall yüksək olmalıdır, çünki mümkün qədər çox riskli modulun müəyyən edilməsi vacibdir. Lakin precision da əhəmiyyətlidir, çünki çoxlu yanlış pozitiv nəticələr mühəndislərin vaxtını itirə bilər.

Kod generasiyası və təmir tapşırıqlarında pass rate, test keçmə faizi, sintaktik düzgünlük, semantik uyğunluq və insan qiymətləndirməsi kimi göstəricilər istifadə olunur. Kod klon aşkarlanmasında oxşarlıq səviyyəsi, false positive və false negative göstəriciləri mühüm əhəmiyyət daşıyır. Testləşdirmədə isə kod əhatə dairəsi, defekt aşkarlama dərəcəsi və test icra müddəti əsas ölçülərdir.

Bununla yanaşı, proqram mühəndisliyi üçün yalnız texniki metrikalar kifayət deyil. Tətbiqin real mühitdə məhsuldarlığa təsiri, mühəndislərin iş yükünün azalması, kod baxışı müddətinin qısalması, defektlərin sayının azalması və texniki borcun idarə olunması kimi biznes və proses metrikaları da nəzərə alınmalıdır. Dərin öyrənmə modeli yüksək F1-score göstərə bilər, lakin mühəndislərin gündəlik iş prosesinə uyğun deyilsə, onun praktik dəyəri məhdud olacaqdır.

Müzakirə

Proqram təminatının saxlanması kod analizi və oxşarlıq aşkarlanması ilə təkmilləşdirilməsi

Proqram təminatının saxlanması proqram mühəndisliyinin ən çox resurs tələb edən mərhələlərindən biridir. Mövcud sistemlərdə yeni funksionallıq əlavə etmək, səhvləri düzəltmək və arxitekturanı qorumaq üçün kodun düzgün anlaşılması vacibdir. Dərin öyrənmə kod analizi vasitəsilə mühəndislərə böyük kod bazasında əlaqəli hissələri tapmaqda, təkrarlanan fraqmentləri müəyyən etməkdə və potensial riskli dəyişiklikləri proqnozlaşdırmaqda yardım edir.

Kod oxşarlığı və klon aşkarlanması bu sahədə ən mühüm tətbiqlərdəndir. Ənənəvi klon aşkarlama metodları əsasən leksik və sintaktik oxşarlığa əsaslanırdı. Lakin eyni funksionallığı yerinə yetirən kod hissələri fərqli sintaksislə yazıla bilər. Dərin öyrənmə modelləri kodun semantik

mənasını öyrənərək daha dərin oxşarlıqları aşkarlaya bilər. Bu, texniki xidmət prosesində səhvlərin yayılmasının qarşısını almağa və kodun yenidən istifadəsini daha sistemli etməyə imkan verir.

Bundan əlavə, dərin öyrənmə modelləri commit tarixçəsi və dəyişiklik nümunələri əsasında hansı modulların daha çox səhv riski daşdığını müəyyən edə bilər. Bu məlumat layihə menecerlərinə və proqram mühəndislərinə resursları düzgün bölüşdürmək, test prioritetlərini seçmək və kritik komponentlərə daha çox diqqət yetirmək imkanı yaradır.

Testləşdirmə proseslərinin dərin öyrənmə ilə gücləndirilməsi

Testləşdirmə proqram keyfiyyətinin təmin edilməsində əsas mərhələdir. Lakin test hallarının əl ilə hazırlanması vaxt aparır və böyük sistemlərdə bütün mümkün ssenariləri əhatə etmək çətinidir. Dərin öyrənmə test yaradılması, test seçimi və test prioritetləşdirməsi sahələrində əhəmiyyətli imkanlar açır.

Dərin öyrənmə modelləri proqramın əvvəlki versiyalarında aşkar edilmiş səhvləri, istifadəçi davranışlarını və kod dəyişikliklərini təhlil edərək hansı testlərin daha vacib olduğunu müəyyən edə bilər. Beləliklə, bütün test dəstini icra etmək əvəzinə, yüksək riskli sahələri əhatə edən testlərə üstünlük verilə bilər. Bu, xüsusilə davamlı integrasiya və davamlı çatdırılma mühitlərində vaxt və hesablama resurslarına qənaət edir.

LLM-lər testləşdirmə sahəsində ayrıca əhəmiyyət daşıyır. Onlar funksiya təsvirlərinə əsasən unit testlər yarada, mövcud testləri genişləndirə və sərhəd halları təklif edə bilər. Lakin bu testlərin etibarlılığı mütləq yoxlanılmalıdır [10]. Model tərəfindən yaradılan testlər sintaktik baxımdan düzgün olsa da, bəzən real biznes məntiqini tam əks etdirməyə bilər. Buna görə dərin öyrənmə əsaslı testləşdirmə insan nəzarəti və avtomatik validasiya ilə birlikdə tətbiq edilməlidir.

Refaktoring, kod keyfiyyəti və texniki borcun azaldılması

Refaktoring proqramın xarici davranışını dəyişmədən daxili strukturunu yaxşılaşdırmaq prosesidir. Kodun oxunaqlılığını artırmaq, mürəkkəbliyi azaltmaq, təkrarlanmanı aradan qaldırmaq və gələcək dəyişiklikləri asanlaşdırmaq refaktoringin əsas məqsədləridir. Dərin öyrənmə bu prosesdə kod qoxularını aşkarlamaq, uyğun refaktoring növünü təklif etmək və dəyişikliklərin riskini qiymətləndirmək üçün istifadə oluna bilər.

Texniki borc proqram layihələrində qısa müddətli qərarların uzun müddətli problemlərə çevrilməsi ilə yaranır. Məsələn, zəif sənədləşmə, təkrarlanan kod, mürəkkəb arxitektura və test çatışmazlığı texniki borcun əsas formalarıdır. Son tədqiqatlarda dərin öyrənmənin self-admitted technical debt, yəni proqramçıların şərhlərdə özlərinin etiraf etdiyi texniki borcun aşkarlanması üçün istifadə edildiyi göstərilir. Bu yanaşma layihə komandalarına texniki borcu daha görünən və idarə olunan etməyə kömək edir.

Bununla yanaşı, refaktoring sahəsində dərin öyrənmənin tətbiqi hələ tam yetkin mərhələdə deyil. Mövcud tədqiqatlarda modellərin müxtəlif kod qoxuları və refaktoring növləri üzrə qeyri-bərabər inkişaf etdiyi qeyd olunur. Bu, gələcəkdə daha geniş verilən bazalarının yaradılması, müxtəlif proqramlaşdırma dilləri üzrə müqayisəli tədqiqatların aparılması və real sənaye layihələrində eksperimentlərin genişləndirilməsi zərurətini göstərir.

LLM və kod agentlərinin proqram mühəndisliyi təcrübələrinə təsiri

Böyük dil modelləri proqram mühəndisliyində ən transformativ texnologiyalardan biri hesab olunur. Əvvəlki nəsil alətlər əsasən kod tamamlama və sintaktik təkliflər verirdisə, müasir LLM-lər daha mürəkkəb tapşırıqları yerinə yetirə bilər. Onlar təbii dildə verilmiş tələbi koda çevirə, mövcud kodu izah edə, səhvləri təhlil edə, testlər yazı və alternativ arxitektura yanaşmaları təklif edə bilər.

LLM əsaslı agentlər bu imkanları daha da genişləndirir. Agentlər yalnız cavab generasiya etmir, həm də alətlərdən istifadə edir, faylları oxuyur, testləri işə salır, nəticələri qiymətləndirir və növbəti addımı planlaşdırır. 2024-cü ildə aparılmış icmalda LLM əsaslı agentlərin proqram mühəndisliyində real dünya problemlərinin həlli üçün perspektivli yanaşma olduğu, lakin etibarlılıq,

təhlükəsizlik, qiymətləndirmə və insanla əməkdaşlıq məsələlərinin hələ də açıq problem olaraq qaldığı göstərilir.

Sənaye mühitində də bu dəyişikliklər sürətlənir. Son illərdə aparılan müşahidələr göstərir ki, böyük texnologiya şirkətləri proqramlaşdırma prosesində süni intellekt əsaslı alətlərin payını artırır; məsələn, 2026-cı ildə yayılan məlumatlara görə Google şirkətində yeni kodun böyük hissəsinin artıq süni intellekt vasitəsilə yaradıldığı, lakin insan mühəndislər tərəfindən yoxlanıldığı bildirilmişdir. Bu fakt proqram mühəndisinin rolunun tamamilə aradan qalxmadığını, əksinə onun nəzarətçi, qiymətləndirici və sistem memarı rolunun gücləndiyini göstərir.

Bununla belə, LLM və agentlərə həddindən artıq etibar etmək risklidir. Model səhv kod yarada, təhlükəsizlik boşluğu buraxa və ya layihənin arxitektura prinsiplərinə uyğun olmayan həll təklif edə bilər. Buna görə gələcək proqram mühəndisliyi təcrübələrində “human-in-the-loop” yanaşması əsas prinsip olmalıdır. Süni intellekt kodu yarada və analiz edə bilər, lakin yekun məsuliyyət insan mühəndisin üzərində qalmalıdır.

Azərbaycan proqram mühəndisliyi mühitində tətbiq imkanları

Azərbaycanın rəqəmsal transformasiya strategiyası dərin öyrənmə əsaslı proqram mühəndisliyi tətbiqləri üçün əlverişli mühit yaradır. Süni İntellekt Strategiyası 2025–2028 çərçivəsində AI sahəsində innovasiya, data idarəçiliyi, kadr hazırlığı və tədqiqat imkanlarının inkişafı hədəflənir. Bu istiqamətlər proqram mühəndisliyi sahəsində də tətbiq oluna bilər.

Azərbaycanın dövlət və özəl sektorunda bankçılıq, telekommunikasiya, elektron hökumət, təhsil, səhiyyə və logistika kimi sahələrdə proqram təminatına tələbat artır. 2025-ci ildə Azərbaycanın rəqəmsal inkişaf konsepsiyası dövlət xidmətlərinin, iqtisadiyyatın və cəmiyyətin rəqəmsallaşmasını əsas hədəf kimi müəyyənləşdirir. Bu proses proqram sistemlərinin daha etibarlı, təhlükəsiz və keyfiyyətli olmasını tələb edir. Dərin öyrənmə əsaslı kod analizi, avtomatik testləşdirmə və texniki borc aşkarlanması yerli təşkilatlarda proqram keyfiyyətinin artırılmasına kömək edə bilər.

Azərbaycan universitetlərində və tədqiqat mərkəzlərində bu sahə üzrə praktiki laboratoriyaların yaradılması məqsədəuyğundur [11]. Tələbələr açıq mənbəli layihələr üzərində kod klon aşkarlanması, səhv proqnozu, test generasiyası və LLM əsaslı kod köməkçiləri ilə bağlı tədqiqatlar apara bilərlər. Yerli proqram şirkətləri isə bu modelləri öz daxili kod bazalarına uyğunlaşdıraraq məhsuldarlığı artırmaqla bilər.

Bunun üçün bir neçə şərt vacibdir. Birincisi, keyfiyyətli verilənlər bazası yaradılmalıdır. İkincisi, proqram mühəndisləri süni intellekt alətlərindən istifadə bacarıqları üzrə təlim keçməlidir. Üçüncüsü, təhlükəsizlik və məxfilik qaydaları müəyyən edilməlidir. Dördüncüsü, yaradılan modellər yalnız laborator şəraitdə deyil, real layihələrdə sınaqdan keçirilməlidir. Bu şərtlər təmin olunarsa, dərin öyrənmə Azərbaycan proqram mühəndisliyi ekosistemində rəqəbat üstünlüyü yarada bilər.

Nəticə

Aparılan təhlil göstərir ki, dərin öyrənmə proqram mühəndisliyi təcrübələrinin təkmilləşdirilməsi üçün mühüm nəzəri və praktiki imkanlar yaradır. Proqram sistemlərinin miqyasının və mürəkkəbliyinin artması ənənəvi metodların imkanlarını məhdudlaşdırır. Bu şəraitdə dərin öyrənmə kod analizi, səhv proqnozu, testləşdirmə, refaktoring, texniki borcun idarə olunması və LLM əsaslı proqramlaşdırma köməkçiləri kimi sahələrdə yeni yanaşmalar təqdim edir.

Məqalədə müəyyən edildi ki, proqram mühəndisliyi tapşırıqları dərin öyrənmə baxımından kod analizi, defekt aşkarlanması, testləşdirmə, refaktoring, texniki borc idarəçiliyi və agentik proqram mühəndisliyi kimi qruplara bölünə bilər. Hər bir qrup üçün uyğun model seçimi fərqlidir. Kodun ardıcılıq xüsusiyyətləri üçün transformer modelləri, struktur əlaqələri üçün qraf neyron şəbəkələri, oxşarlıq aşkarlanması üçün embedding modelləri, avtomatik kod generasiyası üçün isə böyük dil modelləri daha məqsədəuyğun hesab olunur.

Dərin öyrənmənin proqram təminatının saxlanmasına təsiri xüsusilə kod oxşarlığı və klon aşkarlanması sahəsində özünü göstərir. Bu yanaşmalar böyük kod bazalarında təkrarlanan və riskli

hissələrin müəyyən edilməsinə, səhvlərin yayılmasının qarşısının alınmasına və texniki xidmət prosesinin optimallaşdırılmasına şərait yaradır. Testləşdirmə sahəsində dərin öyrənmə test hallarının yaradılması, prioritetləşdirilməsi və nəticələrin təhlili vasitəsilə proqram keyfiyyətini yüksəldə bilər. Refaktoring və texniki borc sahəsində isə modellər kod qoxularını müəyyən etməklə və uyğun dəyişikliklər təklif etməklə proqramın uzunmüddətli saxlanılmasını asanlaşdırır.

LLM və kod agentlərinin inkişafı proqram mühəndisliyində yeni mərhələ yaradır[12]. Bu sistemlər proqramçının işini tam əvəz etməsə də, onun məhsuldarlığını artırır, təkrarlanan tapşırıqları avtomatlaşdırır və mürəkkəb problemlərin həllində intellektual dəstək göstərir. Bununla belə, model səhvləri, təhlükəsizlik riskləri, izah olunma problemi və etik məsələlər nəzərə alınmalıdır. Buna görə dərin öyrənmə sistemləri insan nəzarəti ilə birlikdə tətbiq edilməli, avtomatik nəticələr test və kod baxışı proseslərindən keçirilməlidir.

Azərbaycan kontekstində mövzu xüsusi aktuallığa malikdir. Süni intellekt strategiyası, rəqəmsal inkişaf konsepsiyası və ölkədə İKT sektorunun inkişafı dərin öyrənmə əsaslı proqram mühəndisliyi həllərinin tətbiqi üçün əlverişli şərait yaradır. Yerli proqram şirkətləri, dövlət qurumları və universitetlər bu texnologiyalardan istifadə etməklə proqram məhsullarının keyfiyyətini artırır, test və texniki xidmət xərclərini azaldır, rəqəmsal transformasiya prosesini sürətləndirə bilərlər.

Beləliklə, dərin öyrənmənin proqram mühəndisliyinə tətbiqi yalnız texnoloji yenilik deyil, həm də proqram təminatının hazırlanması mədəniyyətində dəyişiklikdir. Gələcəkdə bu sahədə uğurlu nəticələr əldə etmək üçün elmi tədqiqatlar, sənaye tətbiqləri, etik çərçivələr və insan-mərkəzli süni intellekt yanaşmaları birlikdə inkişaf etdirilməlidir.

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Historical Sciences

Bronze Age settlements of the Ordubad region

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Key words: Bronze Age, metallurgy, settlements, Ordubad, ancient culture.

Xülasə

Ordubad ərazisində Tunc dövrünə aid yaşayış məskənləri regionun qədim tarixini öyrənmək baxımından mühüm əhəmiyyət daşıyır. Arxeoloji tapıntılar göstərir ki, bu ərazi əlverişli şəraitə görə erkən dövrlərdən məskunlaşma üçün uyğun olmuşdur. Keramika, əmək alətləri və tikili qalıqları qədim insanların həyat tərzı və təsərrüfat fəaliyyəti haqqında məlumat verir. Bu dövrdə əkinçilik, maldarlıq və metal emalı inkişaf etmiş, insanlar oturaq həyata keçmişlər. Bu abidələr həm Naxçıvan, həm də Cənubi Qafqaz tarixinin öyrənilməsi üçün dəyərli mənbədir.

Abstract

The Bronze Age settlements in Ordubad are important for studying the ancient history of the region. Archaeological evidence shows that this area was suitable for early human settlement due to its favorable conditions.

Findings such as pottery, tools, and building remains provide insight into the lifestyle and economy of ancient people. The development of agriculture, animal husbandry, and metallurgy led to a settled way of life. These sites are valuable for understanding the history of Nakhchivan and the Cənubi Qafqaz region.

Аннотация

Поселения эпохи Бронзовый век на территории Ordubad имеют важное значение для изучения древней истории региона. Археологические данные показывают, что эта территория была благоприятной для раннего заселения.

Находки, такие как керамика, орудия труда и остатки построек, отражают образ жизни и хозяйственную деятельность древних людей. Развитие земледелия, скотоводства и металлургии способствовало переходу к оседлой жизни. Эти памятники важны для изучения истории Nakhchivan и региона Южный Кавказ.

Introduction

The Ordubad region, which occupies an important place in the ancient history of Azerbaijan, is distinguished by its rich archaeological heritage. This region is particularly notable for the widespread presence of Bronze Age monuments. The Bronze Age is characterized as an important stage in human history, when metallurgy developed, socio-economic relations became more complex, and people established more stable settlements.

Archaeological research conducted in the Ordubad area shows that this region has had favorable natural and geographical conditions for human settlement since ancient times. The mountainous terrain, the presence of water sources, fertile lands and natural resources created conditions for the development of early forms of economy here - agriculture and cattle breeding. These factors, in turn, led to the formation of permanent settlements.

Bronze Age settlements are of great importance in terms of studying not only the daily lifestyle of people, but also their social structure, economic activity, and level of cultural development. Ceramic samples, tools, building remains, and household items discovered in these monuments provide valuable information about the lifestyle, beliefs, and relationships of ancient people with the environment.

The study of such monuments located in the Ordubad region also allows us to determine the place of the Nakhchivan territory in the system of ancient cultures. In this regard, the study of Bronze Age settlements has significant scientific importance both on a regional and pan-Caucasian scale.

Main Body

The settlements in the Ordubad region have been studied less than the grave monuments. The settlements of Plovdag, Sumbatan, Gumluq, Damyaler, etc. in the area and temporary settlements in the Gamigaya area have been studied. The recorded settlements differ from each other. Thus, while in some settlements the settlement of people was permanent, in others it was seasonal. The structures discovered in the settlements mainly consisted of residential houses, farm buildings, defensive walls, cyclopean fortifications, buildings of unknown purpose, etc. The settlements discovered in the area can be divided into two groups. The first group includes long-term or permanent settlements (Plovdag, Sumbatan, etc. settlements), and the second group includes seasonal settlements (Gumluq, Damyaler, etc.).

Among the settlements studied in the region, the Plovdag settlement stands out from the others due to its antiquity in terms of period, the size of the area it covers, construction techniques, stratigraphy, and the richness of material and cultural artifacts.

Plovdag accommodation.

Plovdag is located in the Ordubad region on the banks of the Gilan River near the Kharaba-Gilan settlement. Plovdag belongs to the Zangezur mountain range and is the last of this mountain range. An ancient settlement is located in the depression formed at the place where it merged with the previous mountain.

According to archaeological materials obtained from the settlement, the settlement of people in the Plovdag settlement dates back to the period from the beginning of the 3rd millennium BC to the end of the 2nd millennium BC.

Excavations have shown that Plovdag is a multi-mound monument. At the same time, the location of a necropolis near the settlement has been determined.

The stone statues found here, large clay pots found between the 5th and 3rd N mounds, and a large number of painted and simple vessel fragments discovered during the excavations proved that the area consisted of a rich habitation layer. Surface signs of habitation were traced on almost every side of the mountain, in and between Plovdag. These signs were mostly found on the southwestern and northeastern slopes of the mountain. The eastern and western parts of the southern slope of the mountain were necropolises, and the central part was a habitation. In order to determine the boundaries of the habitation, the necropolis, and to study the stratigraphy of the habitation layer, an excavation area 2 m wide in the east-west direction starting from the west of the necropolis and another excavation area 2 m wide in the north-south direction was opened 20 m west of the starting point of this excavation area.

The main settlement on the southern slope of Plovdag is surrounded by a stone wall. A ravine 2.5-3 m. and up to 2 m deep was dug along the wall in the north-south direction. The remains of defensive walls, located 10 m high from each other and surrounding the mountain, have been identified on the southern side of the mountain. The discovered ravines and walls indicate that

the settlement had a planned defense system. Many settlements of the Bronze Age in the territory of Nakhchivan were surrounded by this type of defense system. Remains of defensive walls built of stone have been discovered around the settlements of Shahtakhti, Kuku I settlement, Aghsal (Orafsa) settlement II Kultepe, etc. [4]

The defensive wall surrounding the Kultepe II settlement was reinforced with rectangular towers located at a certain distance [139,2]. The traditional masonry technique characteristic of the Nakhchivan region was used in the construction of the walls at Kultepe II. The foundation of the walls was built using large-sized stones, the gaps between them were filled with small-sized stones and fixed with mud. The upper part of the walls was built of square-shaped, large-sized raw bricks [139, 2].

The remains of the defensive wall discovered during the research at the Shahtakhti settlement, located near the Shahtakhti kandi in the Kangarli region of Nakhchivan, are similar to the structures discovered at Kultepe II in terms of construction techniques. [134, 2]. According to V.B. Bakhshaliyev, the appearance of fenced settlements indicates the formation of large tribal associations [27, 1].

In general, the defensive walls around many settlements dating back to the 3rd-2nd millennia BC in the Nakhchivan territory were restored in the Late Bronze and Early Iron Ages. Examples of these include Kultepe II, Shahtakhti, Galajig, etc.

It is also known that defensive walls were built around settlements of the Bronze Age that were studied in the Guruchay and Kondalanchay valleys of Azerbaijan. According to Q.S. Ismayilov, the construction of defensive walls around the Garakopaktepe settlement is associated with the emergence of slave states in neighboring territories during this period and the start of their new beekeeping campaigns.

Along with inter-tribal clashes, such campaigns also necessitated the construction of defensive walls around settlements. In our opinion, the construction of defensive walls around some settlements that existed in the Nakhchivan territory in the 3rd-2nd millennia BC was a requirement of the time. Because, starting from this period, the development of productive forces, the emergence of tribal alliances, and inter-tribal conflicts necessitated the construction of defensive walls to protect each settlement from raids.

The structure of the houses discovered in Plovdag has attracted the attention of researchers. Here, 7 rooms and 1 corridor of the house complex with an original plan were discovered. The house complex is a stone structure and is the only house complex dating back to the 3rd-2nd millennium BC discovered in the Nakhchivan region. Houses in Plovdag were built in a planned manner, were mainly two-room and had narrow corridors. One of these rooms was closed, and its connection with the outside environment was through the other room. In addition, there were auxiliary rooms adjacent to the house.

The house complex experienced two construction periods. In the first stage, the houses were dug-out. As a result of the earthquake and flood damage, the houses were completely changed. In the early days, the entrance to the existing rooms was closed, and stone stairs were used at the corners of the house to enter the rooms. Thus, after the restoration period, the houses took on a semi-dug-out appearance. The houses were mainly rectangular and square in plan, and their corners were semicircular. Each room had a utility well [7; 3].

One of the rooms, which were built in a planned manner, was used as a warehouse, and the second was intended for living.

The first room, located on the east side, had a rectangular southern half and a semicircular northern half. The northern side of the room was relatively narrow. According to B.I. Ibrahimli, the reason for the unusual plan of the room is its later-developed western wall. The entrance was from the north-west corner. There was no other exit or window. On the eastern wall, niches were made of flat stones.

A 70 cm diameter household well was dug in the middle of the room. While the well was being cleaned, several kg of millet, embedded in its stone, was found. There were traces of fire on the walls of the room. The beams covering the room burned and fell inside [66, 1].

Among the materials discovered there are fragments of a cauldron, a small painted bowl with a wooden handle and a curved mouth, fragments of a large azan, a fragment of a three-legged abdan with a wide seat and a wooden handle, a fragment of the mouth and shoulder of a large red-colored jug, and fragments of a large azan with a harmoniously repaired seat. In addition, a thick-walled clay brazier was also discovered in the room.

The entrance to the second room was via a staircase from the northwest. The staircase was made of large stones. The height of the staircase was 1-1.2 m and the width was 60-65 cm.

A pillar was found in the center of the northern half of the second room, and a farm well was found in the center of the southern half. Large fragments of a jug and burnt parts of a sabbat were found inside the well. In addition, a round stone and the bones of several large horned animals were found in the well.

The diameter of the farm well is 50-70 cm and the depth is 75-80 cm. A large slab of stone covering its mouth was found next to the well. This room was also subjected to destruction and fire. The thickness of the ash layer in the room was 30 cm.

Among the materials found in the second room were fragments of clay pots belonging to a pitcher and azan, a bowl with a wooden handle and a conical body, a small cauldron (pot), fragments of a double-handled, flat-seated, gray-colored bowl decorated with red paint, and fragments of a wide-mouthed pottery decorated with red paint.

In addition, burnt peas, barley, wheat and grapes were also found in the room. In our opinion, this room was used for storage or household purposes.

Research shows that the settlement was often destroyed and restored many times. The last destruction was accompanied by fire, and the residents did not restore the building, but abandoned it. Based on archaeological materials, it is assumed that this event occurred at the beginning of the 1st millennium BC [3]. There was a corridor 1-1.5 m wide between the interior and the 2nd rooms. The corridor dates back to the period before the restoration.

The walls of another building were discovered to the east of Room 2 in the Plovdag settlement. According to the researchers, these buildings were still used for residential purposes after the restoration. The wall was built with stones on the northeast side, 2 m wide and 3.4 m long, sloping, and connected to the staircase inside Room 2. Here, the door was from the west, a room with an area of 13-14 m². On the west side of the building, a 30 cm wide channel was made with mountain stones in the north-south direction. The lower and upper sides of the channel were closed, and it was not possible to determine whether it was dug with a namaste. Stones were laid out to the east of the channel in the courtyard. Baked clay slabs were laid out in a circular pattern to the south of the building. A clay prayer bell fragment and stone tools were found here [9, 13].

B.I. Ibrahimli suggested that this channel may have been used as a stable. It is believed that domestic animals were kept on the stone-paved floor [66, 2].

During the research in the Nakhchivan region, cases of stone paving were observed at the Kultepe II settlement. According to V.H. Oliyev, this is a characteristic feature of the Kultepe II settlement and serves to keep the settlement clean [139, 2]. In addition, during the excavations, it became clear that the settlement at Kultepe II was surrounded by a deep ditch 3 m wide. According to V.B. Bakhsholiyev, there were certain channels to drain wastewater from the settlement into the canal, and these channels were poured into the ditch [27, 2]. It is likely that the small canal discovered in Plovdag was also used to drain waste from the settlement outside the settlement. In our opinion, the canal was damaged during the destruction and was not reused during subsequent restoration.

The second excavation site is located between the two peaks of Plovdag. The excavation site

covers an area of 400 m². In the western part of the excavation, the walls of a large complex have been identified. In the eastern part of the excavation, T-shaped wall fragments have been discovered. The interesting part of the complex is in the central buildings.

Here, stones of various sizes have been poured in a circular manner in an unsystematic manner. Large flat stones have been densely laid to the east. From here, a 100 cm wide wall was discovered to the west, another wall parallel to this wall, and the remains of a curved wall were discovered on the southwest side of the wall. During the excavation, stone tools, various types of ceramic fragments, and animal bones were discovered mainly from the central part. The few finds due to the excavation area and the nature of the construction led the researchers to conclude that this was not a residential building. No hearth remains were discovered anywhere in the complex covering an area of 400 m² [8, 4]. We believe that these buildings are the remains of some kind of farm building. During the Tobii disaster or destruction, these buildings lost their original structure and were not substantially restored in subsequent periods.

Room 4 had a square plan. A farm well and ground grain were discovered near the southwest corner of the room. In general, the rooms in the Plovdag settlement were connected to each other, as they belonged to one complex. Room 5 was discovered to the east of room 4. The northeast corner of the room is semicircular. The eastern walls rested on the clay soil layer of the mountain. The side of this wall facing the room was worked with large stones, and the other side with inclined stones of various sizes. The width of the wall was more than 1 m in some places.

According to researchers, since this wall was the last wall of the complex in the east, it also had a defensive character. The eastern wall continued to the northwest. This wall had an interesting structure in the northeast corner of room 5. The wall was bent inward, and large stones were arranged like stairs. This was the entrance to room 5. The remains of another wall were discovered to the north of the entrance door. The eastern wall of room 4 forms the western wall of room 5. To the north of this wall, another semicircular building with a diameter of more than 4 m was discovered. The western side of the building was also formed by a building with a semicircular plan. According to researchers, both buildings with a semicircular plan date back to the period after the residential complex.

Most of room 6 was outside the excavation area. The width of the room is 4 m. Unlike the other rooms, this room had a 90 cm wide apse made of large stones on the south side. An ash layer 114 cm deep, covering an area 80-85 cm in diameter, was discovered near the eastern wall of the room.

During the excavation, stone and clay hearths were discovered in the rooms. Inside the rooms and in the corridors, black and red ceramics of various shapes, bone remains of large and small horned animals, stone tools, and burnt wood remains were found. Among these, clay monuments covered with red engobe and decorated with geometric patterns with black paint occupy a special place. According to researchers, during the fire, residents tried to take their belongings out of the rooms. At this time, the internal structure of the rooms was partially changed. The hearths were blown up, and the utility wells were dismantled [8, 4].

Room 7, with an area of 13-14 m², was located northwest of the door of room 6. The eastern wall of the room is semicircular in plan, and the eastern door is rectangular in plan. There was a passage to room 6 on the southern side of the eastern wall, but during the second construction period (i.e., during the restoration period) this passage was blocked by building with stones. Based on the position of the room in the residential complex, the researchers came to the conclusion that initially room 7 was the corridor of room 6. According to B.I. Ibrahimli, since the door of room 6 was blocked during the second construction period (i.e., during the restoration period), room 7 was used for utility purposes [66, 4].

The southern half of room 8 was semicircular in plan. The 50 cm wide wall was decorated with stones of various sizes and clay mortar. Fragments of millet pots were found in the southeastern

part of the room, and fragments of reddish and black clay pots were found in the southern half. Since there was no door or other means of communication between this room and rooms 6 and 7, it was thought that room 8 belonged to another dwelling or to another period. Since there was neither a household well nor a hearth in this room, it was not possible to determine its purpose [9, 3].

According to B.I. Ibrahimli, the discovery of the Kur-Araz culture layer in the monument gives grounds to say that people settled in Plovdag as early as the Early Bronze Age [63, 2].

During the excavations in the central part of the Plovdag-2 necropolis, a 1.2 m thick cultural layer belonging to the residential area was excavated in the lower layer of the stone crypts under the mound. A large number of ceramic fragments, stone tools and osteological remains were found. The discovered stone tools mainly consisted of stones, graters, stone axes and awls. Small horned animal bones were the most common among the osteological remains.

Among the ceramic samples, there were painted, two-tone and black-polished, finely made vessel fragments belonging to the last stage of the Early Bronze Age.

In addition, fragments of black-gray vessel covered with red paint on all sides were also found. No construction remains have been found yet.

Conclusion

In conclusion, it can be noted that the Bronze Age settlements in the Ordubad area play an important role in the study of the life and activities of ancient people. These monuments show that the region has been one of the zones of intensive settlement since ancient times and the population living here had a developed economic system.

Analysis of archaeological materials proves that at that time people had already moved away from a simple nomadic lifestyle and adopted a more sedentary lifestyle, built dwellings and engaged in various industries. In particular, achievements in the fields of ceramic production, metalworking and agriculture indicate a high level of cultural development in these areas.

At the same time, these settlements also provide important information about the social organization, division of labor, and cultural relations of ancient communities. In this regard, the Bronze Age monuments in the Ordubad area are of particular importance not only for the study of local, but also for the history of the South Caucasus in general.

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Medical Sciences

Современные подходы к организационно-управленческому обеспечению создания аллерго- пульмонологического центра

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Аннотация

Аллергические и респираторные заболевания занимают значительное место в структуре хронической неинфекционной патологии и характеризуются высокой распространённостью, хроническим течением и значительным влиянием на качество жизни пациентов. В условиях роста урбанизации, ухудшения экологической ситуации и увеличения числа пациентов с бронхиальной астмой, хронической обструктивной болезнью лёгких и аллергическими заболеваниями возрастает потребность в специализированной медицинской помощи. Целью настоящего обзора является анализ современных организационно-управленческих подходов к созданию аллерго-пульмонологического центра, выявление ключевых проблем и определение перспективных направлений развития. Установлено, что эффективное функционирование центра обеспечивается за счёт внедрения мультидисциплинарных моделей, цифровизации процессов, оптимизации маршрутизации пациентов и развития кадрового потенциала.

Ключевые слова: аллерго-пульмонология, организация здравоохранения, специализированный центр, управление, качество медицинской помощи, бронхиальная астма.

Введение

Аллергические и респираторные заболевания представляют собой одну из наиболее актуальных проблем современной медицины и общественного здравоохранения, оказывая существенное влияние на показатели заболеваемости, инвалидизации и смертности населения. В последние десятилетия во всём мире наблюдается устойчивая тенденция к росту распространённости таких заболеваний, как бронхиальная астма, хроническая обструктивная болезнь лёгких, аллергический ринит, атопический дерматит и другие формы аллергопатологии. Увеличение частоты данных заболеваний обусловлено воздействием комплекса неблагоприятных факторов, включая ухудшение экологической обстановки, рост уровня загрязнения атмосферного воздуха, урбанизацию, изменение образа жизни, а также увеличение распространённости факторов риска, таких как курение, гиподинамия и стресс.

Особую значимость проблема приобретает в условиях крупных городов, где высокая плотность населения, интенсивное промышленное развитие и транспортная нагрузка способствуют росту аллергических и респираторных заболеваний. У пациентов всё чаще отмечается сочетанная патология, характеризующаяся одновременным поражением дыхательной и иммунной систем, что усложняет диагностику и лечение и требует комплексного подхода к оказанию медицинской помощи[1-2].

Высокая распространённость указанных заболеваний, их хроническое течение, склонность к частым обострениям и прогрессированию, а также значительное влияние на качество жизни пациентов формируют существенную нагрузку на систему здравоохранения. Значительные ресурсы направляются на оказание медицинской помощи данной категории пациентов, включая амбулаторное наблюдение, стационарное лечение, медикаментозную терапию и реабилитацию. Кроме того, данные заболевания сопровождаются экономическими потерями, связанными с временной нетрудоспособностью, снижением трудоспособности и увеличением расходов на лечение.

В этих условиях возрастает необходимость совершенствования организации медицинской помощи пациентам с аллергическими и респираторными заболеваниями. Одним из наиболее эффективных решений является создание специализированных аллерго-пульмонологических центров, обеспечивающих комплексный подход к диагностике, лечению, реабилитации и профилактике. Такие центры позволяют сконцентрировать высококвалифицированные кадры, современное диагностическое и лечебное оборудование, а также внедрять инновационные технологии оказания медицинской помощи.

Создание аллерго-пульмонологического центра требует разработки и внедрения эффективных организационно-управленческих решений, направленных на оптимизацию структуры медицинской организации, рациональное распределение ресурсов, повышение доступности и качества медицинской помощи, а также обеспечение преемственности между различными уровнями оказания медицинских услуг. Важным аспектом является формирование мультидисциплинарных команд специалистов, включающих аллергологов, пульмонологов, врачей функциональной диагностики, реабилитологов и медицинских сестёр, что позволяет обеспечить комплексное ведение пациентов[3].

Современные тенденции развития здравоохранения предполагают активное внедрение цифровых технологий, телемедицины и систем поддержки принятия клинических решений, что открывает новые возможности для повышения эффективности работы специализированных центров. Особое значение приобретает также разработка и внедрение клинических протоколов и стандартов оказания медицинской помощи, позволяющих обеспечить единые подходы к диагностике и лечению пациентов.

Создание аллерго-пульмонологического центра является важной научной и практической задачей, направленной на совершенствование системы оказания специализированной медицинской помощи, повышение её эффективности, доступности и качества, а также улучшение клинических исходов у пациентов с аллергическими и респираторными заболеваниями.

Материалы и методы. Настоящее исследование выполнено в формате обзорной научной работы с элементами систематизированного анализа литературы. Проведён поиск научных публикаций в международных базах данных (PubMed, Scopus, Web of Science), а также анализ отечественных источников, клинических рекомендаций и нормативно-правовых документов.

В обзор включены публикации за последние 5–10 лет, посвящённые вопросам организации специализированной медицинской помощи, управления медицинскими

организациями, а также созданию профильных центров. Используются методы описательного, сравнительного и контент-анализа.

Создание аллерго-пульмонологического центра представляет собой сложный, многоуровневый и стратегически значимый процесс, включающий организационные, кадровые, технологические, клинические и экономические аспекты. Формирование таких центров требует системного подхода, основанного на принципах доступности, комплексности, непрерывности, доказательности и пациентоориентированности медицинской помощи. В современных условиях аллерго-пульмонологические центры рассматриваются не только как учреждения оказания специализированной помощи, но и как координационные структуры, обеспечивающие интеграцию всех уровней системы здравоохранения - от первичной медико-санитарной помощи до высокотехнологичной специализированной и реабилитационной помощи[4-7].

Актуальность создания таких центров подтверждается глобальными эпидемиологическими тенденциями. По данным международных исследований, хроническими респираторными заболеваниями страдают более 545 млн человек во всём мире, что составляет около 7–8% населения планеты. Бронхиальная астма диагностируется более чем у 260–300 млн человек, а хроническая обструктивная болезнь лёгких (ХОБЛ) входит в число ведущих причин смертности и инвалидизации, занимая одно из первых мест среди причин преждевременной смерти. Аллергические заболевания, включая аллергический ринит и атопические состояния, демонстрируют устойчивый рост, особенно в индустриально развитых и урбанизированных регионах. Эти тенденции формируют значительное социально-экономическое бремя, обусловленное затратами на лечение, госпитализацию, реабилитацию и потерей трудоспособности.

В Республике Казахстан развитие аллерго-пульмонологической службы происходит на фоне устойчивого роста распространённости заболеваний органов дыхания и аллергической патологии, что обуславливает необходимость совершенствования системы специализированной медицинской помощи. По данным Министерства здравоохранения Республики Казахстан, болезни органов дыхания занимают первое место по заболеваемости и третье место по смертности, уступая лишь сердечно-сосудистым и онкологическим заболеваниям[8].

Отдельного внимания заслуживает динамика бронхиальной астмы, которая демонстрирует устойчивый рост. Так, уровень заболеваемости увеличился с 93,4 случаев на 100 тыс. населения в 2017 году до 126,1 в 2020 году, а число пациентов, состоящих на диспансерном учёте, возросло с 72 тыс. до более чем 109 тыс. за несколько лет. При этом фактическая распространённость заболевания может быть значительно выше официальных данных, что связано с проблемами недодиагностики.

Аллергические заболевания также приобретают всё большую значимость: по оценкам, до 20% населения Казахстана страдает различными формами аллергии, причём наиболее высокие показатели отмечаются в крупных городах, таких как Алматы, Астана и Шымкент. Это напрямую связано с урбанизацией, ухудшением экологической ситуации и высоким уровнем загрязнения воздуха. Кроме того, у городского населения бронхиальная астма выявляется почти в 2 раза чаще, чем в сельской местности, что подчёркивает влияние факторов окружающей среды.

Развитие аллерго-пульмонологической службы в Казахстане в последние годы характеризуется рядом позитивных тенденций. В первую очередь это связано с усилением роли первичной медико-санитарной помощи и внедрением программ динамического наблюдения пациентов. Отмечается снижение частоты госпитализаций при одновременном увеличении числа пациентов, состоящих на учёте, что свидетельствует об улучшении амбулаторного менеджмента заболеваний.

Важным этапом развития стало внедрение клинических протоколов диагностики и лечения бронхиальной астмы, хронической обструктивной болезни лёгких и аллергических заболеваний, что позволило унифицировать подходы к оказанию медицинской помощи и повысить её качество. Одновременно происходит постепенное внедрение современных методов диагностики, включая функциональные методы исследования дыхательной системы, аллергодиагностику и мониторинг состояния пациентов[9].

Однако, несмотря на достигнутые результаты, развитие службы сталкивается с рядом системных проблем. Одной из ключевых остаётся недостаточная оснащённость медицинских организаций современным оборудованием, особенно в регионах. Доступ к высокотехнологичным методам диагностики, таким как бодиплетизмография, молекулярная аллергодиагностика и комплексная функциональная оценка дыхательной системы, остаётся ограниченным.

Серьёзной проблемой является кадровый дефицит. В республике наблюдается недостаток специалистов аллергологов, пульмонологов и врачей функциональной диагностики, особенно на уровне регионов. Это приводит к увеличению нагрузки на имеющихся специалистов и снижению доступности специализированной помощи[10-13].

Дополнительным ограничивающим фактором является недостаточная интеграция различных уровней медицинской помощи. Несмотря на развитие первичной медико-санитарной помощи, сохраняются проблемы преемственности между амбулаторным и стационарным этапами лечения, что приводит к фрагментации медицинской помощи и снижению её эффективности.

В современных условиях особое значение приобретает развитие специализированных центров, способных обеспечить комплексный подход к диагностике и лечению пациентов с аллергическими и респираторными заболеваниями. Создание аллерго-пульмонологических центров в крупных городах Казахстана позволяет сконцентрировать высокотехнологичное оборудование, квалифицированные кадры и современные методы лечения, что способствует повышению качества медицинской помощи.

Перспективным направлением развития является цифровизация здравоохранения, включая внедрение электронных медицинских систем, телемедицины и дистанционного мониторинга пациентов. Для Казахстана, учитывая значительную территорию и неравномерное распределение населения, это особенно актуально, так как позволяет повысить доступность специализированной помощи для отдалённых регионов.

Развитие аллерго-пульмонологической службы в Республике Казахстан характеризуется положительной динамикой, однако требует дальнейшего совершенствования. Приоритетными направлениями являются развитие специализированных центров, модернизация материально-технической базы, подготовка кадров, внедрение мультидисциплинарного подхода и цифровых технологий. Реализация данных мер позволит повысить эффективность системы здравоохранения, улучшить раннюю диагностику и контроль заболеваний, а также снизить их социально-экономическое бремя.

Выводы. Создание аллерго-пульмонологического центра представляет собой стратегически важное направление развития специализированной медицинской помощи, требующее комплексного организационно-управленческого подхода. Такой подход должен быть ориентирован не только на расширение доступности медицинских услуг, но и на повышение их качества, безопасности и клинической эффективности с учётом современных требований системы здравоохранения и принципов пациентоориентированности.

Ключевыми направлениями совершенствования деятельности центра являются развитие и модернизация материально-технической базы, включающей внедрение современного диагностического и лечебного оборудования, а также создание комфортной

и функциональной инфраструктуры для пациентов и медицинского персонала. Не менее значимым аспектом является укрепление кадрового потенциала, предусматривающее повышение квалификации специалистов, развитие междисциплинарного взаимодействия и формирование команды, способной эффективно решать сложные клинические задачи.

Особое значение приобретает внедрение мультидисциплинарных моделей оказания медицинской помощи, обеспечивающих комплексное ведение пациентов с аллергическими и пульмонологическими заболеваниями. Интеграция специалистов различного профиля (аллергологов, пульмонологов, терапевтов, реабилитологов и др.) способствует более точной диагностике, своевременному началу лечения и повышению приверженности пациентов к терапии. Цифровизация процессов является важным инструментом повышения эффективности управления и качества медицинской помощи. Внедрение информационных систем, электронных медицинских карт, телемедицинских технологий и систем мониторинга позволяет оптимизировать маршрутизацию пациентов, сократить время ожидания, повысить прозрачность и управляемость процессов[14-15].

Оптимизация маршрутизации пациентов, включая чёткое разграничение уровней оказания помощи и взаимодействие с первичным звеном здравоохранения, позволяет снизить нагрузку на стационарный сектор, повысить доступность специализированной помощи и обеспечить рациональное использование ресурсов.

Реализация предложенных организационно-управленческих мероприятий позволит не только повысить эффективность функционирования аллерго-пульмонологического центра, но и улучшить клинические исходы, повысить удовлетворённость пациентов, снизить частоту осложнений и госпитализаций, а также уменьшить общую нагрузку на систему здравоохранения. В долгосрочной перспективе это будет способствовать укреплению общественного здоровья и повышению качества жизни населения.

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Организационные аспекты улучшения реанимационной помощи пожилым пациентам(обзор литературы)

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Аннотация

В условиях глобального старения населения возрастает потребность в качественной и своевременной реанимационной помощи пациентам пожилого возраста. Данная категория пациентов характеризуется высокой коморбидностью, снижением функциональных резервов организма и повышенным риском неблагоприятных исходов. Целью настоящего обзора является анализ современных организационных подходов к совершенствованию реанимационной помощи пожилым пациентам в условиях стационара. Проведён анализ отечественных и зарубежных источников, посвящённых вопросам маршрутизации пациентов, кадрового обеспечения, внедрения клинических протоколов, мультидисциплинарного подхода и цифровизации здравоохранения. Установлено, что ключевыми направлениями повышения эффективности являются развитие гериатрически ориентированных моделей помощи, внедрение стандартов качества, оптимизация взаимодействия специалистов и использование информационных технологий.

Ключевые слова: пожилые пациенты, реанимация, интенсивная терапия, организация здравоохранения, качество медицинской помощи, гериатрия.

Современные демографические процессы, характеризующиеся прогрессирующим старением населения, приобретают глобальный характер и оказывают многогранное влияние на социально-экономическое развитие государств и функционирование систем здравоохранения[1]. По данным Всемирная организация здравоохранения, к середине XXI века численность лиц старше 60 лет превысит 2 миллиарда человек, что будет составлять значительную долю мирового населения. Указанная тенденция обусловлена комплексом факторов, включая устойчивое снижение рождаемости, увеличение ожидаемой продолжительности жизни, а также значительный прогресс в области медицины, фармакотерапии и профилактики заболеваний. Старение населения сопровождается изменением структуры заболеваемости, где ведущие позиции занимают хронические неинфекционные заболевания, что формирует новые вызовы для системы здравоохранения.

В условиях демографического старения возрастает потребность в оказании высокотехнологичной и специализированной медицинской помощи, в частности, в услугах анестезиологии, реанимации и интенсивной терапии. Пожилые пациенты значительно чаще нуждаются в госпитализации, характеризуются более тяжелым течением заболеваний, длительными сроками пребывания в стационаре и высокой частотой повторных госпитализаций. Это приводит к увеличению нагрузки на отделения реанимации и

интенсивной терапии, где требуется не только применение современных медицинских технологий, но и эффективная организация лечебно-диагностического процесса. В связи с этим особую значимость приобретает рациональное распределение ресурсов, оптимизация коечного фонда, совершенствование маршрутизации пациентов и внедрение принципов бережливого управления (Lean-технологий) в медицинских организациях[2-3].

Пожилые и старческие пациенты представляют собой сложную клинικο-организационную категорию, требующую индивидуализированного подхода. Для данной группы характерна высокая распространённость коморбидных состояний, включая сердечно-сосудистые заболевания, сахарный диабет, хронические болезни органов дыхания и онкологические патологии. Одновременно широко распространена полипрагмазия, что повышает риск лекарственных взаимодействий и нежелательных побочных эффектов. Возрастные изменения, такие как снижение функциональных резервов органов и систем, иммунологическая дисфункция, саркопения и когнитивные нарушения, существенно ограничивают адаптационные возможности организма. Это приводит к атипичному течению заболеваний, сглаженности клинической симптоматики и затрудняет своевременную диагностику, особенно в условиях критических состояний.

В отделениях интенсивной терапии данные особенности обуславливают необходимость постоянного мониторинга жизненно важных функций, использования расширенных диагностических методов и применения персонифицированных лечебных стратегий. Пожилые пациенты имеют более высокий риск развития осложнений, включая острый делирий, септические состояния, госпитальные инфекции, пролежни, тромбоэмболические осложнения и синдром полиорганной недостаточности. Кроме того, возрастные изменения фармакокинетики и фармакодинамики требуют особой осторожности при назначении лекарственных препаратов, а также постоянной оценки их эффективности и безопасности[4].

Важнейшей проблемой является обеспечение качества и безопасности медицинской помощи данной категории пациентов. В современных условиях активно внедряются стандартизированные протоколы ведения пациентов, клинические рекомендации и системы контроля качества, направленные на снижение частоты медицинских ошибок и неблагоприятных исходов. Особую роль играет развитие гериатрически ориентированных моделей медицинской помощи, основанных на принципах мультидисциплинарного взаимодействия. В рамках таких моделей осуществляется тесное сотрудничество врачей-реаниматологов, терапевтов, гериатров, медицинских сестёр, клинических фармакологов, специалистов по реабилитации и социальной работе. Это позволяет обеспечить комплексный подход к лечению, уходу и восстановлению пациентов.

Одним из ключевых направлений совершенствования является обеспечение преемственности медицинской помощи. Непрерывный подход, охватывающий этапы госпитализации, интенсивной терапии, ранней реабилитации и последующего амбулаторного наблюдения, способствует снижению уровня инвалидизации, улучшению качества жизни пациентов и уменьшению частоты повторных госпитализаций[5-6]. В этой связи возрастает значение реабилитационных мероприятий, направленных на восстановление функционального статуса, когнитивных способностей и социальной активности пациентов пожилого возраста.

Современные цифровые технологии играют всё более важную роль в оптимизации оказания медицинской помощи. Внедрение электронных медицинских информационных систем, телемедицинских технологий, систем поддержки принятия клинических решений и анализа больших данных позволяет повысить точность диагностики, улучшить координацию между специалистами и минимизировать риск врачебных ошибок[7]. Использование

искусственного интеллекта и предиктивной аналитики открывает новые возможности для раннего выявления осложнений и персонализации лечения.

Несмотря на достигнутые успехи, в системе здравоохранения сохраняется ряд серьёзных организационных проблем. К ним относятся дефицит квалифицированных кадров, недостаточный уровень подготовки медицинского персонала в области гериатрии, высокая профессиональная нагрузка, ограниченность финансовых и материально-технических ресурсов, а также отсутствие единых стандартов оказания реанимационной помощи пожилым пациентам. Дополнительным фактором является недостаточная интеграция медицинской и социальной помощи, что снижает эффективность ведения пациентов на постгоспитальном этапе.

Старение населения требует трансформации системы здравоохранения с учётом новых демографических реалий. Совершенствование оказания медицинской помощи пациентам пожилого и старческого возраста в отделениях реанимации должно носить комплексный характер и включать развитие кадрового потенциала, внедрение инновационных технологий, оптимизацию организационных процессов и формирование гериатрически ориентированной модели медицинской помощи [8-10]. Реализация данных направлений позволит повысить эффективность лечения, снизить уровень осложнений и летальности, а также обеспечить достойное качество жизни пациентов старшего возраста.

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Problems and Ways to Improve Functional Diagnostic Services for Preterm Infants in Inpatient Settings

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Abstract

Preterm infants represent one of the most vulnerable patient groups requiring specialized medical care and a comprehensive diagnostic approach. Functional diagnostics plays a key role in the early detection of disorders of vital body systems and the timely correction of pathological conditions. In inpatient settings, a number of organizational and clinical challenges persist, including limited resources, insufficient equipment, a shortage of trained personnel, and the lack of standardized approaches.

The aim of this review is to analyze current challenges and directions for improving functional diagnostic services for preterm infants in hospital settings. It has been established that promising areas include the implementation of modern diagnostic technologies, the development of multidisciplinary approaches, digitalization of processes, and continuous professional development of healthcare personnel.

Keywords: preterm infants, functional diagnostics, inpatient care, neonatology, healthcare organization, quality of medical care.

Introduction

Preterm birth remains one of the leading medical and social challenges in modern neonatology and public health, significantly affecting infant morbidity, disability, and mortality rates. Reduced gestational age and low birth weight are associated with morphofunctional immaturity of organs and systems, which determines the high vulnerability of this group of patients. Preterm infants are significantly more likely to develop respiratory disorders (respiratory distress syndrome, apnea of prematurity), cardiovascular abnormalities (patent ductus arteriosus, hemodynamic instability), neurological complications (intraventricular hemorrhage, periventricular leukomalacia), as well as metabolic and infectious conditions [1].

Advances in neonatology, including the development of intensive care technologies and neonatal support systems, have improved the survival rates of extremely preterm infants. However, this has simultaneously increased the need for high-precision monitoring and timely diagnosis of functional disorders. Under these conditions, functional diagnostics becomes a key tool for early detection of pathological changes, assessment of organ and system maturity, and dynamic monitoring of the infant's condition.

Functional diagnostics in neonatology includes a wide range of methods aimed at assessing vital functions, such as monitoring respiration and oxygenation, electrocardiography, echocardiography, neurosonography, electroencephalography, and other instrumental examinations. The use of these methods allows not only the detection of pathology at preclinical stages but also the timely adjustment of therapeutic strategies, preventing severe complications and adverse outcomes [2].

In inpatient settings, particularly in neonatal intensive care units, functional diagnostics is an integral part of the diagnostic and treatment process and serves as the basis for clinical decision-making. The timeliness and accuracy of diagnostic procedures largely determine treatment effectiveness, the length of hospital stay, and the long-term prognosis of the child.

Despite significant advances in this field, functional diagnostic services for preterm infants face a number of serious organizational and clinical challenges. These include insufficient availability of modern diagnostic equipment, limited access to high-tech diagnostic methods, a shortage of qualified personnel, and the lack of unified standards and diagnostic algorithms. An additional factor is the high workload of medical staff, which may reduce the quality of diagnostic procedures and increase the risk of errors.

Another important issue is the insufficient integration of diagnostic and clinical services, leading to fragmentation of care and reduced efficiency of multidisciplinary collaboration. The lack of effective coordination between specialists complicates comprehensive patient assessment and delays clinical decision-making. In addition, problems with continuity between inpatient and outpatient care remain, which is particularly important for preterm infants requiring long-term follow-up.

Current trends in healthcare development require the implementation of new organizational and technological solutions aimed at improving functional diagnostic services. Particular importance is given to the digitalization of healthcare processes, the development of telemedicine, the implementation of automated data analysis systems, and the formation of multidisciplinary teams. Another important direction is the continuous professional development of medical personnel and the development of standardized diagnostic protocols.

Improving functional diagnostics for preterm infants in inpatient settings is an important scientific and practical task aimed at enhancing the quality of medical care, reducing complications, and improving long-term outcomes.

Materials and Methods

This study was conducted as a review article with elements of a systematic literature analysis. A search of scientific publications was performed in international databases, including PubMed, Scopus, and Web of Science, as well as an analysis of national sources, clinical guidelines, and regulatory documents.

The review included studies published over the past 5–10 years focusing on functional diagnostics in preterm infants, the organization of neonatal care, and the implementation of modern technologies. Descriptive, comparative, and content analysis methods were applied.

Results and Discussion

Functional diagnostics in preterm infants in inpatient settings represents one of the key components of specialized neonatal care, aimed at a comprehensive assessment of vital body systems and timely detection of pathological changes. Due to the morphofunctional immaturity of organs and systems in this category of patients, there is a need for continuous monitoring and dynamic observation [3–4]. In clinical practice, the most commonly used methods include continuous monitoring of vital signs such as heart rate, respiratory rate, blood oxygen saturation, and blood pressure, as well as instrumental diagnostic techniques including echocardiography, neurosonography, electrocardiography, electroencephalography, and others. These methods not only enable early detection of abnormalities but also allow for the evaluation of treatment effectiveness, which is crucial for disease prognosis and the further development of the child.

At the same time, the analysis of the scientific literature reveals a number of significant challenges that limit the effectiveness of functional diagnostic services for preterm infants. One of the most pressing issues is the insufficient availability of modern diagnostic equipment in healthcare facilities. In many hospitals, there remains a shortage of advanced diagnostic tools, including high-precision monitoring devices, modern ultrasound systems, and neurophysiological

equipment [5–6]. This significantly restricts the ability to detect pathological conditions at an early stage and to initiate timely treatment, especially in extremely preterm infants at high risk of complications.

Another important problem is the lack of standardized protocols and algorithms for functional diagnostics, leading to variability in patient assessment approaches and reduced comparability of results. Insufficient standardization of diagnostic procedures may contribute to delays in diagnosis and a decrease in the quality of medical care.

A serious limiting factor is the shortage of qualified personnel, including specialists in functional diagnostics, neonatologists, and nursing staff with specific competencies in the care of preterm infants. The high workload of medical personnel, the need for round-the-clock patient monitoring, and the high level of responsibility contribute to the development of professional burnout. Under such conditions, the risk of diagnostic errors increases, the accuracy of data interpretation decreases, and the overall quality of medical care deteriorates.

The issue of insufficient integration between diagnostic and clinical services is also of particular importance. In the absence of a well-established system of interaction between specialists from different disciplines (neonatologists, cardiologists, neurologists, and functional diagnostics specialists), fragmentation of care is observed [7]. This complicates comprehensive patient assessment, delays clinical decision-making, and may negatively affect treatment outcomes.

In modern healthcare, one of the most effective directions for improvement is the implementation of a multidisciplinary approach to the management of preterm infants. The formation of multidisciplinary teams, including physicians from various specialties, nurses, and other healthcare professionals, ensures comprehensive patient evaluation and treatment. This approach improves diagnostic accuracy, enhances coordination of the treatment process, and reduces the risk of complications.

A promising direction for development is the digitalization of functional diagnostics, including the implementation of electronic medical systems, automated data processing and analysis algorithms, and remote patient monitoring technologies. The use of digital solutions increases the efficiency of data acquisition and interpretation, reduces the workload of medical personnel, and improves the accuracy of clinical decision-making. Furthermore, digitalization enhances quality control and improves the management efficiency of healthcare organizations.

An important aspect of improving functional diagnostic services is the continuous professional development of medical personnel. The implementation of educational programs, regular training, and the adoption of modern diagnostic technologies and clinical standards contribute to improving professional competencies and reducing the likelihood of diagnostic errors [8–9].

Another significant direction is the development of continuity between inpatient and outpatient care. Preterm infants require long-term follow-up after discharge, which necessitates effective interaction between different levels of the healthcare system. The development of outpatient monitoring, early intervention programs, and follow-up care helps reduce readmission rates, improve long-term outcomes, and enhance patients' quality of life.

The results of the analysis indicate that functional diagnostics for preterm infants in inpatient settings requires comprehensive improvement, including modernization of technical resources, strengthening of human capacity, implementation of multidisciplinary approaches, adoption of digital technologies, and ensuring continuity of care.

Conclusions

Functional diagnostics in preterm infants in inpatient settings is a key element of specialized medical care. Despite significant advances in this field, a number of organizational, кадровых, and technological challenges continue to limit its effectiveness. Improving functional diagnostic services requires a comprehensive approach, including the implementation of modern technologies, development of multidisciplinary care models, continuous professional training, and optimization of organizational processes.

The implementation of these strategies will enhance diagnostic quality, ensure timely detection of pathologies, and improve clinical outcomes in preterm infants.

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КЛИНИЧЕСКИЙ СЛУЧАЙ ПЕРВИЧНОЙ ДИАГНОСТИКИ СИСТЕМНОГО СКЛЕРОЗА ЛИМИТИРОВАННОЙ ФОРМЫ У ПАЦИЕНТА МОЛОДОГО ВОЗРАСТА

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ОМИРТАЕВА БАХЫТГУЛЬ АБУБАКИРОВНА

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Аннотация: Системный склероз (СС) — редкое системное аутоиммунное заболевание, характеризующееся фиброзом, васкулопатией и воспалением, приводящими к поражению многих органов и высокой заболеваемости и смертности [1].

Заболевание значительно чаще встречается у женщин; соотношение женщин и мужчин составляет от 3:1 до 8:1 [2]. Распространенность СС в мире составляет около 6 случаев на 100 000 среди мужчин и 28 случаев на 100 000 среди женщин [3]. Несмотря на более низкую распространенность среди мужчин, течение заболевания у них нередко характеризуется большей тяжестью и неблагоприятным прогнозом [2].

Этиология заболевания остается неясной, предполагается роль генетической предрасположенности в сочетании с воздействием факторов окружающей среды [4]. Наиболее ранним клиническим проявлением является феномен Рейно, наблюдающийся у большинства пациентов и характеризующийся фазной сменой окраски кожи пальцев кистей (бледность — цианоз — гиперемия) в ответ на холод или стресс.

Поражение кожи, проходящее в три стадии: отек, уплотнение, атрофия, — является следующим типичным синдромом для СС. Дисфагия и гастроэзофагеальный рефлюкс, обусловленные гипотонией пищевода, являющейся проявлением поражения желудочно-кишечного тракта, развиваются у большинства пациентов с СС (72–96 %) [5].

Ключевые слова: системный склероз, системная склеродермия, синдром Рейно, периодонтит, гастрит, поражение суставов.

Цель исследования: представление клинического случая ранней диагностики лимитированной формы системной склеродермии у молодого мужчины с анализом диагностических трудностей и терапевтических подходов.

Материалы и методы: пациент И., 23 лет, поступил в кардиоревматологическое отделение с жалобами на боли и тугоподвижность в мелких суставах кистей, утреннюю скованность до 20 минут, боли в крупных суставах конечностей, на периодические боли в мышцах плечевого пояса, феномен Рейно, припухлость пальцев кистей рук, стянутость,

сухость кожи лица, чувство кома при приеме твердой пищи, слабость, быструю утомляемость.

Со слов пациента 2019 г. началась очаговая алопеция волосистой части головы с переходом в диффузную форму с самостоятельным восстановлением в 2021 г. С февраля 2024 г. появились артралгии суставов кистей рук и эпизоды вазоспазма пальцев. Отсутствие раннего обращения за медицинской помощью способствовало прогрессированию симптоматики.

В связи с усилением физической нагрузки во время воинской службы нарастал болевой, суставной синдром. В августе 2024 г. Во время прохождения медицинского осмотра выставлен диагноз: Атрозо-артрит кистей. При обследовании положительные СРБ, РФ. Позднее стал отмечать постепенную припухлость пальцев кистей рук, лица, утреннюю скованность до 20 минут, усиление болей в суставах, трехфазное изменение цвета пальцев рук. В сентябре стационарное лечение в военном госпитале с диагнозом Синдром Рейно. Исключены сосудистые нарушения в виде тромбозов сосудов.

Анамнез жизни: Туберкулез, венерические заболевания, вирусные гепатиты отрицает. Травмы, операции – отрицает. Перенесенные заболевания: ОРВИ, тонзиллиты.

Аллергологический анамнез: не отягощен.

St.praesens:Общее состояние удовлетворительное.

Кожные проявления: индурация, уплотнение, блеск кожи лица и кистей.

Феномен Рейно подтвержден холодовой пробой.

Суставной синдром представлен полиартритом с вовлечением мелких суставов кистей.

Проведены общеклинические, биохимические и инструментальные обследования. Лабораторные данные:повышение СОЭ, повышение С-реактивного белка, положительные ANA и ENA, АЦЦП, умеренная протеинурия.

Инструментальные исследования

Капилляроскопия: изменения по типу раннего склеродермического паттерна

ФГДС: хронический гастрит, ассоциированный с *Helicobacter pylori*

КТ органов грудной клетки: патологических изменений не выявлено

ЭХО-КГ: признаков легочной гипертензии не выявлено

Проведена терапия: глюкокортикостероиды (метилпреднизолон), НПВС, сосудистая терапия

После выписки назначен метотрексат как базисный иммунодепрессант и сосудистая терапия. Отмечается частичная положительная динамика на фоне проводимого лечения.

Окончательный диагноз: Системный склероз, лимитированная форма, подострое течение, начальная стадия, умеренной степени активности с поражением кожи и подкожной клетчатки (индурация, отек лица, кисти рук, склеродактилия), сосудов (синдром Рейно), суставов (полиартрит, синовит лучезапястных, коленных суставов), ЖКТ (дисфагия). Кожный счет по Rodnan 13. ANA, ENA позитивный.

Сопутствующий: Хронический НР-ассоциированный гастрит, дуоденит, ремиссия, без нарушения функции пищеварения (K29.5). Хронический периодонтит 6 зуба нижней челюсти слева (K04.5).

Обсуждение: Системный склероз чаще встречается у женщин репродуктивного возраста 30-50 лет, чем у мужчин. У молодого мужчины без значимого анамнеза это заболевание является редким, может привести к тяжелым последствиям и требует тщательного анализа возможных причин. Представленный клинический случай иллюстрирует сложности ранней диагностики системной склеродермии у молодых мужчин. Ключевыми диагностическими критериями стали: феномен Рейно, кожный синдром, наличие аутоантител. Дифференциальная диагностика проводилась с ревматоидным артритом, сосудистыми

заболеваниями и инфекционной патологией. Отсутствие органных поражений на момент диагностики соответствует ранней стадии заболевания и определяет благоприятный прогноз при своевременной терапии. Повышение титров АЦЦП и наличие артрита возможно расценить как оверлап синдром СС+РА, что требует дальнейшего динамического наблюдения. В связи с чем назначение Метотрексата в качестве БМАРП патогенетически оправданно.

Выводы: Системная склеродермия может дебютировать у молодых мужчин, несмотря на редкость данной группы пациентов, ранняя диагностика требует настороженности врача, использование иммунологических методов (ANA, ENA) имеет ключевое значение, своевременное назначение базисной терапии улучшает прогноз. Данный клинический случай подчеркивает необходимость дальнейших исследований, направленных на изучение ранних форм заболевания и оптимизацию диагностических алгоритмов.

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Нутриционный статус детей раннего возраста со стенозом гортани

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Background

Laryngeal stenosis in early childhood is a serious condition often associated with respiratory compromise and increased metabolic demands. These children are at high risk for both acute and chronic malnutrition due to breathing difficulties, increased energy expenditure, and reduced feeding efficiency. Despite the clinical importance of this condition, data on the nutritional status of infants with laryngeal stenosis remain limited. Understanding the prevalence and structure of nutritional disorders in this group is essential for improving clinical management and implementing early nutritional interventions.

Objective

To assess the nutritional status of children under five years of age who were hospitalized due to laryngeal stenosis.

Methods

A retrospective analysis of 95 medical records of children younger than five years hospitalized with laryngeal stenosis was performed. Physical development parameters were evaluated using the 2006 World Health Organization standards, including weight-for-age (WAZ), height-for-age (HAZ), and weight-for-height (WHZ) indicators. Nutritional insufficiency was defined as a Z-score below -2 standard deviations. Statistical analysis included descriptive statistics, Pearson's chi-square test, Fisher's exact test, and logistic regression.

Results

Weight deficiency ($WAZ < -2$ SD) was identified in 28.1% of children, while stunting ($HAZ < -2$ SD) was detected in 24.0%. Overall, 29.1% of patients were diagnosed with malnutrition. Only 19.8% of children received additional enteral nutritional support during hospitalization. The findings demonstrate a high prevalence of both acute and chronic malnutrition among children with laryngeal stenosis, indicating insufficient attention to nutritional therapy in this population.

Conclusion

Children hospitalized with laryngeal stenosis show a high prevalence of acute and chronic malnutrition. These results highlight the importance of mandatory nutritional screening at admission to the otolaryngology department and underscore the need for timely nutritional support to optimize clinical outcomes.

Keywords Laryngeal Stenosis; Infant; Malnutrition; Nutritional Status; Growth Disorders.

Введение

Белково-энергетическая недостаточность (БЭН) у детей остаётся одной из ключевых проблем современной педиатрии, поскольку ассоциируется с повышенной заболеваемостью, снижением иммунной функции, замедлением полноценного развития [1,2,3]. Особого внимания требуют дети с хроническими заболеваниями дыхательных путей, где сочетание дыхательных нарушений, повышенной работы дыхательной мускулатуры и связанных с этим метаболических изменений приводит к формированию отрицательного энергетического баланса. Среди детей со стенозом гортани нарушения нутритивного статуса встречается особенно часто. Анатомические изменения гортанного и глоточного кольца при данной патологии приводят к нарушению процесса глотания, снижению объема потребляемой пищи и нарушению координации глотания и дыхания [4,5,6]. Повышенная потребность в энергии, обусловленная затрудненным дыханием способствует дальнейшему прогрессированию БЭН и ухудшению клинического состояния.

Согласно современным международным рекомендациям, БЭН определяется как состояние дефицита энергии и/или белка, сопровождающееся изменением состава тела, нарушением роста и снижением функциональных возможностей организма [7].

У пациентов с респираторной патологией развития недостаточности питания может быть обусловлено комплексом факторов: гиперметаболизмом, снижением аппетита, катаболическим влиянием провоспалительных цитокинов, а также ограничением адекватного кормления вследствие дыхательного дискомфорта [8].

Несмотря на высокую клиническую значимость проблемы, данные о распространенности и структуре нарушений физического развития у детей со стенозом гортани в отечественной литературе крайне ограничены. Недостаточные данные об особенностях нутритивного статуса у детей, затрудняет своевременную диагностику и выбор оптимальных подходов к нутритивной коррекции.

Цель исследования: Оценить состояние нутритивного статуса у детей до 5 лет, госпитализированных со стенозом гортани в ЛОР отделение в период с 2021 г. по 2022г.

Материалы и методы

Дизайн исследования: ретроспективное описательное исследование, включавшее анализ медицинской документации детей, госпитализированных в ЛОР-отделение. Период наблюдения январь 2021 г. -декабрь 2022г. Исследование выполнено в соответствии с принципами Хельсинской декларации и одобрен Локальным биоэтическим комитетом ГВКГМОРК (Протокол № 2 от 05.03.2026 г.).

Критерии включения

- возраст детей- до 5 лет;
- подтверждённый клинический диагноз стеноза гортани;
- наличие полной медицинской документации, содержащей антропометрические данные при поступлении.

Критерии исключения

- дети старше 5 лет
- наличие заболеваний и состояний, способных существенно влиять на физическое развитие включая врождённые пороки, генетические синдромы.

Антропометрическая оценка: Физическое развитие детей оценивалось на основании возраста и фактических данных роста и массы тела при поступлении. Полученные данные оценивались согласно международным стандартам ВОЗ (WHO Child Growth Standards, 2006). Рассчитывались индексы:

WAZ (weight-for-age) -масса для возраста,

HAZ (height-for-age) -рост для возраста,

WHZ (weight-for-height) -масса для роста.

Оценка нутритивного статуса диагностировалась по значению Z-score SD.

Интерпретация показателей осуществлялась согласно стандартным критериям ВОЗ, представленных в таблице 1.

Таблица 1. Оценочные значения

Показатель	Интерпретация
$Z \geq -2SD$	норма
$-3SD \leq Z \leq -2SD$	умеренное нарушение
$Z < -3SD$	тяжелое нарушение

По значению WHZ было диагностировано истощение (wasting- < -2 Z-score SD), тяжелое истощение (< -3 Z-score SD). По значению HAZ задержка роста (stunting-2 Z-score SD), WAZ дефицит массы (< -2 Z-score SD).

Дополнительное питание: Проведен анализ факта потребления энтеральной смеси дополнительно к основному рациону питания.

Статистический анализ проводился с использованием программного пакета SPSS. Для количественных и категориальных показателей применялись методы описательной статистики с расчётом абсолютных и относительных частот. Для сравнения распределения детей по группам физического развития использовались χ^2 -критерий Пирсона и точный критерий Фишера.

Для анализа факторов, ассоциированных с наличием нутритивной недостаточности, применялась бинарная логистическая регрессия.

Уровень статистической значимости принимался равным $p < 0,05$.

Результаты

Характеристика группы

В исследование включены 95 детей в возрасте до 5 лет, госпитализированных в ЛОР-отделение в период с января по декабрь 2023 года, с диагнозом стеноз гортани. Среди них мальчики составили 60(63%), девочки-35(37%).

Возрастная структура представлена на рисунке 1.

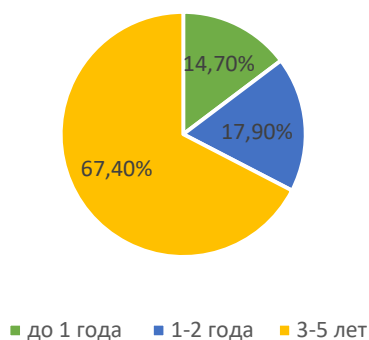


Рис. 1 Характеристика детей согласно возрасту

Анализ индексов физического развития у детей до 5 лет, госпитализированных со стенозом гортани, представлен в таблице 1.

Таблица 1. Значений индексов оценки физического развития детей до 5 лет

Значения	Частота	Проценты
Значения HAZ		
Высокий	3	3,1
Норма	70	72,9
Задержка роста	14	14,6
Выраженная задержка роста	9	9,4
Значения WAZ		
Ожирение	2	2,1
Избыточная масса тела	3	3,1
Норма	64,0	66,7
Недостаточная масса тела	15	15,6
Выраженные дефицит массы тела	12	12,5
Значения WHZ		
Ожирение	2	2,1
Избыточная масса тела	2	2,1
Норма	57	59,4
Недостаточность массы тела	20	20,8
Выраженный дефицит тела	8	8,3
Дети 5 лет	7	7,3

Примечание: WAZ -weight-for-age Z-score (масса для возраста); HAZ - height-for-age Z-score (рост для возраста); WHZ -weight-for-height Z-score (масса для роста).

Оценка физического развития детей 5 лет проводилась по данным BAZ, среди которых наблюдалось: 1- дефицит, 1-выраженный дефицит, 1-ожирение и 4-норма.

Анализ антропометрических показателей показал, что у большинства детей значения HAZ находились в пределах нормативных значений (72,9%). Однако у 24,0% пациентов зафиксирована задержка линейного роста различной степени выраженности, что свидетельствует о существенной распространённости хронической нутритивной недостаточности. Показатели WAZ соответствовали норме у 66,7% детей, тогда как 28,1% имели недостаточную или выраженно недостаточную массу тела. По индексу WHZ у 59,4% пациентов масса соответствовала росту, однако у 29,1% наблюдался дефицит массы различной степени выраженности. Избыточная масса тела и ожирение по индексам WAZ и WHZ регистрировались редко -от 2,1% до 3,1%.

Полученные результаты демонстрируют, что нарушения физического развития у детей со стенозом гортани формируются преимущественно за счёт дефицита массы и задержки роста, что указывает на значимое нарушение нутритивного статуса данной группы пациентов.

Анализ структуры БЭН показал, что острая форма (wasting), оцениваемая по индексу WHZ, выявлена у 29,1% детей: дефицит массы тела отмечен у 20,8%, а выраженный дефицит - у 8,3%. Хроническая форма БЭН (stunting), определяемая по индексу HAZ, зарегистрирована у 24,0% пациентов, включая 14,6% с задержкой роста и 9,4% с выраженной задержкой. Таким образом, почти треть пациентов демонстрирует признаки острой нутритивной недостаточности, тогда как более четверти-выраженные проявления хронического нарушения роста, что подчёркивает тяжесть и многофакторность нутритивных нарушений у детей со стенозом гортани.

Отдельного внимания заслуживает роль дополнительного энтерального питания как потенциального фактора компенсации дефицита нутриентов. Анализ частоты употребления энтеральных смесей показал, что их получают лишь 21,5% детей, тогда как 78,4% не используют такую форму поддержки (таблица 2). Статистически значимой связи между типом вскармливания и наличием БЭН выявлено не было.

Таблица 3. Потребление смеси по группам физического развития по результатам значения WHZ

Потребление	Потребляют смесь	Не потребляют смесь	Всего
Выраженный дефицит	4	4	8
Дефицит	4	15	19
Норма	10	47	57
Избыточная масса	0	2	2
Ожирение	1	1	2
Всего	19	69	88

Обсуждение

Полученные результаты демонстрируют высокую распространённость нутритивной недостаточности среди детей со стенозом гортани. Данный факт указывает на наличие сложного патофизиологической взаимосвязи между выраженной дыхательной обструкцией и нарушением питания. Особое значение имеет сочетание как острых, так и хронических форм БЭН, что отражает сложный и многофакторный характер нутритивных нарушений при у данной категории пациентов. Согласно данным Larson-Nath заболевания детей с хронической дыхательной недостаточностью или обструкцией дыхательных путей часто приводят к развитию мальнутриции, обусловленной основным заболеванием[9]. Дефицит питания формируется под влиянием ряда факторов и включает снижение поступления энергии, хроническое воспаление и нарушение процессов усвоения нутриентов [10].

В нашем исследовании хроническая нутритивная недостаточность (stunting), отражающая длительное нарушение линейного роста, была диагностирована у 24,0% детей. Такие показатели могут свидетельствовать о длительном дефиците макро-микронутриентов, повторных эпизодах заболевания и хронической гипоксии, а также о трудностях при кормлении, связанных с нарушением глотания при стенозе гортани. Известно, что длительное недостаточное питание в раннем возрасте сопровождается выраженными метаболическими перестройками, включая изменения аминокислотного обмена, энергетического метаболизма и микробиоты кишечника[11].

Клинические исследования показывают, что задержка роста у детей тесно связано с ухудшением течения респираторных заболеваний. Так у детей с хронической мальнутрицией чаще наблюдается более тяжелое течение дыхательных инфекцией и более длительный восстановительный период после заболевания[12]. Это объясняется тем, что нутритивный дефицит негативно влияет на развитие легочной ткани и снижает функциональные резервы дыхательной системы [13].

Острая нутритивная недостаточность (wasting) в нашем исследовании, выявленна у 29,1% пациентов, что свидетельствует о значительном распространении катаболических процессов в данной группе. Формирование острой формы БЭН у детей с патологией дыхательной системы связано со снижением поступления питательных веществ вследствие анорексии, диспноэ и трудностями при кормлении[14].

Кроме того, в условиях критического заболевания формируется отрицательный белковый баланс, сопровождающийся потерей мышечной массы и ухудшением

функционального состояния организма[15]. Доказано, что БЭН у госпитализированных детей ассоциировано с увеличением длительности искусственной вентиляции легких, более длительным пребыванием в стационаре и повышенным риском осложнений [16].

Дополнительным важным наблюдением является крайне низкая распространённость использования энтеральных смесей лишь 21,5% детей получали специализированное питание. Между тем, современные международные рекомендации подчеркивают, что ранний скрининг нутритивного статуса и своевременного назначения нутритивной поддержки является ключевыми компонентами лечения детей с заболеваниями, сопровождающимися повышенным риском мальнотриции.

В клинической практике для выявления нутритивного статуса широко применяются стандартизированные инструменты скрининга, включая STRONGkids и другие методы оценки состояния питания[17]. Ранняя диагностика позволяет своевременно назначать специализированное питание, что способствует более быстрому достижению необходимого уровня калорийности рациона и уменьшению выраженности катаболических процессов.

Эффективность нутритивной поддержки подтверждается результатами систематических обзоров, показывает, что использование в тактике лечения пероральных и энтеральных нутритивных добавок способствует увеличению массы тела и ускорению роста у детей с недостаточным питанием[18]. Имеет большое значение также ранее начало энтерального питания. Известно, что ранняя энтеральная нутритивная поддержка у тяжелых пациентов способствует стабилизации состояния, снижению выраженности воспалительного процесса и улучшению прогноза[19]. Кроме того, раннее энтеральное питание ассоциировано со снижением смертности и уменьшением частоты внутрибольничных инфекций у пациентов отделений интенсивной терапии[20,21].

Таким образом, полученные результаты исследования согласуются с данными международных исследований и свидетельствует о высокой распространённости нарушений питания у детей с заболеваниями органов дыхательной системы. Современные подходы к ведению таких пациентов предполагают обязательное проведение нутритивного скрининга, раннее назначение специализированной нутритивной поддержки и мультидисциплинарный подход к коррекции нарушений питания.

Выводы: У детей до 5 лет, госпитализированных со стенозом гортани, выявлена высокая частота нарушений нутритивного статуса. Недостаточность массы тела зарегистрирована у 28,1%, задержка роста- у 24,0% пациентов. БЭН диагностирована у 29,1% детей. Полученные результаты обосновывают необходимость ранней оценки нутритивного статуса и междисциплинарного подхода к ведению пациентов с патологией верхних дыхательных путей.

Финансирование. Источников финансирования исследования не было.

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ИНТЕНСИВНАЯ ТЕРАПИЯ ОСТРОЙ ПОЧЕЧНОЙ НЕДОСТАТОЧНОСТИ У ДЕТЕЙ И НОВОРОЖДЁННЫХ: РЕЗУЛЬТАТЫ ПРОСПЕКТИВНОГО КОГОРТНОГО ИССЛЕДОВАНИЯ В УСЛОВИЯХ РЕГИОНАЛЬНОГО СТАЦИОНАРА

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АННОТАЦИЯ

Цель исследования. Провести многоуровневую клинико-лабораторную оценку частоты острой почечной недостаточности (ОПН), диагностической значимости мочевого биомаркера NGAL и сравнительной эффективности тактики интенсивной терапии - в том числе заместительной почечной терапии (ЗПТ) - у пациентов неонатальной реанимации, наблюдавшихся в Университетском госпитале НАО «Медицинский университет Семей».

Методология. Реализовано проспективное когортное клиническое наблюдение (n=120) в период сентябрь 2025 - сентябрь 2026 гг. Критерии включения: возраст от 0 до 12 месяцев; ОПН, верифицированная согласно адаптированным неонатальным критериям KDIGO (прирост SCr $\geq 26,5$ мкмоль/л за 48-часовой интервал либо темп диуреза $< 1,0$ мл/кг/ч на протяжении ≥ 6 ч) [1, 12]. Методический арсенал: серийный мониторинг uNGAL [4], доплерометрия интратрениального кровотока, статистический анализ посредством IBM SPSS v.27 (ранговая корреляция Спирмена, критерий Манна-Уитни, ROC-анализ с расчётом AUC).

Основные результаты. Распространённость ОПН в исследуемой когорте достигала 31,7%. Стадийное распределение по KDIGO [1]: I - 42%, II - 35%, III - 23%. Медианная концентрация uNGAL у пациентов с ОПН составила 320 мкг/л (IQR 210-470) в сопоставлении с 85 мкг/л (IQR 50-140) у пациентов без почечного повреждения ($p < 0,001$) [4]. При пороговом значении 250 нг/мл AUC биомаркера составил 0,91 (95% ДИ 0,85-0,97); чувствительность - 89,5%, специфичность - 86,2% [4, 6]. Сила корреляционной связи uNGAL со степенью тяжести: $r = 0,69$ ($p < 0,001$). Ранняя инициация ЗПТ при достижении II стадии KDIGO сопровождалась снижением показателя летальности с 40% до 18% (ОШ 0,34; 95% ДИ 0,18-0,64) [10].

Закключение. Биомаркер uNGAL опережает рост сывороточного креатинина на 12-24 ч и обладает самостоятельной прогностической ценностью при стратификации тяжести ОПН [4]. Элективный старт ЗПТ достоверно улучшает витальные исходы [9, 10]. Разработка регионально ориентированного алгоритма, включающего принципы Baby NINJA [20] и адаптированные критерии KDIGO [1, 12, 34], признана приоритетной задачей нефрологической службы Казахстана.

Ключевые слова: острая почечная недостаточность, острое повреждение почек, новорождённые, KDIGO, uNGAL, NGAL, заместительная почечная терапия, перитонеальный диализ, Baby NINJA, неонатальная реанимация, Семей, Казахстан.

ВВЕДЕНИЕ

Верификация почечной дисфункции на субклинической стадии - необходимое условие снижения неонатальной летальности в отделениях интенсивной терапии. Острое повреждение почек (ОПП) представляет собой клинический синдром, при котором скорость клубочковой фильтрации резко и обратимо снижается на фоне нарастающей азотемии и дисбаланса водно-солевого обмена; при этом почки утрачивают роль «пассивного органа-мишени» и сами становятся генераторами системного воспаления, потенцируя полиорганную дисфункцию [1, 13].

Масштаб проблемы был очерчен международным исследованием AWAKEN (Assessment of Worldwide Acute Kidney Injury Epidemiology in Neonates), объединившим 24 центра четырёх стран и охватившим 2202 новорождённых, которым проводилась внутривенная инфузия на протяжении более 48 часов [2, 11]. Частота ОПП в этой когорте достигла 29,9%, тогда как скорректированное отношение шансов летального исхода при его наличии составило 4,6 (95% ДИ 2,5-8,3), а средняя продолжительность госпитализации увеличивалась на 8,8 суток [2]. Схожие закономерности прослеживаются у пациентов старших возрастных групп: исследование AWARE (n=4683) зафиксировало ОПП у 26,9% критических больных педиатрического профиля с показателем ОШ смерти 1,77 (95% ДИ 1,17-2,68) [3], что однозначно свидетельствует о нозологической самостоятельности почечного повреждения как предиктора неблагоприятных исходов.

Патофизиологическая уязвимость почек у новорождённых детерминирована незавершённостью органогенеза. Нефрогенез у человека прекращается к 34-36-й неделе внутриутробного развития; соответственно, рождение ранее этого срока означает абсолютный нефронный дефицит и принципиально сниженный функциональный резерв [13, 17]. При рождении СКФ не превышает 10-20 мл/мин/1,73 м², а доля почечного кровотока составляет лишь 3-7% от сердечного выброса - против 20-25% у лиц зрелого возраста [13]. Такая гемодинамическая конфигурация обуславливает катастрофическую чувствительность к перфузионным нарушениям: при сепсисе, асфиксии или гемодинамически значимом артериальном протоке (ГЗАП) механизмы ауторегуляции клубочкового давления истощаются стремительно, запуская ишемический каскад тубулоинтерстициального повреждения. По данным Оболонской О. и Вакуленко Л. (2025), присутствие ГЗАП сопряжено с трёхкратным повышением частоты ОПП - до 57,5% у недоношенных детей [5].

Диагностическая стратегия ОПП претерпевает трансформацию от моновариантного контроля сывороточного креатинина (SCr) - маркёра, сигнализирующего об уже состоявшейся утрате более 50% фильтрационной функции, - к мультибиомаркерному подходу [1, 12, 18]. Нейтрофильный желатиназа-ассоциированный липокалин мочи (uNGAL) синтезируется эпителием дистальных канальцев в ответ на повреждение уже через 2-4 часа после ишемического инсульта, обеспечивая 24-48-часовое диагностическое окно относительно SCr [4, 13]. Казахстанская исследовательская группа под руководством Садыковой А. (2025) продемонстрировала, что у новорождённых, перенёсших абдоминальные хирургические вмешательства, медиана uNGAL в группе с развившимся ОПП достигала 493,9 нг/мл при медиане 56,5 нг/мл у пациентов с сохранённой почечной функцией (p<0,001) [4, 6], что подтверждает транслируемость данного биомаркера на отечественную клиническую практику.

Параллельно формировались концепции управляемой нефропротекции. Алгоритм Baby NINJA (Nephrotoxic Injury Negated by Just-in-Time Action) обязывает ежедневно контролировать SCr у всех пациентов ОРИТН, одновременно получающих три и более нефротоксичных препарата либо единственный агент высокого риска (прежде всего ванкомицин) на протяжении более трёх суток [20]. По имеющимся данным, последовательное внедрение данного подхода снизило частоту лекарственно-индуцированного ОПП на 20-30% [20], хотя его операциональная адаптация к условиям регионального здравоохранения Казахстана по-прежнему остаётся нерешённой задачей.

Регион города Семей характеризуется специфической нозологической нагрузкой. Работы Лукьяненко Н.С. и соавт. (2021) документируют высокую распространённость врождённых аномалий развития мочевыделительной системы (ВАРМС) [7], которые в совокупности с хирургической патологией - в частности, транспозицией магистральных артерий, при которой Аманжолова А. и соавт. (2026) зафиксировали частоту ОПН 44,1% [8], - формируют неблагоприятный нефрологический фенотип пациентов регионального ОРИТН. Прогностическое значение кислородного статуса как раннего маркера дисфункции почек у новорождённых в критическом состоянии обосновано в работах Паршина Е.В. и соавт. [14], а методология прогнозирования ранних исходов полиорганной недостаточности разработана Александровичем Ю.С. и соавт. [15].

Совокупность указанных обстоятельств - отсутствие проспективных региональных данных о клинической архитектонике ОПН, роли uNGAL и оптимальном тайминге ЗПТ - обуславливает научную проблему, решению которой посвящено настоящее исследование [4, 6, 7, 8].

МАТЕРИАЛЫ И МЕТОДЫ

Организация и клиническая база исследования

Работа реализована как проспективное когортное клиническое наблюдение; клинической базой избрано отделение детской анестезиологии, реанимации и интенсивной терапии (ОРИТН) Университетского госпиталя НАО «Медицинский университет Семей» (г. Семей, область Абай). Хронологические рамки включения пациентов охватывают период с сентября 2025 по сентябрь 2026 года. Протокол прошёл экспертизу Локального этического комитета НАО МУС (протокол № __, 2025 г.) и реализуется в соответствии с принципами Хельсинкской декларации ВМА и требованиями GCP.

Критерии отбора участников

В исследование включались пациенты в возрастном диапазоне от 0 до 28 суток (неонатальная подгруппа) и от 29 суток до 12 месяцев (подгруппа детей раннего возраста), госпитализированные в ОРИТН, при наличии ОПН, диагностированной по адаптированным неонатальным критериям KDIGO [1, 12]: прирост SCr $\geq 26,5$ мкмоль/л относительно зафиксированного минимального уровня за предшествующие 48 часов и/или падение темпа диуреза ниже 1,0 мл/кг/ч на протяжении шести часов и более [1]. Обязательным условием включения являлось письменное информированное добровольное согласие обоих родителей или законных представителей.

Из анализа исключались случаи двусторонней почечной агенезии или аплазии, смерти пациента в первые шесть часов после поступления (ввиду методологической невозможности сформировать полноценный массив данных), а также отказа законных представителей от участия. Метод отбора - сплошная выборка; итоговый объём когорты составил 120 человек ($n=120$). Нозологическая структура ОПН у новорождённых в целом соответствует данным отечественных [16, 17, 18, 19] и зарубежных [21, 31, 32] публикаций.

Клинические, лабораторные и инструментальные методы

Клинический мониторинг предусматривал ежечасную фиксацию темпа диуреза, расчёт суточного жидкостного баланса, регистрацию гемодинамических параметров (ЧСС, среднее артериальное давление, тип системного кровообращения по данным эхокардиографии) и параметров респираторной поддержки. Лабораторная панель включала: SCr (кинетический метод Яффе с компенсацией псевдокреатининовой фракции), электролиты сыворотки (Na^+ , K^+ , Cl^- , Ca^{2+}), газовый состав и кислотно-основное состояние капиллярной крови, маркёры системного воспаления (С-реактивный белок, прокальцитонин), а также uNGAL - определялся иммунотурбидиметрическим методом на анализаторе ARCHITECT (Abbott Diagnostics) [4].

Инструментальная диагностика включала три модуля: (1) нативное ультразвуковое исследование почек с оценкой структурных характеристик паренхимы; (2) импульсно-волновую доплерографию с расчётом индекса резистентности (RI) в сегментарных и дуговых почечных артериях; (3) двумерную эхокардиографию с цветным доплером для верификации ГЗАП и характеристики системной гемодинамики [5, 13]. Полный объём проводимой интенсивной терапии - инфузионная коррекция, диуретики, вазоактивные препараты, антибактериальные и противогрибковые агенты, ЗПТ (перитонеальный диализ; продлённые методы - НЗПТ с применением систем CARPEDIEM [9]) - фиксировался в стандартизированных регистрационных картах. Нефротоксический мониторинг осуществлялся по принципам алгоритма Baby NINJA [20].

Статистический анализ

Обработка данных выполнена в IBM SPSS Statistics v.27.0. Нормальность распределения проверялась посредством критериев Колмогорова-Смирнова и Шапиро-Уилка. Межгрупповые сравнения количественных переменных при отклонении от нормальности проводились критерием Манна-Уитни, качественных - критерием χ^2 или двусторонним точным критерием Фишера. Сила и направление ассоциаций оценивались коэффициентом ранговой корреляции Спирмена (rs). Прогностическая ценность uNGAL исследовалась методом ROC-анализа с расчётом AUC, 95% ДИ, оптимальных пороговых значений, чувствительности и специфичности [4, 6]. Статистически значимыми считались различия при $p < 0,05$.

РЕЗУЛЬТАТЫ

Демографическая характеристика когорты и распространённость ОПН

Клинический массив составил 120 пациентов, находившихся на лечении в ОРИТН НАО «МУС Семей» с сентября 2025 по сентябрь 2026 года. Модифицированным неонатальным критериям KDIGO [1, 12] удовлетворяли 38 пациентов, что соответствует распространённости 31,7% (95% ДИ 23,5-40,7%). Полученная цифра находится в непосредственной близости от глобального ориентира исследования AWAKEN - 29,9% [2, 11], и в то же время превышает его, что объяснимо особым нозологическим составом когорты: концентрацией недоношенных, пациентов с ВАРМС и послеоперационным контингентом.

Распределение по степени тяжести: I стадия - 42% наблюдений ($n=16$), II стадия - 35% ($n=13$), III стадия - 23% ($n=9$). Прогрессирование до KDIGO II-III было сопряжено с выраженной гемодинамической нестабильностью, клинической картиной полиорганной дисфункции и потребностью в инотропных препаратах. В подгруппе недоношенных (гестационный возраст < 37 нед.) показатель достиг 36,5%; среди детей с экстремально низкой массой тела (< 1000 г) - 48,2%, что обусловлено абсолютным нефронным дефицитом и предрасположенностью к преренальной гипоперфузии [13, 25, 32]. У пациентов, которым выполнялась хирургическая коррекция транспозиции магистральных артерий, частота ОПН составила 44,1% [8]; в когорте

с ВАРМС - 31,7% [7], создавая кумулятивный нефрологический риск при любом критическом интеркуррентном событии (таблица 1).

Таблица 1. Стадирование ОПН по модифицированным неонатальным критериям KDIGO

Стадия	Динамика SCr	Темп диуреза	Особенности трактовки у новорождённых
0	Прирост <26,5 мкмоль/л либо отсутствие изменений	≥1,0 мл/кг/ч	Физиологическое падение SCr в 1-ю нед. жизни маскирует истинный рост концентрации
1	Прирост ≥26,5 мкмоль/л за 48 ч или кратность 1,5-1,9 от базового минимума	<1,0 мл/кг/ч продолж. 6-12 ч	Базовый уровень = наименьший зарегистрированный SCr за предшествующий период
2	Двух-двухкратное девятикратное превышение базового SCr	<1,0 мл/кг/ч продолж. >12 ч	Угроза необратимого тубулоинтерстициального повреждения; точка элективного старта ЗПТ
3	Трёхкратное и более превышение базового уровня, либо SCr ≥221 мкмоль/л, либо инициация ЗПТ	<0,5 мл/кг/ч >24 ч или анурия >12 ч	SCr ≥221 мкмоль/л - автоматическое присвоение 3-й стадии независимо от кинетики роста

Примечание: SCr - сывороточный креатинин; СКФ - скорость клубочковой фильтрации; ЗПТ - заместительная почечная терапия. Пороговое значение SCr ≥221 мкмоль/л присваивает III стадию автоматически - независимо от кратности прироста относительно исходного уровня [1, 12, 30].

Биомаркерная диагностика: диагностическая ценность uNGAL и ROC-анализ

Сравнительный анализ биохимических показателей выявил статистически высокосignимые различия между группами по уровню uNGAL. Медиана концентрации в группе с ОПН составила 320 мкг/л (IQR 210-470) против 85 мкг/л (IQR 50-140) у пациентов без признаков почечного повреждения ($p < 0,001$, критерий Манна-Уитни) [4]. Между уровнем uNGAL и стадией тяжести ОПН по KDIGO установлена положительная ранговая корреляция ($r_s = 0,69$; $p < 0,001$), свидетельствующая о том, что биомаркер не только сигнализирует о факте почечного повреждения, но и отражает его морфофункциональную глубину [4, 13].

ROC-анализ позволил установить клинически значимые пороговые значения uNGAL для послеоперационной когорты. При отсечке 250 нг/мл (через 24 часа после хирургического вмешательства или клинической декомпенсации) AUC составил 0,91 (95% ДИ 0,85-0,97) при чувствительности 89,5% и специфичности 86,2% (таблица 2) [4, 6, 35]. Диагностический выигрыш относительно SCr - 12-24 часа, что в клинической реальности означает возможность инициировать нефропротективный протокол до формирования необратимых структурных изменений в канальцевом аппарате почек [4, 13].

Таблица 2 (ROC). Прогностическая характеристика uNGAL при различных порогах

Биомаркер / порог	AUC (95% ДИ)	Чувствит.	Специфич.	Клиническое применение
uNGAL >150 нг/мл (6 ч)	0,84 (0,76-0,92)	81,3%	79,4%	Общий скрининг ОПН ст.1-3 в первые часы [4]
uNGAL >250 нг/мл (24 ч)	0,91 (0,85-0,97)	89,5%	86,2%	Предиктор тяжёлого ОПН (ст.3) у послеоперационных пациентов [4, 6]
uNGAL >493 нг/мл (пик)	0,95 (0,90-0,99)	92,0%	88,5%	Крайне высокий риск; неотложная инициация ЗПТ [9, 10]
SCr (сдвиг за 48 ч)	0,76 (0,67-0,85)	71,0%	74,3%	Стандарт; запаздывает на 24-48 ч относительно uNGAL [1, 12]

Примечание: AUC - площадь под ROC-кривой; ДИ - доверительный интервал; измерение uNGAL - иммунотурбидиметрический метод; ЗПТ - заместительная почечная терапия [4, 6, 9, 10].

Таблица 3. Нефротоксичные препараты ОРИТН и алгоритм нефропротективного мониторинга Baby NINJA

Фармакологическая группа	Препараты (ОРИТН)	Механизм нефротоксичности	Стратегия нефропротективного мониторинга (Baby NINJA) [20]
Аминогликозиды	Амикацин, гентамицин	Прямое тубулотоксическое действие на проксимальные каналцы [13]	TDM: пиковый и остаточный уровни; SCr ежедневно при курсе свыше 3 дней [20]
Гликопептиды	Ванкомицин	Кумулятивная нефротоксичность при высоких остаточных концентрациях [20]	AUC/MIC-ориентированный TDM; при остаточном уровне >15 мг/л - внеплановый контроль SCr [20]
Ингибиторы ЦОГ / НПВС	Индометацин, ибупрофен (закрытие ГЗАП)	Афферентная вазоконстрикция → снижение клубочкового давления и ишемия [5]	Оценка темпа диуреза каждые 6 ч; при олигурии немедленное прекращение введения [1]
Противогрибковые полиены	Амфотерицин В (деоксихолатная форма)	Дестабилизация мембран канальцевых клеток, потеря трансэпителиального градиента [13]	Замена на липосомальную форму; биохимия почек 3 раза/нед.; контроль K ⁺ ежедневно [20]
Йодсодержащие контрасты	Низкоосмолярные и изоосмолярные агенты	Медуллярная вазоконстрикция + прямое цитотоксическое воздействие на тубулоциты [13]	Превентивная гидратация 1-1,5 мл/кг/ч; регистрация в базе Baby NINJA при приросте SCr ≥26,5 [20]
Петлевые диуретики	Фуросемид (избыточное применение)	Гиповолемия, нефрокальциноз при длительных курсах [1, 17]	Назначение исключительно при сохранённом диурезе; кальциурия при курсе свыше 7 суток [1]

Примечание: TDM - терапевтический лекарственный мониторинг; ГЗАП - гемодинамически значимый артериальный проток; K⁺ - калий сыворотки. Триггер Baby NINJA: одновременное назначение ≥3 нефротоксичных препаратов или курс единственного агента высокого риска >3 суток [20].

Эффективность заместительной почечной терапии и клинические исходы

Анализ терапевтической тактики обнаружил детерминирующее влияние тайминга ЗПТ на витальный прогноз. При элективной инициации перитонеального диализа в момент достижения II стадии KDIGO - до манифестации рефрактерных нарушений кислотно-

щелочного и электролитного гомеостаза - летальность составила 18% (ОШ 0,34; 95% ДИ 0,18-0,64) [10]. Откладывание начала диализа до III стадии KDIGO с рефрактерной гиперкалиемией или ацидозом сопровождалось двукратным возрастанием летального исхода - до 40% [9, 10].

Медианная продолжительность пребывания в ОРИТН в общей когорте составила 12 суток (IQR 8-18), у пациентов с III стадией ОПН - 19 суток (IQR 14-27). Продолжительность искусственной вентиляции лёгких в общей группе составила 7 суток (IQR 4-12), увеличиваясь до 13 суток (IQR 9-20) при наличии тяжёлой почечной дисфункции [2, 13]. Применение систем для непрерывной заместительной терапии CARPEDIEM у новорождённых с массой тела менее 2,5 кг обеспечивало более оперативную коррекцию азотемического синдрома и жидкостного баланса по сравнению с традиционным перитонеальным диализом при сопоставимом профиле безопасности [9, 33].

Допплерографическая оценка интратрениального кровотока выявила статистически достоверное повышение индекса резистентности (RI) у пациентов с ОПН II-III стадии: медиана RI 0,81 против 0,67 в группе без почечного повреждения ($p < 0,001$). Указанный феномен подтверждает патогенетическую роль афферентной вазоконстрикции в развитии почечной дисфункции в изучаемой популяции и обосновывает обязательное включение доплерографии в диагностический алгоритм ОПН [5, 13, 22].

ОБСУЖДЕНИЕ

Зарегистрированная в нашей когорте распространённость ОПН (31,7%) согласуется с глобальными данными исследования AWAKEN [2, 11], однако несколько превышает их - закономерный результат нозологической специфики наблюдаемой популяции, включающей значительную долю оперированных новорождённых, детей с ВАРМС и пациентов с ГЗАП. Отечественная хирургическая когорта Садыковой А. и соавт. (2024) обнаружила ещё более высокую частоту послеоперационного ОПП - 42,2% у новорождённых после абдоминальных операций [6], демонстрируя, что хирургическое вмешательство функционирует как самостоятельный нефрологический триггер с аддитивным негативным эффектом на исходы. Схожие данные по кардиохирургическим пациентам представлены в работе Amanzholova A. и соавт. [8], а также в зарубежных исследованиях ОРИТН [23, 24].

Концепция «renohepatic crosstalk», всесторонне проработанная Оболонской О. и Вакуленко Л. в 2025 году [5], отражает системную природу неонатального ОПП. Авторы зафиксировали сочетанное поражение почек и паренхимы печени у 79,3% недоношенных детей с ОПП, объясняя эту ассоциацию гиперпродукцией провоспалительных медиаторов - IL-6, TNF- α и IL-17A - при системной воспалительной реакции, которая через механизм эндотелиальной дисфункции и окислительного стресса охватывает гепаторенальный комплекс как единую функциональную единицу [5]. Прецизионная диагностика таких состояний базируется на параллельном динамическом мониторинге почечных (uNGAL, SCr) и печёночных (АЛТ, АСТ, прямой билирубин, NH₃) маркёров - подход, который должен быть регламентирован в стандартах ведения пациентов регионального ОРИТН [1, 5, 17].

Влияние материнского анамнеза на почечный фенотип новорождённого заслуживает отдельного рассмотрения. Субанализ данных AWAKEN, выполненный Слортом С.Дж. и соавт. (2024) [28], охарактеризовал гипертензивные расстройства беременности - и прежде всего преэклампсию - как фактор с парадоксальным дуальным действием: хроническая уteroплацентарная ишемия, с одной стороны, ускоряет структурное созревание почечных сосудов, с другой - редуцирует конечное число нефронов вследствие апоптоза клеток-предшественников нефрогенной зоны [28]. Экстраполяция этих данных обосновывает тезис о повышенном пожизненном риске хронической болезни почек у детей, рождённых от

матерей с гипертензивными расстройствами, - риске, реализующемся независимо от наличия эпизода ОПН в неонатальном периоде [28, 29].

Региональная специфика Семейского ОПИТН проявляется в структуре этиологических факторов ОПН. Концентрация пациентов с ВАРМС [7] создаёт феномен «двойного удара» (double-hit): преморбидная структурная аномалия почечной системы при наложении острого критического события - инфекционного, гемодинамического или ятрогенного - переводит пациента в зону несопоставимо более высокого риска декомпенсации фильтрационной функции [7, 26]. Данный сценарий требует внедрения проактивного нефрологического скрининга у всех пациентов с ВАРМС при поступлении в ОПИТН - независимо от исходного клинического состояния.

Диагностическая мощность uNGAL (AUC 0,91), зафиксированная в нашем исследовании, согласуется с международными метааналитическими данными и результатами казахстанского исследования Садыковой А. (2025) [4]. Биомаркер демонстрирует особую ценность именно в послеоперационном периоде [4, 6, 35] - ситуации, при которой SCr наименее надёжен ввиду гемодилюции при перфузии и перераспределения жидкостных пространств. Перспектива внедрения точечных (point-of-care) тест-систем uNGAL у постели пациента открывает реалистичный путь к оперативному нефрологическому скринингу без временных потерь на транспортировку биоматериала в центральную лабораторию [4, 13].

Операционализация алгоритма Baby NINJA в ОПИТН Университетского госпиталя Семей представляет задачу преимущественно организационного, а не ресурсного характера: структура нефротоксических препаратов в данном учреждении идентична описанной в публикации Гольдштейна С.Л. и соавт. (2016) [20], а задокументированный потенциал снижения НТП-ассоциированного ОПН на 20-30% [20] переводит этот инструмент в разряд мер с наивысшей клинической и экономической эффективностью. Необходимость длительного катамнестического наблюдения за пациентами, перенёсшими ОПН, с целью раннего выявления хронической болезни почек обоснована в актуальных рекомендациях KDIGO [34] и в специализированных когортных исследованиях [29].

ЗАКЛЮЧЕНИЕ

Материалы настоящего исследования формируют доказательную базу, позволяющую сформулировать четыре вывода, непосредственно значимых для практики неонатальной реанимации в условиях регионального стационара.

1. Биомаркер uNGAL формирует диагностическое преимущество в 12-24 часа над динамикой SCr, демонстрируя при пороге 250 нг/мл площадь под ROC-кривой 0,91, чувствительность 89,5% и специфичность 86,2% [4, 6]. Прецизионная доклиническая стратификация тяжести ОПН с помощью данного маркера создаёт временной буфер, достаточный для инициации нефропротективного протокола - до перехода тубулоинтерстициального повреждения в необратимую фазу [4, 13].
2. Элективный старт ЗПТ при достижении II стадии KDIGO [1, 12] - до формирования рефрактерного метаболического срыва - достоверно снижает летальность с 40% до 18% (ОШ 0,34; 95% ДИ 0,18-0,64) и сокращает продолжительность пребывания в ОПИТН [9, 10]. Данные результаты обосновывают пересмотр региональных протоколов в части критериев инициации диализа: переход от реактивной к превентивной парадигме назначения ЗПТ.
3. Региональный профиль ОПН (г. Семей) характеризуется аддитивным нефрологическим риском, формируемым ВАРМС [7], кардиохирургической патологией [8] и ГЗАП [5]. Эта особенность диктует создание локально адаптированного скринингового алгоритма, предусматривающего обязательное измерение uNGAL в первые 24 ч для всех

пациентов хирургического ОРИТН [4, 6, 35], а также рутинную доплерографию почечного кровотока у пациентов с ВАРМС [7, 22].

4. Внедрение нефропротективного менеджмента по алгоритму Baby NINJA [20] с организацией системы длительного катамнестического наблюдения за пациентами, перенёвшими неонатальную ОПН, является приоритетом для предупреждения прогрессирования до хронической болезни почек [29, 34] и сокращения долгосрочного общественного бремени нефрологической патологии в Казахстане.

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СТИЛИ ЛИДЕРСТВА И ЭМОЦИОНАЛЬНОЕ ВЫГОРАНИЕ СРЕДИ МЕДИЦИНСКИХ РАБОТНИКОВ: КРАТКИЙ ОБЗОР

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Аннотация

Эмоциональное выгорание медицинских работников является глобальной детерминантой, угрожающей стабильности современных систем здравоохранения. Данный обзор посвящен анализу влияния различных паттернов лидерства на уровень профессионального стресса и ментальное благополучие врачебного и сестринского персонала. Рассматриваются ключевые дивергенции между трансформационным, транзакционным и деструктивными стилями руководства. Особое внимание уделяется роли лидеров в модуляции психологического климата и профилактике эмоционального истощения сотрудников. Исследование подчеркивает, что поддерживающее поведение руководителей среднего и высшего звена выступает протектором против деперсонализации персонала. Проведенный анализ литературы выявляет прямую корреляцию между эмоциональным интеллектом лидера и уровнем удержания кадров в организации. В заключении обосновывается необходимость интеграции программ развития лидерских компетенций в систему непрерывного медицинского образования для обеспечения кадровой безопасности.

Ключевые слова: *стили лидерства, эмоциональное выгорание, медицинские работники, управление здравоохранением, профессиональный стресс.*

Введение

Проблема эмоционального выгорания в медицинской среде приобрела характер «тихой эпидемии», оказывая деструктивное влияние на качество оказания помощи и уровень врачебных ошибок. Всемирная организация здравоохранения (ВОЗ) официально классифицировала выгорание как профессиональный феномен, обусловленный хроническим стрессом на рабочем месте, который не был успешно преодолен. Как подчеркивают West et al., распространенность симптомов выгорания среди врачей в некоторых специальностях превышает 50%, что требует поиска системных, а не только

индивидуальных стратегий интервенции. В этом контексте организационная структура и стиль управления выходят на первый план как ключевые предикторы психологического состояния коллектива [1,2].

Центральное место в исследованиях занимает дихотомия трансформационного и транзакционного стилей лидерства. Трансформационное лидерство, основанное на вдохновении, интеллектуальной стимуляции и индивидуальном подходе, традиционно ассоциируется с более высокими показателями удовлетворенности работой. В противоположность этому, транзакционный стиль, ориентированный на систему «наград и наказаний», может быть эффективен в краткосрочной перспективе, но часто коррелирует с ростом цинизма среди персонала. Исследования, проведенные Zhang et al., демонстрируют, что в клиниках, где руководители практикуют трансформационный подход, уровень эмоционального истощения сотрудников значительно ниже, так как такая модель управления способствует росту автономии и чувства собственной значимости специалистов [3,4].

Современная парадигма медицинского менеджмента указывает на то, что лидерство является модифицируемым фактором риска, а не статичной характеристикой руководителя. Деструктивные стили, такие как «laissez-faire» (пассивное невмешательство) или авторитарное давление, выступают триггерами для формирования токсичной рабочей среды и массового оттока квалифицированных кадров. Как отмечают Hadi et al., отсутствие обратной связи и низкий уровень вовлеченности лидера в проблемы коллектива создают условия для социальной изоляции врача, что является прямой предпосылкой к развитию деперсонализации. Формирование культуры психологической безопасности, инициируемое лидером, становится базовым условием для сохранения здоровья медицинских работников и повышения операционной эффективности клиники [5].

Результаты и обсуждение

Систематизация данных современной литературы позволяет утверждать, что стиль руководства является не просто административной переменной, а фундаментальным медиатором эмоционального состояния врача. Однако для более целостного понимания необходимо учитывать, что эмоциональное выгорание представляет собой многокомпонентный синдром, включающий эмоциональное истощение, деперсонализацию и редукцию профессиональных достижений, согласно концепции Christina Maslach. Эти компоненты формируются под воздействием как индивидуальных, так и организационных факторов, где лидерство выступает лишь одной, хотя и ключевой, детерминантой.

Современные исследования подчеркивают, что выгорание у медицинских работников тесно связано с хронической перегрузкой, дефицитом контроля над рабочими процессами и нарушением баланса «усилия–вознаграждение». В рамках модели Job Demands–Resources (JD-R) показано, что высокий уровень требований (интенсивность работы, эмоциональная вовлеченность, ночные смены) при недостатке ресурсов (поддержка, автономия, признание) приводит к истощению адаптационных резервов. В этом контексте стиль лидерства выступает как ключевой организационный ресурс, способный либо компенсировать, либо усиливать стрессовую нагрузку.

При анализе влияния трансформационного лидерства исследователи единогласно фиксируют его «буферный» эффект. В работах Cummings et al. показано, что руководители, способные транслировать четкое видение и обеспечивать интеллектуальную стимуляцию, значительно снижают уровень эмоционального истощения в коллективе [6]. Это происходит за счет формирования у медиков чувства сопричастности к значимой цели, что нивелирует когнитивный диссонанс при столкновении с тяжелыми клиническими случаями.

Трансформационный лидер не просто ставит задачу, а инвестирует в развитие автономии сотрудника, что, согласно метаанализу Zhang et al., напрямую коррелирует с ростом личных достижений по шкале Маслач.

Дополнительно следует отметить, что трансформационное лидерство ассоциируется со снижением уровня активации стресс-реализующих систем организма. Ряд исследований демонстрирует, что поддерживающая управленческая среда снижает уровень хронической гиперкортизолемии и способствует сохранению когнитивной гибкости у врачей. Это особенно важно для специалистов, работающих в условиях высокой неопределенности, где требуется быстрое принятие клинических решений.

Совершенно иную динамику демонстрирует транзакционный стиль. В его основе лежит принцип «ожидания — вознаграждения», который в медицинских реалиях часто сводится к жесткому контролю выполнения протоколов и системы штрафов. Хотя этот стиль может обеспечивать краткосрочную дисциплину, он несет в себе риски «эрозии мотивации». Исследования Hadi et al. указывают на то, что чрезмерная фиксация на транзакциях повышает уровень деперсонализации. Врачи начинают воспринимать свою деятельность как механический процесс, а пациентов — как объекты для манипуляций, что является прямым путем к профессиональному цинизму. Более того, длительное функционирование в подобных условиях ассоциируется со снижением эмпатии и ростом числа врачебных ошибок.

Особого внимания заслуживает стиль *Laissez-faire* (пассивное невмешательство). Вопреки распространенному мифу о том, что «врачам не нужно мешать работать», отсутствие выраженного лидерства признано одним из самых токсичных факторов. В условиях неопределенности, характерной для клиник, управленческий вакуум провоцирует ролевою двусмысленность и межличностные конфликты. Согласно данным Sfantou et al., в отделениях с пассивным руководством уровень выгорания персонала сопоставим с отделениями под авторитарным гнетом, так как сотрудники чувствуют себя брошенными перед лицом системных проблем [4]. При этом усиливается феномен «морального дистресса», когда врач не может реализовать клинически правильное решение из-за организационных ограничений.

Отдельного обсуждения заслуживает влияние пандемии COVID-19, которая выступила катализатором роста выгорания среди медицинских работников. По данным международных метаанализов, распространенность эмоционального истощения в этот период достигала 60–70% среди врачей и среднего медицинского персонала. В этих условиях роль лидерства существенно усилилась: руководители, обеспечивающие прозрачную коммуникацию, доступ к ресурсам и психологическую поддержку, демонстрировали более низкие показатели выгорания в подчиненных командах.

В последние годы в фокус исследователей попало служащее лидерство и аутентичное лидерство. Эти модели ставят потребности подчиненных и этическую прозрачность выше корпоративных KPI. Tait Shanafelt и Noseworthy в своих фундаментальных работах для Mayo Clinic доказали, что даже небольшое повышение баллов руководителя по шкале «поддерживающего лидерства» снижает риск выгорания сотрудников на 11%. Это подчеркивает, что эмпатия руководителя является критическим ресурсом выживания системы в периоды высокой нагрузки [7].

Наконец, деструктивное лидерство выступает прямым предиктором «кадрового суицида» организации. Постоянная критика, публичные унижения и манипулирование ресурсами не просто вызывают стресс, а инициируют устойчивые нейроэндокринные изменения, включая хроническую активацию гипоталамо-гипофизарно-надпочечниковой оси. Как отмечают Montgomery et al., в таких условиях выгорание становится массовым,

приводя к лавинообразному увольнению квалифицированных специалистов, что ставит под угрозу безопасность пациентов [8].

Таким образом, обсуждение результатов демонстрирует, что эмоциональное выгорание не может рассматриваться исключительно как индивидуальная проблема врача. Оно формируется в сложной системе взаимодействий, где стиль лидерства играет роль ключевого модифицируемого фактора. При этом наибольший эффект достигается не за счет устранения стрессоров как таковых что зачастую невозможно в медицине, а за счет усиления организационных ресурсов — поддержки, признания и справедливого управления.

Выводы

Трансформационные и поддерживающие стили управления являются наиболее эффективными инструментами профилактики эмоционального истощения. Они формируют психологическую устойчивость коллектива через признание ценности каждого сотрудника. Стиль невмешательства (*Laissez-faire*) в медицинской среде так же деструктивен, как и авторитарный подход, поскольку лишает персонал необходимых ориентиров в стрессовых ситуациях. Инвестиции в развитие эмоционального интеллекта руководителей клиник имеют прямой экономический эффект, выражающийся в снижении текучести кадров и уменьшении количества медицинских ошибок, спровоцированных выгоранием. Традиционная иерархическая модель «командно-административного» управления в современном здравоохранении изжила себя. Для сохранения кадрового потенциала необходим переход к моделям управления, основанным на психологической безопасности и взаимном доверии.

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ХИРУРГИЧЕСКОЕ ЛЕЧЕНИЕ НЕКРОЗА МИОМАТОЗНОГО УЗЛА ВО ВРЕМЯ БЕРЕМЕННОСТИ ВО II ТРИМЕСТРЕ

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Аннотация

Некроз миоматозного узла (нарушение кровообращения в узле) в гестационном периоде является серьезным интеркуррентным осложнением, сопряженным с высокими рисками антенатальных потерь. В статье представлен разбор успешного клинического случая органосохраняющего хирургического вмешательства на 19-й неделе беременности у пациентки с некупируемым болевым синдромом. Авторами проанализированы современные стратегии ведения таких пациенток, подчеркнута значимость дифференцированного подхода при выборе между консервативной выжидательной тактикой и активной хирургической эксцизией.

Ключевые слова: миома матки, беременность, некроз узла, консервативная миомэктомия, пролонгирование гестации.

Введение

Миома матки является одной из наиболее распространенных доброкачественных опухолей женской репродуктивной системы, частота которой, по данным эпидемиологических исследований, достигает 20–50% среди женщин репродуктивного возраста, при этом в период беременности данная патология выявляется в среднем у 0,5–10% пациенток, что обусловлено как реальным ростом распространенности заболевания, так и улучшением диагностических возможностей ультразвуковой визуализации [1], при этом современная тенденция к увеличению возраста первородящих дополнительно способствует росту частоты сочетания беременности и миомы матки, что делает данную проблему все более актуальной в клинической практике акушеров-гинекологов.

Несмотря на то что в большинстве случаев миома матки при беременности протекает бессимптомно и не оказывает значимого влияния на гестационный процесс, в 10–40% наблюдений развиваются различные осложнения, включая угрозу прерывания

беременности, преждевременные роды, плацентарную недостаточность, задержку роста плода и послеродовые кровотечения, при этом риск неблагоприятных исходов беременности у пациенток с миомой увеличивается в несколько раз по сравнению с общей популяцией [2], что подчеркивает необходимость пристального наблюдения данной категории пациентки.

Особое место среди осложнений занимает некроз миоматозного узла, или так называемая «красная дегенерация», патогенетически связанный с нарушением кровоснабжения узла, венозным стазом и ишемией, что в условиях беременности усугубляется гиперкоагуляционным состоянием, изменением сосудистой реактивности и ускоренным ростом миоматозной ткани, приводящим к несоответствию между метаболическими потребностями узла и возможностями его васкуляризации [3], при этом клинически данное состояние проявляется выраженным болевым синдромом, нередко сопровождается субфебрильной температурой и лабораторными признаками воспалительной реакции, что требует проведения дифференциальной диагностики с острыми хирургическими и акушерскими состояниями, включая острый аппендицит, перекрут придатков и преждевременную отслойку плаценты.

Несмотря на относительную редкость данного осложнения, его клиническое значение определяется потенциальным риском неблагоприятного исхода беременности, а также сложностью выбора оптимальной тактики ведения, поскольку на сегодняшний день отсутствует единый консенсус относительно показаний к хирургическому лечению, и большинство рекомендаций отдает приоритет консервативной терапии, включающей обезболивание, противовоспалительные препараты и динамическое наблюдение [4]. Однако в случаях резистентности к проводимой терапии, нарастания клинической симптоматики или развития осложнений возникает необходимость оперативного вмешательства, которое, несмотря на традиционно высокие опасения, при соблюдении современных принципов акушерской хирургии и адекватном отборе пациенток может быть выполнено с сохранением беременности и благоприятным перинатальным исходом [5]. В связи с этим представление клинических случаев успешного хирургического лечения некроза миоматозного узла во время беременности имеет важное практическое значение, поскольку способствует накоплению доказательной базы и формированию более четких критериев выбора тактики ведения пациенток с данной патологией.

Клинический случай

Опыт ГКБ №7 (г. Алматы). Пациентка К., 25 лет, поступила на 19-й неделе гестации с клиникой «острого живота»: интенсивные боли, тошнота, локальное напряжение передней брюшной стенки.

Анамнез: Миома диагностирована в 2024 году; с началом текущей беременности в 2025 году отмечена бурная пролиферация.

Диагностика: При УЗ-сканировании верифицирован субсерозно-интерстициальный узел по левому ребру матки размером 8х9 см с признаками асептического некроза (отсутствие кровотока при доплерометрии, кистозные полости). Лабораторно выявлен нарастающий лейкоцитоз и повышение уровня С-реактивного белка до 48 мг/л.

Лечение: Консервативная терапия (спазмолитики, токолитики, антибактериальные препараты) в течение 48 часов оказалась неэффективной. На мультидисциплинарном консилиуме была принята активная тактика.

Операция: Выполнена лапаротомная консервативная миомэктомия. В ходе вмешательства подтверждена деструкция капсулы и глубокий некроз тканей узла. Операция завершена с максимальной точностью и тщательным гемостазом.

Исход: Послеоперационный период протекал гладко. Пациентка успешно выписана под наблюдение. Беременность была пролонгирована до 39 недель, завершившись в 2026 году рождением здорового ребенка (8/9 по Апгар) путем планового кесарева сечения.

Обсуждение

Некроз миоматозного узла во время беременности представляет собой относительно редкое, но клинически значимое осложнение, которое, по современным данным, рассматривается не только как локальный патологический процесс, но и как маркер системной декомпенсации маточно-плацентарной гемодинамики, при этом распространенность миомы матки среди беременных варьирует от 0,5% до 10%, достигая в популяционных исследованиях до 20–50% среди женщин репродуктивного возраста, что связано с улучшением диагностики и увеличением возраста первородящих [9], а метаанализ, включающий более 237 000 пациенток, продемонстрировал достоверное повышение риска неблагоприятных акушерских исходов при наличии миомы, включая преждевременные роды, кесарево сечение, предлежание плаценты, отслойку плаценты и послеродовые кровотечения [10], при этом крупные (≥ 5 см) и множественные узлы ассоциированы с наибольшим риском осложнений, что подчеркивает значимость морфологических характеристик опухоли как прогностического фактора; патогенетически некроз миоматозного узла, чаще описываемый как «красная дегенерация», обусловлен нарушением венозного оттока, ишемией и последующим геморрагическим инфарктом ткани узла, причем беременность усиливает эти процессы за счет гиперкоагуляционного состояния, увеличения объема циркулирующей крови и быстрого роста миоматозной ткани, что приводит к несоответствию между потребностями узла и его кровоснабжением, а клинически это проявляется интенсивным болевым синдромом, субфебрилитетом и признаками системной воспалительной реакции, при этом согласно современным клиническим сериям, именно некроз узла во II триместре является одной из причин экстремально преждевременных родов и требует обязательной дифференциальной диагностики при остром абдоминальном синдроме у беременных [8].

Традиционно тактика ведения таких пациенток основывается на приоритете консервативной терапии, включающей анальгетики, противовоспалительные препараты и динамическое наблюдение, что обусловлено высоким риском хирургических осложнений, включая кровотечение и потерю беременности, однако накопленные за последние годы данные демонстрируют, что при неэффективности консервативного лечения и сохраняющемся болевом синдроме выполнение миомэктомии во время беременности может быть оправданным и безопасным при соблюдении строгих критериев отбора пациенток, что подтверждается современными клиническими наблюдениями, где успешные оперативные вмешательства во II триместре позволяли пролонгировать беременность до доношенного срока без значимых осложнений [7], при этом систематические обзоры показывают, что миомэктомия остается более предпочтительной стратегией в контексте репродуктивных исходов по сравнению с альтернативными методами, такими как HIFU, обеспечивая более высокую частоту наступления беременности (56,9% против 23,3%) и живорождения (44,1% против 17,3%) [6], что косвенно свидетельствует о безопасности органосохраняющего хирургического подхода при правильной технике выполнения.

Следует подчеркнуть, что ключевым фактором принятия решения о хирургическом вмешательстве является не только выраженность симптомов, но и динамика состояния пациентки, поскольку длительное сохранение некротизированного узла может приводить к усилению воспалительной реакции, нарастанию болевого синдрома и ухудшению маточно-плацентарного кровотока, что потенциально представляет большую угрозу для беременности, чем своевременно выполненная операция, и в этом контексте

представленный клинический случай соответствует современным тенденциям персонализированной медицины, где активная хирургическая тактика рассматривается как оправданная при наличии строгих показаний, а успешный исход беременности в данном случае согласуется с данными литературы о том, что мультидисциплинарный подход, включающий участие акушеров-гинекологов, хирургов и анестезиологов, а также выполнение вмешательства в специализированных центрах, значительно снижает риски неблагоприятных исходов и позволяет достичь благоприятного материнского и перинатального результата.

Заключение

Некроз миоматозного узла во время беременности требует индивидуального подхода к ведению пациентки. При отсутствии эффекта от консервативной терапии своевременное хирургическое вмешательство может быть единственным способом сохранить здоровье матери и пролонгировать беременность.

Данный клинический случай демонстрирует важность командной работы, клинического опыта и принятия взвешенных решений в условиях высокого риска.

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ORGANIZATION, METHODOLOGY, AND RESULTS OF CANCER SCREENING: THE EXPERIENCE OF KAZAKHSTAN

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Annotation: In this scientific and analytical work, the indicators of incidence and mortality from cervical cancer, breast cancer and colorectal cancer in the regions of our country are considered. The screening methods currently used and the results of this preventive survey of the population are described in detail. Detailed step-by-step algorithms are presented, and the principles of organization and diagnostic capabilities of the screening program for the active detection of these nosological forms of malignant neoplasms in clinically asymptomatic individuals are reflected.

Key words: oncology, primary care, early diagnosis, cancer screening, cervical cancer, breast cancer, colorectal cancer, epidemiology, incidence, mortality, Pap test, smear for oncocytology, ultrasound examination, mammography, hemocult test, fecal occult blood test - FOBT, total colonoscopy.

Today, one of the most important postulates of the oncology service continues to be the early diagnosis of malignant tumors. The purpose of screening is to identify asymptomatic (preclinical) cancer or precancerous conditions in an otherwise healthy target population. In this case, screening plays a leading role in secondary cancer prevention. The key concept of cancer

screening is to identify pathology at a stage of development when the effectiveness of treatment is maximum and the prognosis is most favorable. When precancerous diseases are detected during screening, secondary prevention methods allow to prevent the transition of the initial pathological state to cancer. In this case, the main conditions for screening are the presence of trained personnel and a standard approach to identifying the trait being studied and evaluating the results. The methods used must be sufficiently simple, reliable and reproducible, as well as have sufficient sensitivity and high specificity [1-3].

Screening plays an important role in improving early diagnosis and treatment outcomes. According to the Guide to Cancer Early Diagnosis by Ilbawi A. et al. [4], screening aims to detect unrecognized cancer or its prior lesions in a typically healthy, asymptomatic population through tests or other procedures that can be applied quickly and are widely available to the target population. In screening, the target population is assessed for unrecognized cancer or precancer, and most people tested will not be diagnosed with the disease. Screening should be seen as a process and not as the performance of a specific test, examination, or procedure. The screening process includes a system of informing and inviting the target population to participate; administering the screening test; following-up with test results and referral for further testing among those with abnormal test results; ensuring timely pathologic diagnosis, staging and access to effective treatment with routine evaluation to improve the process. A screening program encompasses the process from invitation to treatment and requires planning, coordination and monitoring and evaluation.

To date, the republican cancer screening program includes three nosological forms of malignant neoplasms - cervical cancer (CC), breast cancer (BC), colorectal cancer (CRC). Let's consider the current epidemiological indicators, methodology and results of cancer screening in our country.

CC in the structure of all malignant tumors of both sexes of the population in 2022 took 6th place with a share of 5.51% (2021 - 4th place, 5.54%), in women - stable 2nd place - 9.7% (9.7%) [5].

The incidence rate per 100 thousand population increased from 9.4 to 9.92. In 10 regions of the republic, the incidence rate is higher than the national average: Pavlodar - 17.2 per 100 thousand people (2021 - 16.7) - the highest level, East Kazakhstan - 14.3 (10.8), North Kazakhstan - 14.3 (10.2), Atyrau - 13.2 (13.8), Zhetysay - 11.7, Karaganda - 11.7 (12.0), Abay - 11.1, Akmola - 11.1 (11.9), Mangistau - 11.1 (9.7), Kostanay - 10.8 (10.6) regions.

Low incidence rates in Zhambyl region - 5.8 per 100 thousand population (5.7), Turkestan region - 6.1 (5.2), Aktobe region - 8.3 (11.6), Kyzylorda region - 8.5 (8.2) areas.

CC in the structure of causes of death from malignant tumors of the population of both sexes in 2022 rose from 9th to 8th position, with a share of 4.6% (2021 - 4.3%), mortality from CC is stable at 3.1 per 100 thousand population (3.1).

The mortality rate from CC in 10 regions is higher than the national average: Akmola - 4.2 per 100 thousand population (2021 - 3.1) - maximum level, West Kazakhstan - 4.1 (4.8), Pavlodar - 3.8 (5.6), Almaty - 3.7 (2.5), Zhetysay - 3.7, Atyrau - 3.4 (4.0), East Kazakhstan - 3.3 (3.8), Karaganda - 3.2 (4.7), Kostanay - 3.2 (2.4) regions and Almaty city - 3.4 (2.9).

Below the national average, mortality was recorded in Abay region, cities Astana, Shymkent - 2.9 per 100 thousand population, Mangistau - 2.8 (3.0), Turkestan - 2.3 (2.2), Aktobe - 2.2 (3.0), North - Kazakhstan - 2.0 (2.6), Kyzylorda regions - 1.7 (3.5) - the best result [5].

In 12 regions, a 100% level of morphological verification of the diagnosis was ensured, the lowest or worst indicator for the third year was in the Kyzylorda region - 94.3%, below the national average indicators in Akmola - 98.8%, Atyrau - 98.9%, Kostanay - 98, 9%, Mangistau - 97.6%, Pavlodar - 96.6%, regions and Almaty city - 98.5%;

In a number of regions, the frequency of diagnosis of stage I-II CC was below the national

average (88.1%) - in Akmola - 76.2% (2021 - 73.6%) - the worst result in the country, in Karaganda - 77, 2%, Zhetysu - 82.9%, Abay - 83.8%, Kostanay - 84.3%, Aktobe - 85.5%, West Kazakhstan - 85.7%, Pavlodar - 81.3%, while that in the Atyrau region - 100.0% result.

The proportion of stage IV CC is higher than the national average (2.7%) in the following regions: the worst result is in Zhetysu (6.1%), above the national average in Karaganda - 5.1% (2021 - 5.6%), Akmola - 4.8% (2.3%), Kostanay - 4.5% (4.4%), North Kazakhstan - 3.9% (7.4%), Almaty - 3.7 % (5.1%), Zhambyl - 2.9% (0.0) regions, cities Almaty – 3.6% (1.8%) and Shymkent – 3.8% (5.9%). The lowest neglect is in the East Kazakhstan region - 1.0% (0.7%).

Late diagnosis rates (III-IV stages) for CC are above the national average - 11.9% (15.4% in 2021) were noted in Akmola - 23.8% (2021 - 26.4%) - worst result, Karaganda - 22.8% (35.2%), Pavlodar - 18.8% (20.8%), Zhetysu - 17.1% (24.2%), Abay - 16.2% (12.8%), Kostanay - 14.6% (15.6%), Aktobe - 14.5% (9.6%), West Kazakhstan - 14.3% (32.4%) regions. The lowest neglect is in the Mangistau region - 6.0% (20.8%).

Across the country, the five-year survival rate of patients with CC registered in 2018 was 59.9% in 2022, with a decrease from the level of 2021 (67.5% for those registered in 2017), and with a significant range in by region, from the maximum – 72.9% (2021 – 70.7%) in the North Kazakhstan region, to the minimum – 34.9% (64.4%) in the Atyrau region [5].

CC screening is a periodic, comprehensive examination of women of a certain age group as part of a special medical program to prevent and reduce incidence and mortality from CC.

Type of screening - population. The purpose of screening is to identify pre-invasive diseases of the cervix with subsequent recovery. The screening method is a cytological examination of a smear for oncocytology from the cervix (traditional and liquid cytology). Coloring according to the "Papanicolaou test" (Pap test). Interval - 1 time in 4 years. Target group: women aged 30-70 years who are not registered in the dispensary for CC. The expected results are a decrease in incidence and mortality from CC.

Screening steps:

1) Preparatory - formation of target groups, information support and invitation to screening. The preparatory stage is carried out by the nurses of the primary health care organization responsible for preventive measures and includes: annual compilation of a list of women subject to screening in the coming year by November 15 of the current year, followed by monthly correction; informing target groups of the female population about the need for screening; screening invitation; ensure timely screening.

2) Screening - filling out a statistical card of a preventive medical examination (screening) of an outpatient (form 025-08/y), a register of patients subject to cytological screening and taking material for cytological examination from the cervix. The screening examination of the target groups of the female population is carried out by a specially trained midwife of the primary health care organization.

3) The final one is obtaining the results of cytology, informing the woman and developing further management tactics, fill out accounting and reporting statistical documentation. Responsible for the final stage of screening is the obstetrician-gynecologist of primary health care [6].

Cytological screening of CC is a complex of organizational and medical measures aimed at early detection of precancerous and neoplastic diseases of this localization and at reducing the mortality of this cohort of patients. For traditional cytology, a smear containing 8-12 thousand cells of stratified squamous epithelium (including cells of metaplastic epithelium) is considered adequate; for liquid cytology - 5 thousand cells. For both methods, the number of cells of endocervical epithelium and/or metaplastic epithelium (from the transformation zone) must be at least 10 (single or in clusters). If more than 75% of the cells of the stratified squamous epithelium are covered with erythrocytes, leukocytes, etc., then the quality of the smear is

considered unsatisfactory.

Interpretation of the results of a cytological study is carried out according to the Bethesda-terminology cytological system:

Intraepithelial changes and malignant processes are absent (NILM). This group includes cytological conclusions about the normal state of the epithelium, as well as the presence of various non-neoplastic diseases. Normally, squamous epithelial cells, groups of cells of columnar epithelium and metaplastic epithelium, a small number of leukocytes, and rod/mixed microflora are found in preparations. In the presence of non-neoplastic processes, their nature and, if possible, the cause are specified: atrophic changes, reactive changes associated with inflammation, including typical regeneration. In addition, the presence of microorganisms is indicated: *Trichomonas vaginalis*, fungi, morphologically corresponding to *Candida* spp., bacterial vaginosis, cellular changes corresponding to the defeat of Herpes simplex virus, squamous epithelial cells with atypia of unknown significance (ASC-US), squamous epithelial cells with atypia of unclear significance, not excluding the presence of a high degree of intraepithelial changes (ASC-H). Low-grade squamous intraepithelial changes (LSIL) include lesions associated with HPV and CIN I, high-grade squamous intraepithelial changes (HSIL) include CIN II, CIN III, carcinoma in situ and cases suspected of invasion, squamous cell carcinoma, cervical (glandular) epithelium with atypia of unknown significance, cells of the cervical (glandular) epithelium, possibly neoplasia, endocervical adenocarcinoma in situ, endocervical adenocarcinoma, endometrial adenocarcinoma, secondary adenocarcinoma, unclassified carcinoma, other malignant tumors.

There are certain features when taking material for oncocytology: firstly, the examined woman should be informed about the exclusion of sexual intercourse, vaginal manipulations, including douching, baths, tampons, etc. 2 days prior to sampling. Taking material for cytological examination is carried out by the midwife of the examination room of the department of medical examinations of the primary health care organization: the traditional method (2 glasses - with obligatory fixation in 96% alcohol, it is preferable to use glass slides with a polished edge, which are easily marked) or the liquid cytology method (one container with stabilizing liquid); the code or surname of the patient, identical to the code and surname in the form for sending material for cytological examination, should be clearly marked on the glasses or container [6].

At the same time, when using the traditional method, the biomaterial is delivered to the cytological laboratory as soon as possible after its collection in specialized containers for glass slides with 96% alcohol. If there are visible visual changes in the cervix, then the material is taken from the woman and, without waiting for the results, she is referred for an examination by an obstetrician-gynecologist.

A cytological study is carried out in centralized cytological laboratories at oncological institutions, where an archive of cytological preparations of patients involved in the screening examination is formed, regardless of the result, for a period of at least 10 years with the formation of a computer database.

What material and technical equipment is required to take material for a Pap test? It is as follows: soap and water for washing hands, a light source for cervical examination, a gynecological chair, a disinfected speculum and gloves, an Eyre spatula, a glass slide and a marking pen, a container with a stabilizing solution for liquid cytology, a fixative solution (96% alcohol), a container with warm water for lubricating and warming the vaginal mirrors, a 0.5% chlorine solution for disinfecting gloves and instruments, or another approved for this purpose. And, of course, the registration form itself.

For carrying out liquid cytology, you additionally need: a disposable cervix brush, a container with a stabilizing solution for liquid cytology, and a fixing solution.

At the same time, a smear for oncocytology cannot be taken: during menstruation, earlier than 48 hours after sexual contact or after using lubricants, vinegar or Lugol solution, tampons or

spermicides, after vaginal examination or douching, and also during the treatment of genital infection.

Now, regarding the results of CC screening. In 2022, 771,282 women of the target group aged 30 to 70 years were examined during cytological screening (in 2021 - 757,454).

During cytological screening in 2022, 392 cases of cervical cancer were identified (319 in 2021). The detection rate increased from 0.42 to 0.51 per 1000 women examined

High detection of CC during screening is ensured in Aktobe, Almaty, Atyrau, East Kazakhstan, Kyzylorda, Pavlodar, North Kazakhstan, Turkestan regions and Shymkent city. The detection rate in these regions ranges from 0.55 to 1.59 per 1000 women examined. The best indicator is in Atyrau region - 1.59. Compared to 2021, there is an increase in detection in 10 regions, with the exception of Akmola, Aktobe, Zhambyl, Kostanay, Mangistau, North Kazakhstan regions and Shymkent city. The worst result in Astana is 0.15 per 1000 women examined [5].

Cytologically, cervical precancer was detected in 1.16% of those examined (2021 – 0.99%). The detection rate of precancer below 0.6% (the planned indicator for 2022, according to the Comprehensive Plan) was noted in Aktobe, Karaganda and Kostanay regions.

A high proportion of stage I CC (70% or more) was detected in 6 regions of the country (in 8 in 2021): Kostanay, Mangistau (94.7% - best result), North Kazakhstan, Turkestan regions, cities Almaty and Astana. Low levels of early detection of CC (below 50%) were not observed in any region.

Localized processes (stages I-II) were identified in 99.2% of all cases of detected cancer (96.5%). In the Akmola and Karaganda regions, cases of CC were identified not only in localized, but also in widespread stages of the process. A total of 3 cases of CC in stage III and no cases in stage IV were identified (11 and 0, respectively) [5].

BC ranks first in the structure of the frequency of malignant tumors of both sexes in the population with a share of 14.7% (2021 - 15.4%). This situation has been stable since 2004; in addition, BC ranks first and remains consistently in this position in the structure of female oncopathology. The incidence of BC in 2022 in the country as a whole increased to 26.5 per 100 thousand (2021 – 26.3). In the structure of cases, BC occupies the 1st ranking place in the vast majority of regions and cities of the country, except for three: Akmola, Kyzylorda and North Kazakhstan regions, where lung cancer takes the 1st ranking place [4].

Above the national average - 26.5 per 100 thousand of us. – incidence of BC in 10 regions of the country: Abay – 33.3, Akmola – 32.7 (2021 – 29.8), East Kazakhstan – 44.7 (39.9) – the highest level, West Kazakhstan – 31.2 (28.4), Karaganda – 40.2 (40.1), Kostanay – 37.5 (35.8), Pavlodar – 43.2 (47.4), North Kazakhstan – 34.7 (38.2) regions and Almaty city – 35.4 (34.5), Astana city – 31.5 (28.4). Below average indicators per 100 thousand of us. in Aktobe - 21.6 (24.3), Almaty - 21.9 (17.7), Atyrau - 22.8 (15.7), Zhambyl - 14.2 (15.1), Zhetysu - 22.8, Kyzylorda - 14.6 (14.4), Mangistau - 14.7 (17.3), Turkestan - 11.3 (11.7) regions and Shymkent city - 14.9 (21.9) [5].

BC ranks third in the structure of causes of death from malignant tumors in the population of both sexes for the thirteenth year in a row, amounting to 8.1% in 2022 (2021 – 8.7%). In the republic as a whole, mortality from BC decreased by 13.0%, from 6.2 to 5.4 per 100 thousand people.

The regions where mortality from BC is higher than the national average include: Abay - 10.1 per 100 thousand people (maximum level), East Kazakhstan - 8.0 (2021 - 8.5), Pavlodar - 7.1 (10.0), North Kazakhstan - 7.0 (11.4), Kostanay - 6.9 (7.5), Akmola - 6.5 (8.2), West Kazakhstan - 5.7 (6.9), Zhambyl - 5.5 (4.8) and Astana city – 6.3 (6.6), Almaty city – 6.6 (9.5). The indicators are significantly lower in Aktobe - 4.5 (3.5), Almaty - 4.5 (5.8), Zhetysu - 4.0, Atyrau - 3.7 (3.0), Kyzylorda - 4.4 (4.1), Turkestan - 3.6 (3.6), Mangystau regions - 2.7 (3.6) - the lowest level [5].

Mass screening to identify BC patients should mainly involve healthy women without any signs of the disease or symptoms. Screening not only helps to detect hidden forms of cancer that

can be treated, but also has psychological value for women. As a result of screening, women are convinced that they do not have BC, and this is the most important potential success of such programs. While the ultimate goal of screening is to reduce BC mortality, its immediate goal is to detect cancer before clinical manifestation. However, BC is a heterogeneous disease, which can significantly affect the effectiveness of screening. Screening models for BC are usually based on the fact that the majority of detected tumors are invasive cancers in the early stage of progression. In addition, it must be taken into account that the detection of cancer (or its precursors) before clinical manifestation increases the risk of false positive diagnosis [7,8].

Mammography has a sensitivity of 95% and a specificity of 97%. These indicators decrease when examining women with denser mammary glands (young age, use of hormone therapy), with low quality mammography, and also with insufficient qualifications of the radiologist. Detection of high-grade invasive cancer by screening, when the tumor is not yet detected by clinical examination (palpation), means the possibility of reducing mortality from BC [9].

Preventive screening for early detection of BC in the Republic of Kazakhstan includes [10]:

1) mammography of both mammary glands in two projections - direct and oblique in the mammography room of the city, district polyclinic (mobile medical complex). All digital mammograms in the presence of a system for archiving and transferring medical images are copied to CDs and other electronic media and transferred to the server of the mammography room of the Cancer Center using specialized licensed software integrated between medical organizations; in case of impossibility of digital transmission - they are printed on X-ray film at a scale of 1:1 - 100% (1 patient - 1 set - 2 or 4 mammograms) with subsequent transfer to the mammography room of the Cancer Center;

2) interpretation of mammograms according to the BI-RADS classification (M0t, M0d, M1, M2, M3, M4, M5) by two or more independent radiologists of the same medical organization - double reading or different medical organizations: a radiologist of the mammography room city, district polyclinic (mobile medical complex) - the first reading, and the radiologist of the mammography room of the Cancer Center - the second reading;

3) in-depth diagnostics - targeted mammography, ultrasound examination (hereinafter - ultrasound) of the mammary glands, trepanobiopsy, including under ultrasound or stereotaxic control for histological examination, which is carried out in case of detection of pathological changes on mammograms (M0d) in the mammography room of the Cancer Center.

√ An average medical worker or a responsible person of the organization of outpatient care sends the patient for mammography to the district, city polyclinic.

√ The X-ray laboratory assistant of the mammography room of the city, district polyclinic (mobile medical complex) performs mammography, fills out a referral for double reading of mammograms and transmits the referral through information interaction.

Radiologist of the mammography office of the city, district polyclinic (mobile medical complex): fulfills the requirements for the safety and quality of mammographic examinations; evaluates the quality of the images provided and the correctness of the installation; performs repeated mammography in the M0t category (technical errors of mammography); determines the radiological density of the mammary glands on the ACR scale (A, B, C, D) indicating this parameter in the study protocol; conducts the first reading of mammograms with interpretation of the BI-RADS classification results. In the M0d category (undetermined or suspicious radiological changes requiring additional examination), the study protocol indicates the predominant pathology: education, asymmetry, violation of architectonics, microcalcifications; sends mammograms, electronic copies of mammograms through the archiving system and transfer of medical images to the workplace of the mammography office of the Cancer Center together with directions for double reading of mammograms; directs low-dose computed tomographic images through the system of archiving and transferring medical images to the workplace of the computer

tomography office of the Cancer Center together with copies of images recorded on CD-ROMs or other electronic media and directions for double reading.

◆ The radiologist of the mammography room of the Cancer Center: evaluates the quality of the provided images and the correctness of the styling. Viewing digital x-ray images transferred to the server or on digital media (CD, DVD) is carried out on a monitor for interpreting digital x-ray images with a resolution of at least 5 megapixels, which has a certified grayscale transmission in accordance with the DICOM standard; conducts a double (second) reading of mammograms with the interpretation of the results according to the BI-RADS classification, using, if necessary, archival images. Organizes the third reading according to indications. With double reading, an independent interpretation of the images is carried out (blinding method - the second radiologist does not know the results of the first reading); in the M0m category (technical errors in mammography), recommends repeat mammography; in the M0d category (uncertain or suspicious radiographic changes requiring additional examination), the study protocol indicates the predominant pathology: education; asymmetry, violation of architectonics, microcalcifications; recommends that the outpatient care organization, according to indications, invite the patient for in-depth diagnostics (targeted mammography, ultrasound of the mammary glands, trephine biopsy, including under ultrasound or stereotaxic control, followed by histological examination of the material); collects and archives all mammograms (films and electronic media) made as part of the examination. The shelf life of mammograms is at least 3 years after leaving the age subject to a screening study; the results of the double (second) reading are transferred to the outpatient care organizations through information exchange.

◆ Indications for in-depth diagnostics are the conclusions of double reading mammograms M0d (uncertain or suspicious X-ray changes requiring additional examination).

◆ In-depth diagnostics is carried out in two stages. At the first stage, ultrasound is performed, according to indications, targeted mammography, possibly with an increase (with asymmetry, violation of architectonics and the presence of microcalcifications). When visualizing a suspicious pathology (M4 and M5), the second stage is performed - trepanbiopsy, including under ultrasound control and stereotaxic control for histological examination.

◆ Histological examination is carried out in the laboratory of pathomorphology or pathological bureau. Morphological interpretation of the biopsy is carried out in accordance with the recommendations of the World Health Organization.

◆ Physician or responsible person of the outpatient care organization:

- 1) upon receipt of a mammography result according to the BI-RADS classification:
 - in case of M0t (technical errors in mammography) - sends the patient for a second X-ray examination to the mammography room of the city, district polyclinic (mobile medical complex);
 - with M0d (undefined or suspicious X-ray changes requiring additional examination) - sends the patient for in-depth diagnostics to the mammography room of the Cancer Center;
 - with M1 (no changes detected) - recommends that the patient undergo a follow-up mammography examination after 2 years. With radiological density of the mammary glands, C and D are sent for ultrasound of the mammary glands to exclude a false-negative result of mammography;
 - with M2 (benign changes), refer the patient for a consultation with an oncologist (mammologist) of the clinical diagnostic department, followed by a screening mammography examination after 2 years;
 - with M3 (probable benign changes) - sends the patient for short-term dynamic radiation observation to the local doctor with the recommendation of control mammography or ultrasound in 6 months;
 - with M4 (signs that cause suspicion of malignancy), M5 (practically reliable signs of malignancy) and if it is technically impossible to perform a trepanbiopsy or a biopsy is refused, a

referral to an oncologist (mammologist) of the clinical diagnostic department for dynamic observation and decision on the verification of the identified pathology;

2) upon receipt of the result of a histological examination:

- benign education - refers the patient to an oncologist (mammologist) of the clinical diagnostic department for dynamic monitoring, followed by a screening mammography examination after 2 years;

- formation with an indeterminate malignant potential or carcinoma in situ - refers the patient to the Cancer Center for consultation and treatment, followed by dynamic observation by an oncologist (mammologist) of the clinical diagnostic department at the place of her attachment;

- malignant neoplasm - refers the patient to the Cancer Center for treatment and follow-up;

3) communicates the results of the screening examination to the patient in any available way (by telephone, in writing, through electronic means of communication);

4) enters the results of double reading, in-depth diagnostics, histological examination, recommendations of the radiologist of the Cancer Center mammography room into the information system.

Establishing the size of the primary tumor is especially important in screening. Tumor size is an important criterion for evaluating the quality of screening and determining the ability of X-ray mammography to detect non-palpable tumors. Therefore, it is extremely important that pathologists measure tumor diameter as accurately as possible. The smaller the size of the primary tumor, the greater the likelihood of error in determining its size.

Let's analyze the results of BC screening. Mammography screening identified 1,570 cases of BC in 2022 (1,402 in 2021). The cancer detection rate increased from 1.78 to 1.94 per 1000 examined. The best result is in the Karaganda region – 2.63 per 1000 women examined. Low detection rate per 1000 examined, compared to the republican average, in Atyrau (1.72), Zhambyl (0.58), Kyzylorda (1.68), Mangistau (0.42 - worst result), Turkestan (1.22) regions and cities Astana (1.5) and Shymkent (1.58). Compared to 2021, there was an increase in the detection of BC in 9 regions, with the exception of Aktobe (decrease from 2.87 to 2.19 per 1000 women examined), Karaganda (from 2.73 to 2.63), Mangistau (from 1.10 to 0.42), North Kazakhstan (from 3.27 to 2.31), Turkestan (from 1.36 to 1.22) regions and cities Astana (from 1.54 to 1.50), Almaty (from 2.24 to 2.18) and Shymkent (from 2.35 to 1.58) [5].

In 2022, the proportion of patients identified during screening studies with early stages of BC (stage 0-I) was 50.2% during screening (in 2021 - 47.9%). A high proportion of stages 0-I BC (over 50%) was recorded in 8 regions (in 8 in 2021): Akmola, West Kazakhstan, Karaganda (70.8% - best result), Pavlodar, North Kazakhstan, Turkestan regions, cities Astana and Shymkent. Low levels of early detection of BC (below 40%) were noted in Aktobe (19.3% - worst result), Zhambyl (34.8%), Kostanay (39.5%), Mangistau (27.3%) regions and Almaty city (37.3%). Localized cancer (0-I and II stages) amounted to 96.2% (2021 - 95.5%), while not a single case was detected in stages III-IV in Atyrau, West Kazakhstan, Zhambyl, Kyzylorda, Mangistau, Pavlodar regions, cities Astana and Shymkent. A total of 46 cases of breast cancer in stage III and 14 in stage IV were identified (52 and 11, respectively) [5].

Epidemiological indicators of CRC in the form of colon cancer and colorectal cancer are considered separately for objective reasons.

Colon cancer with a specific gravity of 5.53% (2021 - 5.2%) in the structure of oncopathology of both sexes of the population has risen to 5th place, in men it remains in 6th place - 5.8% (5.5 %), for women - in the 5th - 5.3% (4.91%) The incidence rate of cancer of this localization in the country in the reporting year increased from 8.8 to 9.95 per 100 thousand population.

The incidence of colon cancer in 10 regions is higher than the national average - 9.95 per

100 thousand population: Kostanay - 20.7 (2021 - 15.9), Pavlodar - 18.8 (15.3), North Kazakhstan - 18, 0 (12.7), East Kazakhstan - 16.9 (13.4), Karaganda - 15.4 (15.0), Akmola - 14.6 (10.2), West Kazakhstan - 11.0 (10.1), Abay - 10.0 (9.0) regions and cities Almaty – 12.8 (12.1) and Astana – 10.5 (9.0). As in 2021, colon cancer was detected much less frequently in Turkestan - 3.1 per 100 thousand population (2.7), Kyzylorda - 4.1 (4.6), Zhambyl - 5.5 (5.8), Almaty - 6.3 (4.7), Zhetysu - 6.4, Mangistau - 6.8 (4.9) regions and Shymkent city - 5.0 (4.0) [5].

Rectal cancer in the structure of malignant neoplasms of both sexes retains 7th place in rank with a specific gravity of 4.9% (2021 - 4.92%), but in men it dropped from 4th to 5th place - 6.1%, for women – from 9th to 10th – 4.0%. The incidence rate per 100 thousand population increased from 8.4 to 8.8.

A high incidence rate was recorded in Kostanay - 17.8 per 100 thousand population (2021 - 16.2), East Kazakhstan - 17.7 (13.9), North Kazakhstan - 15.6 (15.1), Pavlodar – 14.9 (18.1), Karaganda – 13.3 (11.7), Abay – 12.9, West Kazakhstan – 12.9 (9.8), Akmola – 10.3 (13.1) regions and Astana city – 10.3 (9.0). Traditionally, a low incidence of rectal cancer is observed in Mangistau - 3.1 (2.8), Turkestan - 3.3 per 100 thousand population (2.7), Zhambyl - 3.7 (5.1), Kyzylorda - 4, 1 (5.3), Almaty – 5.3 (5.6) regions and in Shymkent city – 5.5 (5.0) [5].

Rectal cancer in the structure of causes of death from malignant neoplasms of the population of both sexes in 2022 remained in 5th place with a share of 5.41% (2021 – 5.41%). In the republic as a whole, the mortality rate from this form of cancer was 3.6 per 100 thousand population (3.87).

The mortality rate per 100 thousand population was higher than the national average in East Kazakhstan - 7.8 (2021 - 8.6) - the maximum level, Pavlodar - 7.5 (7.6), Abay - 5.9, North Kazakhstan - 5.8 (4.3), Kostanay - 4.9 (4.9), West Kazakhstan - 4.8 (4.2), Karaganda - 3.8 (5.2) regions. Below the national average - 3.8 per 100 thousand population, mortality in Aktobe - 3.2 (4.1), Almaty - 2.6 (2.6), Atyrau - 2.5 (3.4), Zhetysu - 2, 6, Zhambyl - 3.3 (2.7), Turkestan - 2.1 (1.6), Mangistau - 1.9 (1.2), Kyzylorda regions - 1.8 (2.1) - the lowest figure , and cities Almaty – 3.7 (4.3), Shymkent – 2.6 (2.1).

Colon cancer in the structure of causes of death from malignant neoplasms of the population of both sexes in 2022, as in 2021, ranks 6th, with a share of 5.2% (2021 – 5.0%). At the same time, the mortality rate in the country decreased by 5.6%, from 3.6 to 3.4 per 100 thousand population.

Mortality rates in 10 regions are higher than the national average: East Kazakhstan - 7.1 per 100 thousand population (2021 - 5.1) - maximum level, Pavlodar - 5.6 (6.0), Kostanay - 5.3 (5.6), Akmola – 5.2 (3.8), Abay – 5.1, Karaganda – 5.1 (5.6), West Kazakhstan – 4.8 (4.4), North Kazakhstan – 4.8 (5.0) regions and cities Astana – 3.6 (2.7), Almaty – 4.5 (5.3). Low mortality rates from colon cancer were noted in Kyzylorda - 1.2 per 100 thousand population (2.7) - the best result, Turkestan - 1.3 (1.7), Mangistau - 1.6 (2.6), Aktobe – 2.0 (2.5), Zhetysu – 2.4, Zhambyl – 2.5 (3.7), Atyrau – 2.5 (1.8), Almaty – 2.6 (1.8) regions and cities Astana – (2.7), Shymkent – (2.4).

For colon cancer (94.0%) - 100% verification level was achieved in 3 regions (Abay, Almaty and Turkestan regions), high rates in the Astana city (98.5%), Shymkent city (98.0%), Zhambyl (98.4%), Atyrau (98.2%) regions, low – in Akmola region (86.7%), Almaty city (84.3%), in the Kyzylorda region (61.8%) – the worst result since 2017.

For rectal cancer (97.4%) - in 6 regions there is a 100% verification level, the worst level is still in the Kyzylorda region - 85.3%, lower than the republican average in the Akmola region - 92.6%, Aktobe region - 96 .8%, Mangystau region - 87.0%, Pavlodar region - 95.3%, Almaty city - 93.2% [5].

The frequency of diagnosis of stage I-II rectal cancer, as a visually accessible localization (68.9% - national average) in the regions, was: in Akmola - 34.6% - the worst result, as in 2021, in the country (2021 - 44.1%), Mangistau - 47.8%, Abay - 53.9%, West Kazakhstan - 59.1%, Almaty -

66.2%, Zhetysu - 68.6%, Karaganda - 65, 7% regions and Shymkent city - 62.9%.

For colon cancer (52.4%), early diagnosis rates are higher in Pavlodar (65.9% - best result), Abay, Aktobe, Atyrau, East Kazakhstan, Zhambyl, Zhetysu, Karaganda, Kostanay, Pavlodar, North Kazakhstan, Turkestan regions and Shymkent. The lowest figure (23.5%) is in the Kyzylorda region.

For colon cancer (17.3%), the rates of neglect at stage IV are higher - in Akmola - 31.0% - the worst result (2021 - 20.3%), Zhetysu - 27.3%, Abay - 23.1% , Turkestan - 22.2% (29.1%), Karaganda - 28.1% (28.6%), West Kazakhstan - 18.8% (8.2%), Mangistau - 17.6% (19 .4%) regions and cities Astana - 18.0% (22.9%), Shymkent - 20.0% (22.7%). The lowest level of neglect is 2.9% in the Kyzylorda region (7.9%).

The proportion of stage IV in rectal cancer (13.1%) is higher in Akmola - 29.6% - the worst result (2021 - 19.4%), Abay - 19.7%, Kyzylorda - 17.6% (9.1%), Karaganda - 16.9% (28.4%), Almaty - 15.6% (17.0%), Kostanay - 14.8% (11.1%), Zhambyl - 13.3 % (13.6%) regions and Shymkent city - 14.5% (12.5%). The lowest level of neglect - 6.0% - is in the Atyrau region (12.5%).

Late diagnosis of rectal cancer as a visually accessible localization (stages III-IV) in 2022 amounted to 31.1% (in 2021 - 33.5%).

For rectal cancer, the level of neglect is higher than the national average - 31.1%, the indicators in Akmola - 65.4% (2021 - 55.9%) - the worst result in the country, Mangistau - 52.2% (38.1%), Abay – 46.1% (30.6%), West Kazakhstan – 40.9% (25.4%), Karaganda – 34.3% (46.5%), Almaty – 33.8% (35.7 %), Zhetysu - 31.4% (34.1%) regions and Shymkent city - 37.1% (42.9%). The lowest neglect is in the Atyrau region - 12.0% (17.5%).

In the country as a whole in 2022, the five-year survival rate of patients with CRC registered in 2018 decreased to 40.4% (2021 - 52.9% for those registered in 2017); there is a significant dispersion of indicators by region, from maximum – 56.1% (47.5%) in the Kyzylorda region, to minimum – 24.3% (51.5%) in the Aktobe region [5].

Screening of CRC screening is the systematic use of screening studies in an asymptomatic population. The purpose of screening is to identify people with abnormalities suggestive of CRC. These persons in the future need additional examination to clarify the diagnosis. Opportunistic screening is the non-systematic use of screening tests in routine medical practice. A screening program is much more challenging than an early detection program. At the same time, the success of the screening program is largely determined by the awareness of the population and medical workers about the possibilities of early diagnosis of CRC. The feasibility of a screening program is determined by several factors that relate to the disease being screened, the screening test, the characteristics of the population, and the characteristics of the healthcare system.

The first factor is that the disease must be well understood, common enough in the target population to justify screening, have a recognizable early stage; treatment of the disease at an early stage should be more effective than at a later stage.

The second is that the test should be characterized by sufficient sensitivity, i.e. the ability to detect cancer among people with the disease; sufficient specificity - the probability that among people who do not have a disease, the test result will be negative; have a high positive predictive value (positive predictive value) or, in other words, the likelihood that people with a positive test result have the disease; have a high predictive value of a negative result (negative predictive value), i.e. the likelihood that people with a negative test result do not have the disease; security; low cost; and acceptability - the likelihood that people for whom this test is intended will agree to the examination (which to some extent depends on the awareness of the population about the possibilities and importance of early diagnosis).

The third factor is that the healthcare system should be ready for maximum screening test coverage of the target group, have the resources to confirm the diagnosis, appropriate treatment and follow-up of people with positive test results, and regularly conduct screening tests at regular intervals. At the same time, the benefits of screening must outweigh the potential physical and

psychological harm and justify the financial costs of its implementation [11].

The factors most significant for the development of CRC are:

- the presence of chronic inflammatory bowel diseases, adenomatous polyps, cancer of other localization, etc.;
- family history (presence of one or two first-degree relatives with CRC or familial diffuse intestinal polyposis);
- the age of men and women over 50 years old, taking into account the fact that more than 90% of patients with colorectal cancer are people of this age (medium risk).

Age, regardless of gender, is an important risk factor for CRC. After the age of 50, the incidence of CRC increases from 8 to 160 per 100,000 population. Thus, people who have reached the age of 50, even in the absence of symptoms, constitute a moderate risk group for CRC.

The second category of increased risk of CRC (20%) is made up of persons with a genetic and family predisposition, suffering from chronic inflammatory bowel diseases, diffuse familial polyposis.

The high-risk CRC group is determined by the so-called Amsterdam criteria (the presence of malignant tumors in two generations, the presence of cancer in a first-line relative under the age of 50 years), in this case, CRC screening should be carried out after the age of 30 years [12].

The degree of individual risk of developing CRC is determined before screening to select the scope of studies and the frequency of their conduct.

The interval for oncological colorectal screening is 1 time in 2 years, target group: men and women aged 50-70 years, with the exception of persons registered at the dispensary for CRC and colon polyposis. At the same time, when forming the target group, one should take into account the absence of severe concomitant diseases, such as the presence of a common malignant neoplasm, cerebrovascular diseases in the stage of decompensation, chronic obstructive pulmonary disease with respiratory failure, cirrhosis of the liver, myocardial infarction with congestive heart failure, diabetes mellitus with vascular complications. and others, which are highly likely to lead to death in the next 10 years.

The first step in screening for CRC is the fecal occult blood test (FOBT). Traditionally, such methods include a benzidine test for occult blood in the feces. This is a biochemical method based on the assessment of pseudoperoxidase activity of hemoglobin. There is ample evidence that invitation to guaiac FOBT screening (gFOBT) reduces CRC mortality by approximately 15% in age-matched average-risk populations.

To ensure the effectiveness of screening with gFOBT, the interval for screening under the national screening program should not exceed two years. To date, there is an immunochemical FOBT method - iFOBT, which is superior in efficiency to gFOBT in terms of the probability of detecting adenoma and cancer. iFOBT has improved analysis performance compared to gFOBT.

Immunochemical (immunochromatographic) examination of feces for occult blood - iFOBT or hemocult test is carried out for all men and women of the target group using an express method, which allows you to get a result within 3-5 minutes, without the participation of a medical worker. However, the evaluation of the test is carried out only by a medical worker in the PHC preventive department.

With a positive analysis of feces for occult blood, the second stage of colorectal screening is performed, which consists in endoscopic examination of the colon - total colonoscopy [6]. At the same time, in this case, this medical manipulation is of a therapeutic and diagnostic nature, since it allows one-stage removal of adenomatous polyps, which, according to various authors, occur in every third subject after 50 years of age. At the same time, women have 20% fewer polyps than men, but they have more right-sided lesions, which are more difficult to detect using fecal blood tests, because they are less traumatic [13,14].

What results were obtained from screening for CRC? In 2022, 937,859 men and women of

the target group aged 50 to 70 years were examined during colorectal screening (in 2021 - 920,640) [5].

Colorectal screening revealed 325 cases of colorectal cancer in the reporting year, which is 114 cases more than in the previous year (211 cases). The detection rate increased from 0.23 to 0.35 per 1000 patients examined. Low detection of colorectal cancer was noted in Zhambyl, Karaganda, Kostanay, Kyzylorda, Mangistau, Turkestan - the worst result, East Kazakhstan regions, Astana city - from 0.07 to 0.30 per 1000 examined. The best result is in the North Kazakhstan region – 0.81 per 1000 examined. Compared to 2021, there was a decrease in the detection of colorectal cancer per 1000 people examined during screening in Karaganda (from 0.22 to 0.21), Kostanay (from 0.29 to 0.28), Mangistau (from 0.20 to 0.12) regions and Astana city (from 0.20 to 0.19).

Colon precancer (adenoma detection rate) was detected in 27.5% of patients who underwent colonoscopy (2021 – 22.8%). The detection rate of precancer in Akmola, Aktobe, Almaty (8.5% is the worst result), West Kazakhstan, Zhambyl, Kostanay, Kyzylorda, Mangistau, Pavlodar, North Kazakhstan, Turkestan regions and cities is lower than the national average Astana and Shymkent. The best result is 36.2% in Almaty city. It should be noted that the planned indicator for the detection of precancer of the colon and rectum in the country for 2022, according to the Comprehensive Plan, was 23.0% and was achieved.

In 2022, the proportion of patients identified during screening studies with early stages of malignant neoplasms (stages 0-I) was 26.2% during colorectal screening (in 2021 - 27.5%).

High early detection of colorectal cancer (above 30%) was noted in Akmola, West Kazakhstan, Karaganda, Kostanay, Kyzylorda, Turkestan regions and Astana city (57.1% - the best result). Not a single case of early cancer has been identified in the Mangistau region. Cases of cancer in stages III-IV detected during screening were registered in Akmola, Aktobe, Almaty, West Kazakhstan, Zhambyl, Karaganda, Kostanay, Mangistau regions and Almaty city. A total of 21 cases of colorectal cancer in stage III and 3 in stage IV were identified (in 2021 - 18 and 5, respectively) [5].

The complex analysis carried out allows us to conclude that satisfactory results of cancer screening can be achieved only with its proper organization, high quality of implementation, active participation in population screening, the use of highly sensitive tests and instrumental methods of preventive examination, as well as subsequent accurate diagnosis of identified tumors and timely treatment. High-quality screening leads to early diagnosis of pedological diseases and malignant pathology in the early stages, which, in turn, increases the effectiveness of treatment and improves the prognosis of the disease. Target groups that, for one reason or another, do not participate in screening should be informed that there are no other methods other than screening that would reduce mortality from malignant neoplasms. Incidence and mortality rates from cervical cancer, breast cancer and colorectal cancer clearly reflect the epidemiological situation with this pathology in the regions of our country.

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ПОЗИТРОНДЫҚ ЭМИССИЯЛЫҚ ТОМОГРАФИЯ ӘДІСІМЕН ДИАГНОСТИКАЛЫҚ ЗЕРТТЕУЛЕР ЖҮРГІЗУ КЕЗІНДЕ ПАЦИЕНТТЕРДІ РАДИАЦИЯЛЫҚ ҚОРҒАУДЫ ОҢТАЙЛАНДЫРУ

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Аннотация

Бұл мақалада позитрондық эмиссиялық томография (ПЭТ) әдісін қолдану кезінде пациенттерді радиациялық қорғауды оңтайландыру мәселелері қарастырылады. ПЭТ диагностикалық әдісінің физикалық негіздері, радиофармпрепараттардың ерекшеліктері және пациентке түсетін сәулелену дозасының құрылымы талданған. Иондаушы сәулеленудің биологиялық әсерлері сипатталып, радиациялық қауіптің негізгі аспектілері айқындалған. Сонымен қатар, радиациялық қорғаудың халықаралық қағидаттары – негізделгендік, оңтайландыру (ALARA принципі) және дозалық бақылау – жан-жақты қарастырылған. Пациенттердің қауіпсіздігін қамтамасыз етуге бағытталған практикалық шаралар мен заманауи технологиялардың рөлі көрсетілген. Зерттеу нәтижелері ПЭТ зерттеулерін жүргізу кезінде сәулелену дозасын төмендету мен диагностикалық тиімділікті сақтау арасындағы тепе-теңдікті қамтамасыз етудің маңыздылығын дәлелдейді.

Түйінді сөздер: Позитрондық эмиссиялық томография, радиациялық қорғау, иондаушы сәулелену, радиофармпрепараттар, ALARA принципі, сәулелену дозасы, ядролық медицина, ПЭТ/КТ, радиациялық қауіпсіздік, диагностикалық бейнелеу.

Қазіргі заманғы ядролық медицинада позитрондық эмиссиялық томография (ПЭТ) жоғары ақпараттылыққа ие диагностикалық әдіс ретінде кеңінен қолданылады. Бұл әдіс қатерлі ісіктерді ерте кезеңде анықтауда, аурудың таралуын бағалауда және ем нәтижесін бақылауда маңызды рөл атқарады.

Алайда ПЭТ зерттеулері иондаушы сәулеленумен байланысты болғандықтан, пациенттердің радиациялық қауіпсіздігін қамтамасыз ету мәселесі ерекше назарды талап етеді. Осы тұрғыда радиациялық қорғауды оңтайландыру принциптерін сақтау халықаралық стандарттар мен ұсынымдарға сәйкес жүргізілуі тиіс [1].

Позитрондық эмиссиялық томография – радионуклидтік диагностика әдісі, ол позитрон шығаратын изотоптарды қолдануға негізделген. Ең жиі қолданылатын радиофармпрепарат – ^{18}F -фтордезоксиглюкоза (^{18}F -FDG), ол глюкоза метаболизмін бейнелеуге мүмкіндік береді [2].

Позитрондар аннигиляция процесінде екі қарама-қарсы бағытталған гамма-кванттарды (511 кэВ) түзеді, олар детекторлар жүйесі арқылы тіркеледі. Осы деректер негізінде үшөлшемді кескін қалыптасады. Бұл әдіс ағзадағы функционалдық өзгерістерді анатомиялық өзгерістерге дейін анықтауға мүмкіндік береді, бұл оның диагностикалық құндылығын арттырады.

ПЭТ/КТ кезінде сәулелену дозасы

- 18F-FDG енгізу арқылы бір стандартты ПЭТ-зерттеу кезінде пациенттің алатын тиімді дозасы шамамен **8–9 мЗв** ($\pm \sim 1,5$ мЗв), препараттың белсенділігі ~ 450 МБк.
- Біріктірілген ПЭТ/КТ зерттеулерінде (PET + диагностикалық CT) жалпы тиімді доза **$\sim 14–24$ мЗв** дейін жетуі мүмкін, КТ параметрлеріне байланысты.
- Басқа деректерге сәйкес, ПЭТ/КТ зерттеулерінің орташа дозасы бір тексеру үшін **20–25 мЗв**.
- Стандартты ПЭТ протоколдары бойынша кейбір бағалаулар **7–14 мЗв** аралығында.

Салыстыру үшін:

- Адамға табиғи жылдық фондық сәулелену дозасы шамамен **2–3 мЗв/жыл**.
- Кеуде қуысының рентгенографиясы – **$\sim 0,1$ мЗв**, ал КТ зерттеуі – **~ 7 мЗв**.

Қайталау жиілігі және жинақталған доза

- Үлкен шолу бойынша, шамамен 3 жылда ауруханада **10 878 ПЭТ/КТ зерттеуі** өткізілген, 8029 пациентте (орташа 1,3 зерттеу науқасқа).
- Осы пациенттердің ішінде жинақталған дозасы **≥ 100 мЗв** болғандардың үлесі шамамен **0,22 %**.
- Егер жыл сайын ПЭТ/КТ жасалса, 5 жыл ішінде сәулеленуге байланысты қатердің өсу ықтималдығы (мысалы, 40 жастағы ерлер үшін) **$\sim 0,85$ %** болуы мүмкін.

Дозаны оңтайландыру

- КТ параметрлерін оңтайландыру пациенттің дозасын **шамамен 29 %** азайтуға мүмкіндік береді, диагностика сапасын жоғалтпай.
- Заманауи детекторлар мен реконструкция алгоритмдерін қолдану (Time-of-Flight, жетілдірілген PSF-алгоритмдер, TrueX) пациент үшін аз дозада сапалы бейнелер алуға мүмкіндік береді.

Көрсеткіш	Мәні
Тек ПЭТ тиімді дозасы	$\sim 8–9$ мЗв
ПЭТ/КТ тиімді дозасы	$\sim 14–25$ мЗв
Табиғи жылдық фондық доза	$\sim 2–3$ мЗв
Қайталау зерттеулерінің жиілігі	$\sim 1,3$ науқасқа
Жинақталған дозасы ≥ 100 мЗв	$\sim 0,22$ %
Дозаны азайту ықтималдығы	~ 29 % оңтайландыру кезінде

Кесте 1. Негізгі көрсеткіштер

ПЭТ зерттеуі кезінде пациент сәулеленудің ішкі көзіне (енгізілген радиофармпрепарат) және кей жағдайда сыртқы көзіне (ПЭТ/КТ құрамындағы компьютерлік томография) ұшырайды. Орташа тиімді доза 5–25 мЗв аралығында өзгеруі мүмкін [3].

Иондаушы сәулеленудің биологиялық әсерлері екі негізгі топқа бөлінеді:

- **Детерминирленген әсерлер** – белгілі бір доза шегінен асқанда байқалады
- **Стохастикалық әсерлер** – ықтимал сипатта болады және қатерлі ісік даму қаупімен байланысты

Сондықтан медициналық сәулелену кезінде дозаны басқару және бақылау – радиациялық қауіпсіздіктің негізгі элементі болып табылады.

Халықаралық радиациялық қорғау комиссиясының (ICRP) ұсынымдарына сәйкес радиациялық қорғау үш негізгі принципке негізделеді [4]:

1. Негізделгендік (Justification)

Әрбір зерттеу пациентке күтілетін пайда ықтимал зияннан жоғары болған жағдайда ғана жүргізілуі тиіс. ПЭТ зерттеуін тағайындау клиникалық көрсеткіштерге негізделуі қажет.

2. Оңтайландыру (Optimization, ALARA принципі)

Сәулелену дозасы «мүмкіндігінше төмен, бірақ жеткілікті деңгейде» (ALARA) болуы тиіс.

Бұл үшін:

- енгізілетін радиофармпрепарат белсенділігін азайту
- сканерлеу параметрлерін оңтайландыру
- жоғары сезімтал детекторларды қолдану

3. Дозалық шектеулер (Dose limitation)

Пациенттер үшін тікелей шектеулер қолданылмаса да, бүкіл әлемдің тәжірибеде диагностикалық анықтамалық деңгейлер (DRL) пайдаланылады.

Принцип	Қолданылу кезеңі	Негізгі мақсаты	Дозаға әсері	Артықшылығы
Негізделгендік (Justification)	Зерттеуді тағайындау алдында	Қажетсіз зерттеулерді болдырмау	Жанама	Сәулеленуді толық болдырмауға мүмкіндік береді
Оңтайландыру (ALARA)	Зерттеу жүргізу кезінде	Дозаны мүмкіндігінше азайту	Тікелей	Пациент сәулеленуін нақты төмендетеді
Дозалық бақылау (DRL)	Зерттеуден кейін және мониторинг	Дозаларды бақылау және стандарттау	Жанама	Сапаны тұрақты бақылауға мүмкіндік береді

Кесте 2. Салыстырмалы анализ

Радиациялық қорғауды тиімді ұйымдастыру үшін келесі шаралар маңызды:

- **Протоколдарды стандарттау** – зерттеу әдістерін біріздендіру дозаны бақылауға мүмкіндік береді
- **Пациентті дұрыс дайындау** – бұл жалған нәтижелерді азайтып, қайта зерттеулер санын қысқартады
- **Балалардағы дозаны бейімдеу** – педиатриялық пациенттер радиацияға сезімтал болғандықтан, арнайы хаттамалар қажет
- **Гибридті технологияларды оңтайландыру** – ПЭТ/КТ кезінде КТ дозасын төмендету

- **Сапаны бақылау жүйелері** – аппараттардың техникалық жағдайын тұрақты тексеру

Шара	Нақты сандық нәтиже
Протоколдарды оңтайландыру	Жалпы сәулелену дозасы 28.7 % төмендеген
КТ параметрлерін төмендету	КТ дозасы 34.9 % азайған , кескін сапасы сақталған
Радиофармпрепарат белсенділігін азайту	ПЭТ компоненті бойынша доза 23.4 % төмендеген
Балаларға арналған салмақтық протокол	Доза стандартты хаттамамен салыстырғанда 20–50 % төмен
Заманауи толық дене ПЭТ/КТ технологиясы	Инъекция белсенділігі 3 есе азайтылған
Жаңа жоғары сезімтал сканерлер	ПЭТ компонент дозасы шамамен 50 % қысқарған

Кесте 3. Шараға байланысты нақты сандық нәтиже

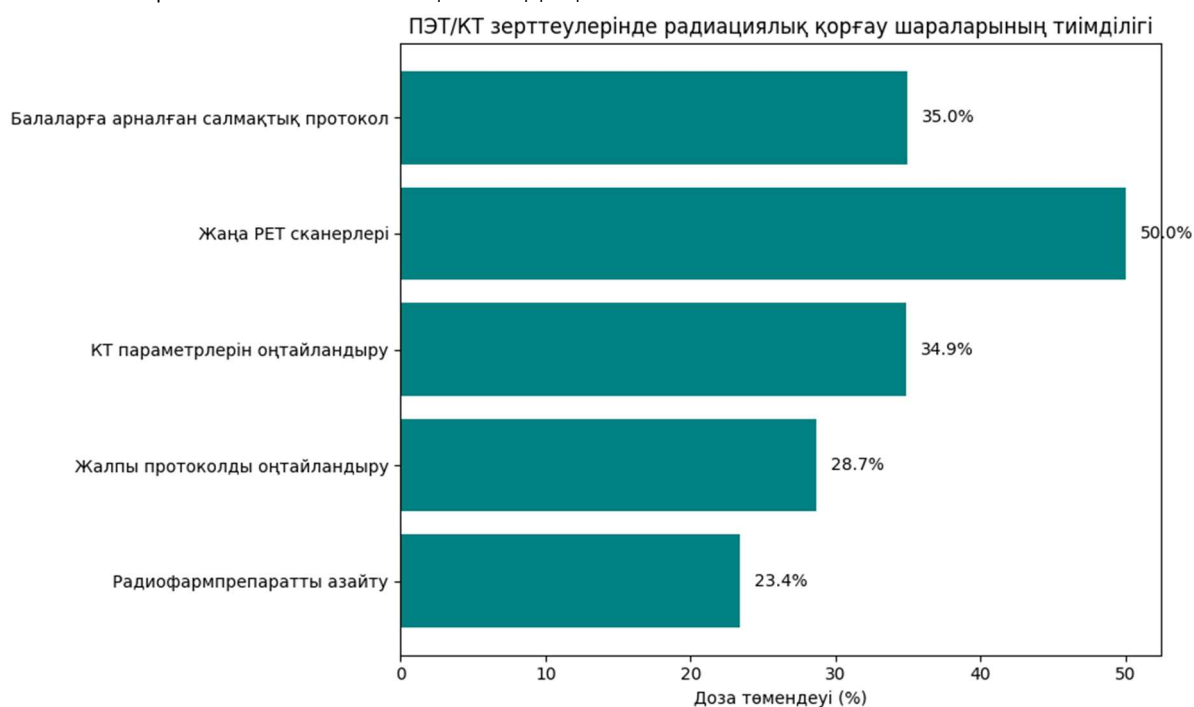


Диаграмма 1. Эффективтілік

Соңғы жылдары ПЭТ технологиясында радиациялық жүктемені азайтуға бағытталған инновациялар енгізілуде:

- уақытша ажыратымдылығы жоғары детекторлар (TOF-технологиялар)
- жасанды интеллект негізіндегі реконструкция алгоритмдері
- төмен дозалы және ультра төмен дозалы бейнелеу әдістері

Бұл технологиялар кескін сапасын сақтай отырып, сәулелену дозасын айтарлықтай төмендетуге мүмкіндік береді [5].

Қорытынды

Позитрондық эмиссиялық томография – жоғары дәлдікті диагностикалық әдіс болғанымен, радиациялық әсермен байланысты тәуекелдерді қамтиды. Осыған байланысты пациенттерді радиациялық қорғауды оңтайландыру медициналық тәжірибеде маңызды орын алады.

Негізделгендік, ALARA принципін сақтау және заманауи технологияларды енгізу арқылы ПЭТ зерттеулерінің қауіпсіздігі мен тиімділігін арттыруға болады.

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Legal Sciences

Tourism Service Contract, Problems and Existing Challenges

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Abstract

The article discusses the legal nature of the tourism service contract, its importance in the tourism business and the existing challenges in terms of protecting consumer rights. Special attention is paid to the obligation of the tourist, as a weak party to the contract, to provide information correctly. The paper analyzes the Georgian legislation regulating the tourism service contract, judicial practice and its compliance with the relevant EU directives. It also discusses the existing violations in the field of tourism services, their impact on the development of the tourism sector and the economic situation of the country. The role of digital platforms and existing gaps in the field of tourism services are emphasized. Based on the research, existing problems and recommendations for their solution are presented.

Keywords: tourist, contract, consumer, violation, obligation to provide information, digital platform.

Introduction

Tourism is one of the fastest growing sectors in the modern world, which has a significant impact on both the development of the national economy and the international image of the country. Tourism is of particular importance for Georgia, as the country's geographical location, natural resources and cultural heritage create important prerequisites for the development of tourism. Relations in the field of tourism services are mainly regulated by a tourism service agreement, which defines the rights and obligations of the parties. This agreement is one of the important legal instruments aimed at protecting the interests of tourists as consumers and ensuring the quality of services. After the adoption of the Association Agreement between Georgia and the European Union, special importance is attached to the harmonization of national legislation with European legal standards, including in the field of tourism and consumer protection.

Relevance and scientific significance of the study

Tourism is one of the important factors in the country's economic development. Since Georgia signed the Association Agreement with the European Union in 2014, special attention has been paid to the approximation of legislation in the field of tourism services to European standards. Today, this issue is even more relevant in the conditions when the implementation of European standards of consumer protection is an international obligation of Georgia and we have many shortcomings in this regard in real practice. According to EU law, a tourist is considered a consumer, which obliges the state to create a legal environment that ensures effective protection of his rights. In order to attract tourists to the country, it is necessary to create a safe environment, developed infrastructure and high quality of service.

Research methodology

The research is based on the following methods:

- ✓ Analysis of completed court cases;
- ✓ Analysis of statistical information;
- ✓ Comparative legal method

Legal nature of a tourist service contract

A tourist service contract is regulated by Articles 657–667 of the Civil Code of Georgia¹. This contract is one of the specific institutions of civil law and is: bilateral, pecuniary, fixed-term, consensual by its nature. The parties to the contract are: the travel organizer (tourist enterprise) and the tourist (traveler). According to Article 657 of the Civil Code of Georgia, under a tourist service contract, the travel organizer is obliged to provide the tourist with the agreed service, and the tourist is obliged to pay the appropriate remuneration.

According to German case law, a tourist service contract is often considered a type of labor contract, since the organization of the service includes complex activities.

Civil-legal aspects of a tourist service contract

A tourist service contract is based on such basic principles of civil law as:

- ✓ Freedom of contract;
- ✓ Good faith;
- ✓ Equality of the parties;
- ✓ Proper performance of obligations.²

In a tourist service contract, the tourist is often considered a weak party, since he is completely dependent on the information provided by the tourist company. From the point of view of civil law, an important issue is breach of contract and liability. In the event that the tourist company fails to provide the services stipulated in the contract, the tourist has the right to demand:

- ✓ Proper performance of the service;
- ✓ Reduction of the price of the service;
- ✓ Termination of the contract;
- ✓ Compensation for the damage caused.

Compensation for damage may include both material and, in certain cases, moral damage.

Problems in the field of tourist services

Obligation to inform the tourist

The obligation to inform the tourist is one of the main tools for consumer protection. The travel organizer is obliged to provide the tourist with complete and accurate information about the conditions of the trip.

The Law of Georgia “On Protection of Consumer Rights”³ (March 29, 2022) separately identifies the obligation to provide information to the consumer. In EU law, this issue is regulated by the “Package Travel and Related Travel Arrangements” Directive, which determines a detailed list of information that must be provided to the tourist before concluding the contract.

A number of problems have been identified in the tourism services sector in Georgia. One of the important problems is misleading tourists when receiving various services. In practice, there have been cases when tourists were charged significantly higher prices in restaurants using the so-called “double menu”. There are also frequent cases in transportation services when tourists are provided with incorrect information about the travel destination and financial pressure is exerted on them. Such violations negatively affect the country’s tourism image and the development of the tourism sector. A number of problems have been identified in the tourism service sector in Georgia, including:

- ✓ Insufficient information provision;

¹ Civil Code of Georgia 1997;

² Commentary on the Civil Code of Georgia, Book III, 2019.

³ Law of Georgia “On Protection of Consumer Rights”, 2022

In many cases, tourists are not provided with complete information about the terms of service.

- ✓ Problems related to the quality of service;

In practice, there are frequent cases when tourists are provided with different or inferior services.

- ✓ Violations committed against tourists;

In the tourism sector, such violations of the law are often recorded as:

- ✓ Deception of tourists;
- ✓ Artificially increasing the price of services;
- ✓ Using double menus in restaurants;
- ✓ Deception in transportation services

Such actions negatively affect the country's tourism image. Incomplete provision of information leads to violation of consumer rights and legal liability.

Legal issues of package tours

In modern tourism, package tours are widely spread, which include a combination of several services. This issue is regulated in detail in the European Union, while in Georgia, the relevant special regulation has not been fully developed. This creates a legal vacuum and increases the risks of consumer protection.

Contemporary challenges

One of the important challenges in the field of tourism services is the development of digital platforms. Online booking systems complicate the determination of liability, which creates additional difficulties in terms of protecting consumer rights. Also problematic are the provision of insufficient information, inconsistent service quality, misleading tourists, unfair pricing policies, etc. These factors negatively affect the country's tourism image.

Tourism services are strictly regulated in EU law. Of particular importance is Directive 2015/2302⁴, which defines in detail the conditions of tourism services and consumer protection mechanisms. Georgian legislation partially complies with the above standards, but requires additional refinement, especially in the direction of the obligation to inform tourists and consumer protection mechanisms.

Analysis of judicial practice⁵

Disputes related to tourist service contracts are relatively rare in Georgian judicial practice, although existing cases reveal significant trends. Courts mainly focus on the fulfillment of the obligation to provide information and the compliance of the service with the terms of the contract. According to judicial practice, if the service does not comply with the agreed terms, this is considered a breach of the contract and entails the liability of the service provider. It is especially important that courts evaluate not only the formally provided information, but also its actual accuracy and completeness. In practice, it has also been shown that tourist companies often do not take full responsibility for the services provided by third parties, which leads to disputes. This problem indicates the need to improve legal regulation.

Digital platforms

With the development of tourism, digital platforms have acquired an important role, providing online booking of tourist services. In such conditions, it becomes difficult to identify the responsible person, since several entities are involved in the relationship: the platform, the direct service provider and the consumer. The problem is that platforms often act as intermediaries and do not consider themselves service providers, as a result of which the consumer is deprived of an effective mechanism of legal protection. This issue is especially relevant for Georgia, where the

⁴ Directive (EU) 2015/2302 on package travel and linked travel arrangements.

⁵ <https://www.supremecourt.ge/ka/decisions>

digital tourism market is developing rapidly, although the relevant legal regulation has not yet been established.

Determining the scope of the tour operator's liability in a tourist service contract is one of the important issues. According to the general principles of civil law⁶, liability arises from a breach of obligation, although extended liability is given special importance in the field of tourist services. The so-called "single liability" principle is established in EU law, according to which the tour operator is responsible for the entire package, including services performed by third parties. This approach significantly strengthens the standard of consumer protection. Such a clear regulation is not fully established in Georgian legislation, which in practice leads to the problem of distribution of responsibility and often harms the interests of tourists.

Tourism is one of the leading sectors of the Georgian economy. The development of tourism in the country has a significant impact on employment, the growth of small and medium-sized businesses and the inflow of foreign currency. Trust in the tourism sector is directly related to the effectiveness of legal protection. Violation of consumer rights and unfair practices reduce the country's competitiveness in the international tourism market. Accordingly, improving legal mechanisms is not only a legal but also an economic necessity.

Assessment

The tourism service contract plays an important role in the legal regulation of relations in the tourism sector. Despite the fact that Georgia has legal norms regulating this contract and has adopted the Law "On Protection of Consumer Rights", practice shows that the existing mechanisms are not sufficient and need to be improved. It is necessary to:

- ✓ Improve legislation;
- ✓ Harmonize with EU standards;
- ✓ Expand the obligation to inform tourists;
- ✓ Tighten sanctions;
- ✓ Develop judicial practice

Effective protection of the rights of tourists as a weak party will contribute not only to protecting the interests of consumers, but also to the development of the tourism sector and the economic progress of the country.

The Georgian legal framework creates a general regulatory basis in the field of tourism services, however, it fails to ensure the level of consumer protection that is established in European law. The main problems are: the absence of special regulation on package tours, unclear distribution of responsibilities - insufficient standardization of information provision; the EU legal model shows that a high standard of consumer protection is achieved through the existence of a detailed regulation and a clear system of responsibilities. It is important for Georgia to implement reforms in this direction in order to ensure both the protection of consumer rights and the sustainable development of the tourism sector.

The issues of tourism service contracts and consumer protection have been widely studied within the framework of both international and European law. The existing literature emphasizes the special legal position of the tourist as a consumer and the obligation of the state to ensure his effective protection.

The World Tourism Organization (UNWTO)⁷ in its reports considers tourism as an important factor of economic development and draws special attention to the need for ethical and legal protection of consumers. Of particular importance is the "Global Code of Ethics for Tourism", which defines

⁶ <https://matsne.gov.ge/ka/document/view/31702?publication=138>

⁷ <https://www.untourism.int/node/14904>

the basic principles of conduct in the tourism sector and emphasizes the importance of transparency.

The legal approach of the European Union is represented by Directive (EU) 2015/2302⁸, which creates one of the highest standards of consumer protection. European Commission documents emphasize the importance of pre-contractual information and the sole responsibility of the tour operator for the performance of package tours.

In the academic literature, Geraint Howells, Hans-Wolfgang Micklitz⁹ and Stephen Weatherill¹⁰ focus on the development of consumer protection law and its political and economic significance. Their works show that modern consumer law is based on the principle of protection of the weaker party and a clear system of allocation of responsibility.

Studies published in the journals *Tourism Management*¹¹ and *Journal of Consumer Policy*¹² confirm that the main challenges in the field of tourism services are information asymmetry, the complexity of regulating digital platforms, and the ambiguity of liability. Accordingly, the existing literature unanimously indicates that effective legal regulation of tourism services requires a high level of harmonization, especially with EU standards.

⁸ <https://eur-lex.europa.eu/eli/dir/2015/2302/oj/eng>

⁹ Howells, Geraint , Hans-W Micklitz , Mateja Durovic , and André Janssen , ed. *Consumer Protection in Asia*. Oxford: Hart Publishing, 2022. Bloomsbury Collections. Web. 12 Mar. 2024;

¹⁰ [Geraint Howells](#), [Stephen Weatherill](#), *Consumer Protection Law*.

¹¹ https://www.scimagojr.com/journalsearch.php?q=16547&tip=sid&clean=0#google_vignette

¹² <https://scispace.com/journals/journal-of-consumer-policy-h6w8945n>

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ПРАВОВЫЕ АСПЕКТЫ МИРНОГО СОГЛАШЕНИЯ

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Аннотация. Данная глава представляет комплексный анализ правовых аспектов мирного соглашения между государствами, находившимися в вооружённом конфликте [1, 2], с особым акцентом на применение норм международного права и положений Венской конвенции о праве международных договоров 1969 года [2]. Исследование раскрывает соотношение между принципом территориальной целостности и правом народов на самоопределение [3], анализирует место мирного договора в иерархии источников международного права, а также рассматривает его связь с системой универсальных и региональных международно-правовых актов [1, 4]. Особое внимание уделяется проблеме императивных норм (*jus cogens*) [2] и их применению при оценке действительности мирных соглашений. Исследование опирается на практику Международного суда ООН [15, 17], решения региональных судебных органов и международно-правовую доктрину [9, 10, 11]. Выводы настоящей главы имеют как теоретическое значение для развития науки международного права, так и практическое применение при разработке и толковании конкретных мирных договоров.

Ключевые слова: мирное соглашение, императивные нормы (*jus cogens*), Венская конвенция, территориальная целостность, самоопределение народов, источники международного права, Международный суд ООН, постконфликтное урегулирование, договорное право, международный правопорядок

Введение. Мирное соглашение между государствами, завершившими вооружённый конфликт, представляет собой уникальный феномен в системе международного права [1], сочетающий в себе элементы политического компромисса с юридической техникой договорного нормотворчества [11]. Специфика мирных договоров состоит в том, что они одновременно являются инструментом фиксации политического результата конфликта и источником долгосрочных правовых обязательств [1, 2], определяющих характер межгосударственных отношений на десятилетия вперёд.

Актуальность исследования правовых аспектов мирного соглашения обусловлена целым рядом факторов [11]. Во-первых, в условиях множественных вооружённых конфликтов, разворачивающихся на постсоветском пространстве и в других регионах мира, вопросы правового оформления мирных договоров приобретают особую практическую значимость. Во-вторых, развитие системы международного права [1], включая расширение практики применения норм о правах человека, экологическому правопорядку и постконфликтному правосудию, требует переосмысления традиционной концепции мирных договоров. В-третьих, разрешение противоречий между различными принципами международного права [3] — такими как территориальная целостность, право на самоопределение, суверенное равенство государств — требует глубокого правового

анализа и выработки обоснованных подходов к толкованию и применению норм международного права.

Целью данной главы является установление места мирного договора в системе источников международного права [1, 11], раскрытие его правовой природы и анализ применимого к нему правового режима [2]. Для достижения указанной цели в главе решаются следующие задачи: определение содержания концепции императивных норм [2, 19] и их роли при оценке действительности мирных соглашений; анализ процедуры заключения мирного договора в соответствии с Венской конвенцией о праве международных договоров [2]; исследование соотношения мирного договора с другими источниками международного права [1, 4]; выявление специфики правового режима мирных соглашений в сравнении с иными международными договорами.

Методология исследования основана на применении системно-структурного анализа [11], позволяющего рассматривать мирное соглашение как комплексный правовой институт в его взаимосвязи с другими элементами системы международного права [1]. Используются формально-юридический метод при толковании положений Венской конвенции [2] и иных нормативных актов, сравнительно-правовой анализ при рассмотрении практики различных государств и международных органов, а также историко-правовой подход при прослеживании эволюции института мирного договора в международном праве [20].

Источниками исследования являются универсальные международные договоры [1, 2, 4], резолюции Совета Безопасности ООН [1], решения Международного суда ООН и других судебных органов [15, 17, 18], научные работы отечественных и зарубежных специалистов в области международного публичного права [9, 10, 11, 12, 13, 14], а также практические примеры заключения и исполнения мирных договоров в различных регионах мира.

2.1. Мирное соглашение и императивные нормы международного права. В доктрине и практике современного международного публичного права концепция императивных норм (*jus cogens*) занимает центральное место при оценке легитимности и действительности любых международных договоров [1, 11], включая мирные соглашения [19]. Согласно статье 53 Венской конвенции [2], договор является ничтожным, если в момент заключения он противоречит императивной норме общего международного права — норме, которая принимается и признаётся международным сообществом государств в целом как норма, отклонение от которой недопустимо и которая может быть изменена только последующей нормой общего международного права, носящей такой же характер [2].

К числу таких норм относятся: запрет применения силы и угрозы силой [1]; запрет геноцида; запрет рабства; запрет апартеида и расовой дискриминации; принцип суверенного равенства государств [1]; принцип территориальной целостности [1, 3]; мирное разрешение международных споров [4]; добросовестное выполнение принятых обязательств [2].

Соотношение принципа территориальной целостности и права народов на самоопределение применительно к урегулированию региональных конфликтов является центральным теоретическим вопросом [3], требующим чёткого международно-правового ответа. Декларация о принципах международного права 1970 года [3], принятая Генеральной Ассамблеей ООН единогласно в виде Резолюции 2625 (XXV), содержит принципиальную оговорку: ничто в положениях о самоопределении не должно толковаться как санкционирующее или поощряющее любые действия, которые вели бы к расчленению или к частичному или полному нарушению территориальной целостности суверенных государств, соблюдающих в своей деятельности принцип равноправия и самоопределения народов.

Таким образом, право народов на самоопределение не является абсолютным [3] и не может быть использовано для оправдания сепаратизма в государствах, реализующих принципы демократического управления. Мирное соглашение, стремящееся легализовать результаты вооружённого конфликта в форме территориальных изменений, должно основываться на чётком соблюдении норм *jus cogens* [2, 19], что служит гарантией законности и легитимности достигнутого компромисса.

2.2. Мирное соглашение и венская конвенция о праве международных договоров.

Венская конвенция о праве международных договоров 1969 года [2] является универсальным кодифицирующим актом, регулирующим весь «жизненный цикл» международного договора — от начала переговоров до его прекращения [2, 11]. Оба государства являются её участниками, что означает полную применимость Конвенции ко всем аспектам заключения, действия и исполнения мирного договора и исключает возможность ссылок на «неприменимость» её положений к данному конкретному случаю [2].

Процедура заключения мирного соглашения, регламентированная статьями 7–18 Венской конвенции [2], включает несколько последовательных стадий. Первая — проведение переговоров и принятие текста договора путём голосования представителей государств [2]. Вторая — установление аутентичности текста (обычно путём подписания *ad referendum* или парафирования), после чего текст считается окончательным [2]. Третья — выражение согласия на обязательность договора: согласно статье 14 Конвенции [2], согласие государства на обязательность договора выражается ратификацией, если договор предусматривает такое согласие путём ратификации [2].

Именно ратификация высшим законодательным органом придаёт договору статус акта, обязывающего государство на всех уровнях его правовой системы [2, 11]. Принципиально важным является положение статьи 62 Венской конвенции [2] о коренном изменении обстоятельств (*rebus sic stantibus*). Международный суд ООН в решении по делу «Габчиково-Надьмарош» [17] установил, что данная доктрина применяется крайне ограничительно и не может быть использована для одностороннего выхода из договоров, устанавливающих территориальный режим [2, 17].

Применительно к мирному договору это означает: ни одна из сторон не сможет в будущем ссылаться на «изменение политической обстановки» или «смену правительства» как на основание для прекращения обязательств по договору [2, 11]. Данное разъяснение лишает оппонентов мирного договора правового аргумента, который они могли бы использовать после смены власти в той или иной стране.

2.3. Взаимосвязь мирного соглашения с другими международно-правовыми актами.

Мирное соглашение является синтетическим актом, базирующимся на системе ранее принятых многосторонних документов [1, 11]. Принцип системности международного права требует, чтобы нормы международного права толковались во взаимосвязи, а не изолированно [1, 11]. Данный принцип нашёл отражение в практике Международного суда ООН: в решении по делу «Никарагуа против США» (1986) [15] Суд прямо указал, что нормы договорного права и международного обычного права применяются параллельно и взаимодополняющее [1, 15].

Алма-Атинская декларация 1991 года [4] является ключевым отправным документом: она зафиксировала обязательство бывших союзных республик признавать и уважать территориальную целостность друг друга и нерушимость существующих в рамках СНГ границ [4]. Мирный договор конкретизирует данный принцип: переводит общую

декларацию в плоскость детальной делимитации и демаркации государственной границы на местности [2, 11].

Хельсинкский заключительный акт СБСЕ 1975 года [4] закрепляет десять основополагающих принципов («декалог»), включая нерушимость границ [4], территориальную целостность [1, 3, 4] и мирное урегулирование споров [4]. Статья 103 Устава ООН [1] устанавливает приоритет обязательств по Уставу перед иными международными соглашениями: данный приоритет распространяется и на мирный договор, зарегистрированный в Секретариате ООН [1, 2].

Система международных договоров по правам человека непосредственно влияет на содержание мирного соглашения [11]. Конвенция о защите прав человека и основных свобод [5] и оба Международных пакта [6, 7] устанавливают минимальные стандарты защиты, которые должны соблюдаться при реализации мирного договора [11]. Международный суд ООН в ряде решений установил, что мирные соглашения не могут служить оправданием для нарушения норм международного гуманитарного права и прав человека [15, 17, 18].

Заключение. На основе проведённого анализа правовых аспектов мирного соглашения можно сформулировать следующие основные выводы. Во-первых, мирный договор между государствами представляет собой особую форму международного договора [1, 11], обладающую уникальными характеристиками и требующей специального правового режима [19]. Он одновременно является политическим документом, фиксирующим результаты вооружённого конфликта, и строгим юридическим актом [2, 11], устанавливающим долгосрочные обязательства сторон. Это двоякое качество предъявляет повышенные требования к качеству договорного текста, детальности его положений и наличию механизмов контроля над исполнением [11].

Во-вторых, мирное соглашение должно полностью соответствовать императивным нормам международного права (*jus cogens*) [2, 19], что служит гарантией его законности и легитимности [2]. В частности, мирный договор не может служить средством легализации результатов незаконного применения силы [1] или нарушения принципа территориальной целостности государств [1, 3]. Право народов на самоопределение, хотя и является важным принципом международного права [3], не может быть противопоставлено принципу территориальной целостности суверенных государств, соблюдающих демократические стандарты управления [3].

В-третьих, процедура заключения мирного договора полностью регулируется Венской конвенцией о праве международных договоров 1969 года [2], что обеспечивает единообразное применение правовых норм и исключает ссылки на национальные особенности той или иной правовой системы [2]. Ратификация договора высшим законодательным органом является необходимым условием для придания ему силы обязательного источника права во внутренней правовой системе государства [2, 11].

В-четвёртых, мирное соглашение существует не в изоляции, а в контексте всей системы международного права [1, 11], включая как универсальные многосторонние договоры [1, 2], так и региональные соглашения [4], решения международных судебных органов [15, 17, 18] и обычное международное право [1]. Его толкование и применение должны осуществляться в свете этого более широкого правового контекста, с учётом принципа системности [1, 11].

В-пятых, мирные договоры не могут служить оправданием для нарушения норм международного гуманитарного права [11], прав человека [5, 6, 7] и экологического права. Напротив, они должны включать специальные положения, обеспечивающие соблюдение этих норм и создающие механизмы ответственности за их нарушение [11].

Таким образом, правовые аспекты мирного соглашения представляют собой сложную область международного права [1, 11], требующую глубокого анализа и учёта множества взаимодействующих правовых принципов и норм [1, 2, 3]. Надлежащее правовое оформление мирного договора является залогом его устойчивости и способности обеспечить долгосрочный и справедливый мир между ранее враждующими государствами [11].

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VERGİ QANUNVERİCİLİYİNİN POZULMASINA GÖRƏ MƏSULİYYƏT VƏ VERGİ TƏQSİRİNİN FORMALARI

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Xülasə

Bu məqalədə vergi qanunvericiliyinin pozulmasına görə məsuliyyət və vergi hüquqpozmalarında təqsirin formaları araşdırılır. Tədqiqatda vergi hüququnun anlayışı, hüquq sistemində yeri, Azərbaycanda formalaşma xüsusiyyətləri və vergi məsuliyyətinin hüquqi mahiyyəti təhlil olunur. Məqalədə vergi hüquqpozmasının obyekt, obyektiv tərəf, subyekt və subyektiv tərəf kimi tərkib elementləri izah edilir, təqsirin qəsd və ehtiyatsızlıq formaları müqayisəli şəkildə qiymətləndirilir. Eyni zamanda təbii fəlakət, xəstəlik, səlahiyyətli orqanların yazılı izahlarına əsasən hərəkət etmə və pozuntunun könüllü aradan qaldırılması kimi təqsiri istisna edən hallar nəzərdən keçirilir. Nəticədə müəyyən edilir ki, vergi məsuliyyətinin ədalətli tətbiqi üçün təqsirin düzgün müəyyənləşdirilməsi, hüquqi müəyyənlik prinsipinin qorunması və vergi ödəyicilərinin hüquqlarının təmin edilməsi mühüm əhəmiyyət daşıyır.

Açar sözlər: vergi hüququ, vergi məsuliyyəti, vergi qanunvericiliyi, vergi təqsiri, qəsd, ehtiyatsızlıq, vergidən yayınma.

Giriş

Vergi hüququ müasir hüquq sisteminin mühüm sahələrindən biri olmaqla dövlətin maliyyə əsaslarının formalaşmasında və ictimai-iqtisadi münasibətlərin tənzimlənməsində xüsusi rol oynayır. Dövlətin sosial, iqtisadi, müdafiə, idarəetmə və digər ümummilli funksiyalarının həyata keçirilməsi üçün zəruri maliyyə ehtiyatlarının əsas mənbələrindən biri məhz vergilərdir. Bu baxımdan vergi münasibətləri yalnız iqtisadi xarakter daşımır, həm də hüquqi tənzimləmənin mühüm obyektini kimi çıxış edir. Vergi hüququ dövlətlə vergi ödəyiciləri arasında yaranan münasibətləri tənzimləyir, tərəflərin hüquq və vəzifələrini müəyyən edir, vergi öhdəliklərinin yerinə yetirilmə qaydalarını və pozuntu hallarına görə məsuliyyət mexanizmlərini müəyyənləşdirir.

Vergi münasibətlərinin səmərəli tənzimlənməsi üçün məsuliyyət institutunun xüsusi əhəmiyyəti vardır. Vergi qanunvericiliyinin pozulması halları dövlət büdcəsinə daxilolmaların azalmasına, vergi intizamının zəifləməsinə, sahibkarlıq subyektləri arasında qeyri-bərabər rəqabət şəraitinin yaranmasına və bütövlükdə maliyyə sabitliyinin pozulmasına səbəb ola bilər. Buna görə də vergi qanunvericiliyinin pozulmasına görə məsuliyyət həm fiskal maraqların qorunması, həm də hüquqi ədalətin təmin olunması baxımından mühüm əhəmiyyət kəsb edir.

Lakin vergi məsuliyyəti yalnız formal pozuntu faktına əsaslanmamalıdır. Hüquqi məsuliyyətin əsas prinsiplərindən biri şəxsin təqsirli davranışına görə məsuliyyət daşmasıdır. Vergi hüququnda təqsir şəxsin qanunsuz hərəkətinə və ya hərəkətsizliyinə psixi münasibətini ifadə edir. Bu münasibət qəsd və ehtiyatsızlıq formalarında təzahür edə bilər [1]. Vergi hüquqpozmalarının düzgün tövsif edilməsi, məsuliyyət tədbirlərinin ədalətli tətbiqi və vergi ödəyicilərinin hüquqlarının qorunması üçün təqsirin müəyyən edilməsi mühüm şərtidir.

Mövzunun aktuallığı ondan ibarətdir ki, müasir dövrdə vergi münasibətləri getdikcə mürəkkəbləşir. Sahibkarlıq fəaliyyətinin genişlənməsi, maliyyə əməliyyatlarının rəqəmsallaşması, beynəlxalq iqtisadi əlaqələrin inkişafı və vergi inzibatchılığının təkmilləşməsi vergi öhdəliklərinin düzgün yerinə yetirilməsi məsələsini daha da əhəmiyyətli edir. Bu şəraitdə qəsdən törədilən vergi

hüquqpozmaları ilə ehtiyatsızlıqdan və ya obyektiv səbəblərdən yaranan pozuntuların fərqləndirilməsi xüsusi zərurətə çevrilir.

Məqalənin məqsədi vergi qanunvericiliyinin pozulmasına görə məsuliyyət institutunu, vergi hüquqpozmalarında təqsirin formalarını, təqsiri istisna edən halları və Azərbaycan Respublikasında bu sahənin hüquqi tənzimlənmə xüsusiyyətlərini təhlil etməkdir.

Təhlil

Vergi hüququnun anlayışı və hüquq sistemində yeri

Vergi hüququ dövlətin maliyyə fəaliyyətinin mühüm istiqaməti olan vergitutma sahəsində yaranan ictimai münasibətləri tənzimləyən hüquq normalarının məcmusudur. Vergi münasibətləri dövlətin və bələdiyyələrin gəlirlərinin formalaşdırılması, vergi öhdəliklərinin müəyyən edilməsi, vergi nəzarətinin həyata keçirilməsi və qanun pozuntularına görə məsuliyyət tədbirlərinin tətbiqi ilə bağlı yaranır.

Vergi hüququnun predmeti dövlət, vergi ödəyiciləri, vergi agentləri, vergi orqanları və digər iştirakçılar arasında yaranan münasibətlərdir. Bu münasibətlər əsasən publik-hüquqi xarakter daşıyır. Çünki vergilər dövlət hakimiyyəti tərəfindən müəyyən edilir və məcburi xarakterə malikdir. Vergi münasibətlərində tərəflər bərabər hüquqi mövqedə olmur; dövlət vergi orqanları vasitəsilə hakimiyyət səlahiyyətlərini həyata keçirir, vergi ödəyiciləri isə qanunla müəyyən edilmiş öhdəlikləri yerinə yetirməli olurlar.

Vergi hüququ maliyyə hüququnun mühüm yarım sahəsi olmaqla yanaşı, konstitusiya hüququ, inzibati hüquq, mülki hüquq və cinayət hüququ ilə sıx bağlıdır. Konstitusiya hüququ vergi öhdəliklərinin ümumi əsaslarını müəyyən edir. Azərbaycan Respublikası Konstitusiyasının müvafiq müddəalarına əsasən, hər kəs qanunla müəyyən edilmiş vergiləri və digər dövlət ödənişlərini ödəməlidir. Eyni zamanda heç kəs qanunda nəzərdə tutulmayan və ya qanunda göstərilən həcmdən artıq vergi ödəməyə məcbur edilə bilməz. Bu prinsip vergi hüququnda qanunçuluğun əsas təminatlarından biridir.

Inzibati hüquq vergi orqanlarının fəaliyyət qaydaları, inzibati nəzarət və inzibati məsuliyyət məsələləri ilə bağlıdır [2]. Cinayət hüququ isə vergi münasibətlərini daha ağır hüquqpozmalar, xüsusilə vergidən yayınma cinayətləri baxımından qoruyur. Mülki hüquqla əlaqə isə vergi münasibətlərinin əmlak münasibətləri ilə bağlı olmasında özünü göstərir. Bununla belə, vergi münasibətləri hakimiyyət və tabelik əsasında qurulduğundan onlar birbaşa mülki hüquq münasibətləri kimi qiymətləndirilmir.

Azərbaycanda vergi hüququnun formalaşması

Azərbaycan Respublikasında müstəqil vergi hüququnun formalaşması ölkənin dövlət müstəqilliyi əldə etməsi ilə bağlıdır. Sovet dövründə vergi siyasəti və maliyyə münasibətləri mərkəzləşdirilmiş idarəetmə sisteminin tərkib hissəsi idi. Azərbaycan SSR-in vergi sahəsində müstəqil qərar qəbul etmək imkanları məhduddu idi. Müstəqillik əldə edildikdən sonra Azərbaycan öz vergi sistemini yaratmaq, onu bazar iqtisadiyyatının tələblərinə uyğunlaşdırmaq və beynəlxalq standartlara yaxınlaşdırmaq zərurəti ilə üzləşdi.

1990-cı illərdən başlayaraq qəbul edilmiş vergi qanunları, dövlət vergi xidməti haqqında normativ aktlar və sonrakı islahatlar ölkədə vergi hüququnun institusional əsaslarını formalaşdırdı. Azərbaycan Respublikasının Vergi Məcəlləsinin qəbul edilməsi isə bu sahədə mühüm mərhələ oldu. Vergi Məcəlləsi vergi sisteminin əsas prinsiplərini, vergi növlərini, vergi ödəyicilərinin və vergi orqanlarının hüquq və vəzifələrini, vergi nəzarətinin forma və metodlarını, habelə vergi qanunvericiliyinin pozulmasına görə məsuliyyət tədbirlərini müəyyən edir.

Vergi Məcəlləsinin əhəmiyyəti ondan ibarətdir ki, o, vergi münasibətlərini sistemli şəkildə tənzimləyən əsas normativ hüquqi aktdır [3]. Bu Məcəllə yalnız vergilərin hesablanması və ödənilməsi qaydalarını deyil, həm də vergi ödəyicilərinin hüquqlarının müdafiəsi, artıq ödənilmiş vergilərin qaytarılması, vergi orqanlarının qərarlarından şikayət verilməsi və təqsiri istisna edən hallar kimi məsələləri də əhatə edir.

Vergi qanunvericiliyinin pozulmasına görə məsuliyyətin mahiyyəti

Vergi qanunvericiliyinin pozulmasına görə məsuliyyət vergi öhdəliklərinin yerinə yetirilməməsi və ya lazımcı yerinə yetirilməməsi nəticəsində tətbiq olunan hüquqi təsir tədbirləridir. Bu məsuliyyətin məqsədi yalnız şəxsi cəzalandırmaq deyil, həm də vergi intizamını təmin etmək, dövlət büdcəsinə dəyən zərərin qarşısını almaq və gələcək pozuntuların profilaktikasını həyata keçirməkdir.

Vergi məsuliyyətinin mahiyyətini düzgün anlamaq üçün bərpaedici və cəzalandırıcı tədbirləri fərqləndirmək lazımdır [4]. Vergi borcunun və ona hesablanan faizlərin ödənilməsi ilk növbədə bərpaedici xarakter daşıyır. Çünki burada məqsəd dövlət büdcəsinə daxil olmalı olan vəsaitin bərpa edilməsidir. Maliyyə sanksiyaları və cərimələr isə daha çox cəzalandırıcı xarakterə malikdir və hüquqpozma törədən şəxsin qanunsuz davranışına hüquqi reaksiya kimi çıxış edir.

Azərbaycan Respublikasının Vergi Məcəlləsinə əsasən, vergi qanunvericiliyinin pozulmasına görə vergi ödəyiciləri, vergi agentləri, onların nümayəndələri və vergi orqanlarının vəzifəli şəxsləri məsuliyyət daşıya bilərlər [5]. Bu yanaşma göstərir ki, vergi məsuliyyəti yalnız vergi ödəyicisinə yönəlmiş birtərəfli mexanizm deyil. Vergi orqanlarının qanunsuz hərəkətləri və ya hərəkətsizliyi də hüquqi məsuliyyət doğura bilər. Bu, vergi münasibətlərində qanunçuluq və qarşılıqlı hüquqi məsuliyyət prinsipinin təzahürüdür.

Vergi qanunvericiliyinin pozulmasına görə məsuliyyət müxtəlif formalarda ola bilər. Bunlara maliyyə məsuliyyəti, inzibati məsuliyyət, cinayət məsuliyyəti, mülki məsuliyyət və müəyyən hallarda intizam məsuliyyəti daxildir. Vergi hüquqpozmalarının xarakterindən, ictimai təhlükəlilik dərəcəsi, zərərin həcmindən və təqsirin formasından asılı olaraq məsuliyyət növü dəyişə bilər.

Vergi hüquqpozmasının tərkibi

Vergi hüquqpozmasının mövcud olması üçün müəyyən hüquqi elementlərin birlikdə mövcudluğu tələb olunur. Bu elementlər obyekt, obyektiv tərəf, subyekt və subyektiv tərəfdən ibarətdir.

Vergi hüquqpozmasının obyekt vergi qanunvericiliyi ilə qorunan ictimai münasibətlərdir. Buraya dövlətin və bələdiyyələrin büdcə gəlirlərinin formalaşması, vergi öhdəliklərinin düzgün yerinə yetirilməsi və vergi intizamının qorunması daxildir. Vergidən yayınma və ya vergi hesabatlarında yanlış məlumatların verilməsi bu münasibətlərə zərər vurur.

Obyektiv tərəf hüquqpozmanın xarici ifadəsidir. Bu, hərəkət və ya hərəkətsizlik formasında ola bilər. Məsələn, vergi bəyannaməsinin vaxtında təqdim edilməməsi, gəlir və xərclər barədə yanlış məlumat verilməsi, vergi məbləğinin azaldılması, uçot sənədlərinin düzgün aparılmaması obyektiv tərəfin nümunələridir. Bəzi hallarda hüquqpozmanın baş verməsi üçün zərərli nəticə və bu nəticə ilə hərəkət arasında səbəbli əlaqə də tələb olunur.

Subyekt vergi hüquqpozmasını törədən şəxsdir. Bu, fiziki şəxs, hüquqi şəxs, vergi agent, vəzifəli şəxs və ya digər iştirakçı ola bilər [6]. Cinayət hüququ baxımından isə subyekt adətən müəyyən yaş həddinə çatmış və anlaqlı fiziki şəxsdir.

Subyektiv tərəf hüquqpozmanı törədən şəxsin öz hərəkətinə və nəticəyə psixi münasibətidir. Məhz burada təqsir anlayışı əsas rol oynayır. Təqsir olmadıqda şəxs hüquqi məsuliyyətə cəlb edilə bilməz. Bu prinsip vergi məsuliyyətinin ədalətli tətbiqi üçün xüsusi əhəmiyyət daşıyır.

Müzakirə

Vergi təqsirinin anlayışı və formaları

Vergi hüququnda təqsir şəxsin vergi qanunvericiliyini pozan hərəkətinə və ya hərəkətsizliyinə, habelə həmin davranışın nəticələrinə psixi münasibətidir. Təqsir hüquqi məsuliyyətin əsas şərtlərindən biridir. Şəxs yalnız o halda məsuliyyət daşımalıdır ki, onun qanunsuz davranışı şüurlu və iradi xarakter daşısin.

Təqsirin əsas formaları qəsd və ehtiyatsızlıqdır. Qəsd o zaman mövcud olur ki, şəxs öz hərəkətinin qanunsuz xarakterini dərk edir, onun mənfi nəticələrini qabaqcadan görür və bu

nəticələrin baş verməsini istəyir və ya onlara şüurlu surətdə yol verir. Vergi münasibətlərində qəsdə misal olaraq vergi bəyannaməsində bilərəkdən yanlış məlumatların göstərilməsi, gəlirlərin gizlədilməsi, saxta sənədlərdən istifadə edilməsi və vergi bazasının süni şəkildə azaldılması göstərilə bilər.

Ehtiyatsızlıq isə şəxsin lazımi diqqət və ehtiyatlılıq göstərməməsi nəticəsində vergi qanunvericiliyinin pozulmasıdır. Bu zaman şəxs pozuntunun baş verəcəyini qabaqcadan görməyə bilər, lakin görməli və görə biləcək vəziyyətdə olur. Məsələn, mühasibat sənədlərinin diqqətsiz aparılması, qanunvericilik dəyişikliklərinin izlənilməməsi və ya vergi hesabatlarının lazımi yoxlama aparılmadan təqdim edilməsi ehtiyatsızlıq formasında təqsir yarada bilər.

Vergi hüququnda qəsd və ehtiyatsızlığın fərqləndirilməsi mühüm praktiki əhəmiyyət daşıyır. Çünki vergi pozuntusunun qəsdən törədilməsi daha ağır hüquqi nəticələrə səbəb ola bilər. Xüsusilə vergidən yayınma cinayətlərində qəsd əsas subyektiv əlamət kimi çıxış edir. Cinayət məsuliyyəti üçün şəxsin vergi ödəməkdən yayınmaq niyyətinin sübut edilməsi vacibdir.

Təqsiri istisna edən hallar

Vergi qanunvericiliyində təqsiri istisna edən hallar xüsusi əhəmiyyətə malikdir. Bu hallar göstərir ki, vergi öhdəliyinin pozulması faktı mövcud olsa belə, şəxs bütün hallarda məsuliyyətə cəlb edilməməlidir [7]. Əgər pozuntu şəxsin iradəsindən asılı olmayan səbəblərdən baş veribsə və ya şəxsin qanuni davranış imkanı obyektiv olaraq mövcud olmayıbsa, məsuliyyətin tətbiqi ədalətli hesab edilə bilməz.

Təbii fəlakət və digər fəvqəladə, qarşısıalınmaz hallar təqsiri istisna edən əsas hallardan biridir. Zəlzələ, daşqın, yanğın, müharibə şəraiti və digər fors-major hallar vergi ödəyicisinin öz öhdəliyini vaxtında yerinə yetirməsinə mane ola bilər. Bu hallarda şəxsin davranışını qəsd və ya ehtiyatsızlıq kimi qiymətləndirmək mümkün deyil.

Fiziki şəxsin xəstəlik səbəbindən öz hərəkətlərini idarə edə bilməməsi də təqsiri istisna edən haldır. Hüquqi məsuliyyət üçün şəxsin şüurlu və iradi davranışı tələb olunduğundan, belə qabiliyyətin olmadığı vəziyyətdə təqsirdən danışmaq mümkün deyil.

Vergi ödəyicisinin və ya vergi agentinin səlahiyyətli dövlət orqanının yazılı izahına və ya göstərişinə əsasən hərəkət etməsi də təqsiri istisna edir [8]. Bu halda şəxs qanuna zidd davranmaq niyyətində olmur, əksinə, rəsmi izahə etibar edərək öz öhdəliyini düzgün yerinə yetirdiyini düşünür. Bu prinsip hüquqi müəyyənlik və legitim gözləntilərin qorunması baxımından vacibdir.

Vergi ödəyicisinin vergi yoxlaması başlanmazdan əvvəl öz səhvini könüllü şəkildə aradan qaldırması da məsuliyyətin tətbiqinə təsir edən mühüm haldır. Bu davranış vergi ödəyicisinin xoş niyyətini və qanuna uyğunlaşmaq istəyini göstərir. Lakin belə hallarda müəyyən faizlərin ödənilməsi zərurəti saxlanıla bilər, çünki dövlət büdcəsinə vəsaitin gec daxil olması maliyyə nəticələri yaradır.

Vergi məsuliyyəti və cinayət məsuliyyəti arasında fərq

Vergi qanunvericiliyinin pozulması hər zaman cinayət məsuliyyəti yaratmır. Cinayət məsuliyyəti yalnız ictimai təhlükəlilik dərəcəsi yüksək olan, qanunda cinayət kimi nəzərdə tutulan və təqsirli şəkildə törədilən əməllərə görə tətbiq olunur. Vergidən yayınma müəyyən məbləğ həddini keçdikdə və qəsdən törədildikdə cinayət məsuliyyəti yarada bilər.

Vergi məsuliyyəti ilə cinayət məsuliyyəti arasında əsas fərqlərdən biri tətbiq olunan sanksiyaların xarakteridir [9]. Vergi məsuliyyəti adətən maliyyə sanksiyaları, faizlər və cərimələrlə ifadə olunur. Cinayət məsuliyyəti isə cərimə, islah işləri, azadlıqdan məhrumetmə və digər cinayət-hüquqi cəza tədbirlərini nəzərdə tuta bilər.

Digər fərq sübutetmə səviyyəsi ilə bağlıdır. Cinayət məsuliyyəti üçün şəxsin təqsiri, xüsusilə qəsdə daha ciddi şəkildə sübut edilməlidir. Vergi hüquqpozmalarında isə inzibati və maliyyə məsuliyyəti üçün bəzən obyektiv göstəricilər əsas rol oynasa da, təqsirin mövcudluğu yenə də prinsipial əhəmiyyət daşıyır.

Burada mühüm problem maliyyə sanksiyaları ilə inzibati cərimələrin bəzən eyni və ya oxşar hüquqpozmalar üzrə tətbiq olunmasıdır. Bu vəziyyət hüquqi müəyyənlik və eyni əmələ görə ikiqat

məsuliyyətə yol verilməməsi prinsipi baxımından müzakirə doğurur. Vergi hüququnun daha sistemli inkişafı üçün maliyyə və inzibati məsuliyyət tədbirləri arasındakı sərhədlər daha dəqiq müəyyən edilməlidir.

Müddət məsələləri və hüquqi müəyyənlik

Vergi qanunvericiliyinin pozulmasına görə məsuliyyətin tətbiqində müddətlər mühüm rol oynayır [10]. Müddət institutunun məqsədi həm dövlət orqanlarını vaxtında hərəkət etməyə məcbur etmək, həm də vergi ödəyicilərinin qeyri-müəyyən müddət ərzində məsuliyyət təhlükəsi altında qalmasının qarşısını almaqdır.

Azərbaycan vergi qanunvericiliyində vergi hüquqpozmalarına görə məsuliyyətə cəlb etmə müddətləri müəyyən edilmişdir. Lakin bu müddətlərin başlanğıcı, pozuntunun aşkar edilməsi anı, davam edən hüquqpozmalar və müddətin dayandırılması kimi məsələlər bəzən praktiki çətinliklər yaradır. Xüsusilə vergi yoxlaması nəticəsində aşkar edilən pozuntularda müddətin hansı andan hesablanması məsələsi hüquqi mübahisələrə səbəb ola bilər.

Hüquqi müəyyənlik prinsipi tələb edir ki, vergi ödəyicisi öz davranışının hüquqi nəticələrini əvvəlcədən görə bilsin. Buna görə də məsuliyyət müddətləri, sanksiyaların tətbiq qaydaları və vergi orqanlarının səlahiyyətləri qanunvericilikdə aydın və dəqiq şəkildə göstərilməlidir.

Xarici ölkələrin təcrübəsi

Xarici ölkələrin təcrübəsi göstərir ki, vergi cinayətləri əksər hallarda qəsdən törədilən əməllər kimi qiymətləndirilir. ABŞ, Almaniya, Fransa, Yaponiya, İspaniya, Bolqarıstan və Çin kimi ölkələrdə vergi ödəməkdən yayınma, saxta bəyannamə təqdim etmə, gəlirləri gizlətmə və uçot sənədlərini saxtalaşdırma ciddi hüquqi nəticələr doğurur.

Bu ölkələrin qanunvericiliyində fərqli yanaşmalar mövcud olsa da, ümumi tendensiya ondan ibarətdir ki, qəsdən vergidən yayınma dövlətin maliyyə maraqlarına ciddi təhlükə kimi qəbul edilir. Bəzi ölkələrdə könüllü açıqlama və vergi borcunun ödənilməsi cinayət məsuliyyətindən azad edilməyə və ya cəzanın yüngülləşdirilməsinə səbəb ola bilər. Bu yanaşma vergi intizamının yalnız cəza vasitəsilə deyil, həm də könüllü uyğunlaşma mexanizmləri ilə təmin olunmasının mümkünlüyünü göstərir.

Azərbaycan üçün də bu təcrübə əhəmiyyətlidir [11]. Vergi ödəyicilərini cəzalandırmaqla yanaşı, onların könüllü şəkildə səhvlərini düzəltməsinə imkan verən mexanizmlərin inkişaf etdirilməsi vergi sistemə etimadı artırır.

Nəticə

Aparılan təhlil göstərir ki, vergi qanunvericiliyinin pozulmasına görə məsuliyyət vergi hüququnun əsas institutlarından biridir. Bu institut dövlətin fiskal maraqlarının qorunmasına, vergi intizamının təmin edilməsinə və büdcə gəlirlərinin sabitliyinə xidmət edir. Lakin məsuliyyətin tətbiqi yalnız formal pozuntu faktına əsaslanmamalı, qanunçuluq, ədalət, hüquqi müəyyənlik və təqsir prinsipləri ilə uzlaşdırılmalıdır.

Vergi hüququnda təqsir məsuliyyətin əsas şərtlərindən biri kimi çıxış edir. Şəxsin vergi qanunvericiliyini pozan davranışı yalnız o halda hüquqi məsuliyyət doğurmaldır ki, həmin davranış qəsd və ya ehtiyatsızlıq formasında təqsirli olsun [12]. Qəsd daha çox vergidən yayınma, gəlirlərin gizlədilməsi, yanlış məlumatların bilərəkdən təqdim edilməsi kimi hallarda özünü göstərir. Ehtiyatsızlıq isə lazımi diqqət və ehtiyatlılığın göstərilməməsi nəticəsində yaranan pozuntulara aiddir.

Təqsiri istisna edən hallar vergi məsuliyyətinin ədalətli tətbiqi üçün mühüm təminatdır. Fors-major hallar, şəxsin xəstəlik səbəbindən öz hərəkətlərini idarə edə bilməməsi, rəsmi yazılı izah və göstərişlərə əsasən hərəkət etməsi, habelə pozuntuların könüllü şəkildə aradan qaldırılması məsuliyyətin tətbiqində nəzərə alınmalıdır. Bu hallar göstərir ki, vergi hüququ yalnız cəza mexanizmi deyil, həm də hüquqi ədaləti təmin edən tənziqləmə vasitəsidir.

Məqalədə həmçinin müəyyən edildi ki, Azərbaycan vergi qanunvericiliyində maliyyə, inzibati və cinayət məsuliyyəti arasında bəzi sərhədlər daha dəqiq müəyyənləşdirilməlidir. Oxşar

hüquqpozmlar üzrə müxtəlif məsuliyyət mexanizmlərinin mövcudluğu hüquqi qeyri-müəyyənlik yarada bilər. Bu baxımdan qanunvericiliyin sistemləşdirilməsi və məsuliyyət tədbirlərinin daha aydın təsnif edilməsi zəruridir.

Nəticə olaraq qeyd etmək olar ki, vergi məsuliyyəti institutunun təkmilləşdirilməsi üçün təqsirin formaları qanunvericilikdə daha dəqiq ifadə olunmalı, vergi ödəyicilərinin hüquqi müdafiə mexanizmləri gücləndirilməli, könüllü uyğunlaşma alətləri genişləndirilməli və vergi nəzarəti sahibkarlıq fəaliyyətinə əsassız müdaxilə yaratmadan həyata keçirilməlidir. Bu yanaşma həm dövlətin maliyyə maraqlarını qoruyar, həm də vergi ödəyicilərinin hüquqlarının daha etibarlı müdafiəsini təmin edir.

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ЭФФЕКТИВНОСТЬ УГОЛОВНО-ПРАВОВОГО МЕХАНИЗМА ПРОТИВОДЕЙСТВИЯ НЕЗАКОННОМУ ОБОГАЩЕНИЮ: СРАВНИТЕЛЬНОЕ ИССЛЕДОВАНИЕ ЗАРУБЕЖНОГО ОПЫТА

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АННОТАЦИЯ

В статье анализируется эффективность уголовно-правового механизма противодействия незаконному обогащению через сравнительное исследование зарубежных моделей и международных стандартов. Отправной точкой выступает ст. 20 Конвенции ООН против коррупции (UNCAC), закрепляющая незаконное обогащение как факультативный состав («государства должны *рассмотреть* введение», с оговоркой о конституционных принципах).

Цель исследования выявить, какие конструкции нормы (элементы состава, круг субъектов, стандарты доказывания, санкции и режимы конфискации) повышают практическую результативность расследования и преследования коррупции при соблюдении гарантий справедливого процесса. В качестве методологической основы применяются сравнительно-правовой анализ и функциональное сопоставление моделей (англосаксонская и континентальная традиции), с опорой на руководства и обзоры, систематизирующие типологии «unexplained wealth/illicit enrichment».

Ключевые слова: Незаконное обогащение, уголовно-правовой механизм, антикоррупционная политика, сравнительно-правовой анализ, конфискации необоснованных активов.

THE EFFECTIVENESS OF THE CRIMINAL-LAW MECHANISM TO COUNTER ILLICIT ENRICHMENT: A COMPARATIVE STUDY OF INTERNATIONAL EXPERIENCE

ABSTRACT

This article analyzes the effectiveness of the criminal-law mechanism to combat illicit enrichment through a comparative study of international models and international standards. The starting point is Article 20 of the United Nations Convention against Corruption (UNCAC), which establishes illicit enrichment as an optional offence ("States should consider introducing it," with a reservation regarding constitutional principles).

The purpose of the study is to identify which legal frameworks (elements of the offence, scope of subjects, standards of proof, sanctions, and confiscation regimes) enhance the practical effectiveness of investigations and prosecutions of corruption while upholding fair trial guarantees. The methodological framework utilizes comparative legal analysis and a functional comparison of models (Anglo-Saxon and Continental traditions), drawing on guidelines and reviews that systematize typologies of "unexplained wealth/illicit enrichment."

Keywords: Illicit enrichment, criminal law mechanism, anti-corruption policy, comparative legal analysis, confiscation of unjustified assets.

ВВЕДЕНИЕ

Проблема незаконного обогащения занимает особое место в системе современных антикоррупционных мер и рассматривается как один из ключевых инструментов повышения прозрачности публичной власти. В условиях глобализации финансовых потоков и усложнения коррупционных схем традиционные составы взяточничества и злоупотребления должностными полномочиями не всегда позволяют эффективно преследовать случаи существенного необъяснимого прироста активов у публичных должностных лиц. В этой связи институт незаконного обогащения приобретает самостоятельное значение в уголовно-правовой политике государств.

Международно-правовую основу регулирования составляет United Nations Convention against Corruption, статья 20 которой предусматривает возможность криминализации незаконного обогащения как значительного увеличения активов публичного должностного лица, не соответствующего его законным доходам, при условии соблюдения конституционных принципов государства. Разъяснения и методические рекомендации по имплементации данного положения разрабатываются, в частности, United Nations Office on Drugs and Crime, что свидетельствует о высокой значимости данного института в международной антикоррупционной архитектуре (Marchuk, I. 2014).

Однако практика показывает, что эффективность уголовно-правового механизма противодействия незаконному обогащению существенно различается в зависимости от национальной модели правового регулирования. В одних странах акцент делается на уголовной ответственности и санкциях, в других — на механизмах конфискации необоснованных активов, финансовом контроле и декларировании имущества. Особую дискуссию вызывает вопрос соотношения данного состава с принципом презумпции невиновности, распределением бремени доказывания и стандартами справедливого судебного разбирательства.

Актуальность настоящего исследования обусловлена необходимостью комплексной оценки зарубежного опыта с целью выявления факторов, влияющих на результативность правоприменения. Сравнительный анализ позволяет определить оптимальные модели законодательного конструирования состава преступления, процессуальные гарантии и инструменты финансового расследования, способствующие реальному снижению уровня коррупции (Basel Institute on Governance. 2022).

Целью работы является исследование эффективности уголовно-правового механизма противодействия незаконному обогащению на основе сравнительного анализа зарубежных правовых систем, выявление их преимуществ и ограничений, а также формулирование выводов о направлениях совершенствования национального законодательства.

Обзор литературы

Проблематика незаконного обогащения в последние десятилетия стала предметом активного научного и практического обсуждения в рамках антикоррупционных исследований. Существенный вклад в формирование международных стандартов внесла United Nations Convention against Corruption, закрепившая в статье 20 концепцию криминализации незаконного обогащения как значительного увеличения активов публичного должностного лица, не соответствующего его законным доходам. Данный подход вызвал широкую дискуссию в научной литературе относительно его соответствия

принципам уголовного права, прежде всего презумпции невиновности и запрету самооговора.

Аналитические материалы United Nations Office on Drugs and Crime рассматривают незаконное обогащение как дополнительный инструмент противодействия коррупции, который должен применяться в сочетании с финансовым контролем, механизмами декларирования доходов и эффективной системой конфискации активов. В этих публикациях подчеркивается, что эффективность нормы во многом зависит от четкости законодательной формулировки и процессуальных гарантий.

В европейской доктрине значительное внимание уделяется соотношению незаконного обогащения с традиционными составами коррупционных преступлений. Исследователи анализируют его как «субсидиарный» механизм, позволяющий преодолеть трудности доказывания конкретного акта получения взятки. При этом подчеркивается необходимость соблюдения баланса между публичными интересами борьбы с коррупцией и защитой прав человека, гарантированных, в частности, практикой European Court of Human Rights.

В странах Латинской Америки незаконное обогащение рассматривается как устоявшийся уголовно-правовой институт. Ряд авторов отмечает, что включение данного состава в уголовные кодексы способствовало повышению уровня ответственности публичных служащих и усилению превентивного эффекта. Вместе с тем исследователи указывают на риски формального применения нормы без достаточного обоснования финансовых расчетов и анализа законных источников дохода.

В англосаксонской правовой традиции акцент смещен в сторону инструментов гражданско-правовой конфискации и процедур, связанных с необъяснимым богатством (unexplained wealth orders). Научные публикации анализируют их как альтернативу прямой криминализации, позволяющую обходить сложные вопросы уголовного доказывания. В этой связи в литературе активно обсуждается практика применения подобных механизмов в правовой системе United Kingdom, где конфискационные процедуры используются параллельно с уголовным преследованием.

Таким образом, анализ научных источников показывает отсутствие универсальной модели уголовно-правового регулирования незаконного обогащения. Литература подчеркивает, что эффективность механизма зависит от комплексности подхода: сочетания уголовной ответственности, финансового мониторинга, прозрачности публичной службы и развитых процедур возврата активов. В научном дискурсе сохраняется полемика относительно оптимального распределения бремени доказывания, критериев «существенности» прироста активов и пределов вмешательства государства в имущественную сферу личности (Rose, C., Kubiciel, M., & Landwehr, O. 2015).

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

Проведённый сравнительно-правовой анализ зарубежных моделей криминализации незаконного обогащения позволил выявить как общие закономерности, так и существенные различия в механизмах их реализации. В центре внимания находились: конструкция состава преступления, распределение бремени доказывания, субъектный состав, санкции, а также связь уголовной ответственности с институтами конфискации активов.

1. Нормативные модели криминализации

Базовой международной отправной точкой является United Nations Convention against Corruption, статья 20 которой формулирует незаконное обогащение как значительное увеличение активов публичного должностного лица, не соответствующее его законным доходам. Однако имплементация данной нормы в национальные законодательства носит вариативный характер.

В странах Латинской Америки (например, Argentina, Colombia) незаконное обогащение закреплено как самостоятельный состав преступления с чётко определённым субъектом — публичным должностным лицом. В ряде европейских государств применяется более осторожный подход с усилением механизмов финансового контроля и конфискации.

В правовой системе United Kingdom акцент сделан на институте unexplained wealth orders (UWO), который действует в рамках гражданско-правовой процедуры и позволяет требовать объяснения происхождения активов без прямой уголовной квалификации.

2. Сравнительная характеристика моделей

Критерий	Латиноамериканская модель	Континентально-европейская модель	Англосаксонская модель
Правовая природа	Уголовный состав	Уголовный + финансовый контроль	Гражданско-правовой инструмент
Субъект	Публичное должностное лицо	Публичное лицо	Лицо с существенными активами
Бремя объяснения	Частично переносится на обвиняемого	Сохраняется баланс	Требование объяснения активов
Основной инструмент	Уголовное наказание	Уголовное преследование + конфискация	Конфискация активов

Источник: United Nations. (2003). *United Nations Convention against Corruption*.

Представленная таблица демонстрирует различие правовых подходов к противодействию незаконному обогащению. В латиноамериканской модели доминирует уголовно-правовой механизм с возможностью лишения свободы и обязательной конфискацией активов. Европейская модель ориентирована на баланс между уголовной ответственностью и финансовым контролем с сохранением процессуальных гарантий. В англосаксонской системе ключевую роль играет гражданско-правовой инструмент, позволяющий изымать необъяснимые активы без обязательного вынесения уголовного приговора.

Таким образом, сравнительный анализ подтверждает, что наибольшая эффективность достигается при комплексном сочетании уголовного преследования и механизмов финансовой конфискации при соблюдении принципа презумпции невиновности.

Заключение

Проведённое сравнительное исследование показало, что эффективность уголовно-правового механизма противодействия незаконному обогащению напрямую зависит от качества законодательной конструкции нормы и уровня её институционального обеспечения. Само по себе закрепление данного состава в уголовном законодательстве не гарантирует снижения уровня коррупции, если отсутствуют развитые механизмы финансового контроля, прозрачности публичной службы и реальной конфискации незаконно приобретённых активов.

Международной правовой основой криминализации незаконного обогащения выступает United Nations Convention against Corruption, закрепляющая возможность введения соответствующей нормы с учётом конституционных принципов государств. Практика имплементации демонстрирует различные модели: от классической уголовной

ответственности (Аргентина, Колумбия) до комбинированных и гражданско-правовых инструментов (Великобритания).

Сравнительный анализ позволил выделить ключевые факторы эффективности механизма:

- чёткое определение признаков «существенного» прироста активов;
- сохранение баланса между публичным интересом и презумпцией невиновности;
- развитая система декларирования доходов и контроля расходов;
- использование финансово-аналитических инструментов и цифровых технологий;
- активное применение института конфискации активов.

Особое значение имеет соблюдение процессуальных гарантий, поскольку чрезмерное смещение бремени доказывания способно вызвать противоречие с принципами справедливого судебного разбирательства. Эффективная модель предполагает, что обвинение доказывает факт несоответствия активов законным доходам, а обязанность лица представить разумное объяснение не подменяет презумпцию невиновности.

Таким образом, наибольшую результативность демонстрируют комплексные системы, где уголовная ответственность интегрирована с финансовым мониторингом, международным сотрудничеством и механизмами возврата активов. Перспективным направлением совершенствования законодательства является развитие баланса между уголовным преследованием и инструментами гражданско-правовой конфискации при строгом соблюдении прав человека и принципов уголовного права.

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Sociological Sciences

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ОСОБЕННОСТЕЙ САМООТНОШЕНИЯ У СТУДЕНТОВ, ЗАНИМАЮЩИХСЯ И НЕ ЗАНИМАЮЩИХСЯ СПОРТИВНЫМИ БАЛЬНЫМИ ТАНЦАМИ

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Аннотация:

В статье представлено экспериментальное исследование, посвященное особенностям самооотношения у студентов, занимающихся и не занимающихся спортивными бальными танцами. Целью исследования является выявление различий в проявлениях самооотношения между спортсменами и не спортсменами, а также анализ влияния спортивной деятельности на развитие и формирование самооотношения как компонента самосознания. В рамках данного исследования проведена диагностика самооотношения у двух групп респондентов: студентов, занимающихся спортивными бальными танцами, и студентов, не вовлеченных в спортивную деятельность. Полученные результаты показали статистически значимые различия в восприятии собственной личности, уровне самооценки и самооотношения между участниками, что подтверждает гипотезу о значимом влиянии спортивной активности на формирование этих психологических характеристик.

Ключевые слова: самооотношение, спортивные бальные танцы, самооценка, самосознание, идентичность, психологическое развитие, психология спорта, личностное развитие.

Введение

Занятия спортивными бальными танцами представляют собой не только форму физической активности, но и эффективный метод эмоциональной разрядки, развития координации и музыкального слуха. Помимо этого, танцы служат отличной школой жизни, где молодежь учится взаимодействовать в паре, развивает уверенность в своих действиях и преодолевает различные виды давления, связанные с участием в спортивных

соревнованиях. Эти аспекты делают спортивные бальные танцы важным элементом личностного роста и самовыражения.

Тем не менее, влияние спортивных бальных танцев на формирование самоотношения у молодежи остается малоизученной темой в современной психологии. Самоотношение, как компонент самосознания, тесно связано с восприятием себя в социальной среде, а также с психологическими аспектами, возникающими в процессе активной физической деятельности. С учетом того, что спортивные бальные танцы являются видом танцевального спорта, они предполагают не только физические усилия, но и значительные эмоциональные и интеллектуальные нагрузки. Это делает спортивные бальные танцы потенциально важным фактором в развитии самоотношения, поскольку, подобно другим видам спорта, занятия танцами предполагают активное участие личности в процессах самореализации, конкуренции и преодоления личных границ [1].

Актуальность исследования заключается в необходимости изучения влияния занятий спортивными бальными танцами на особенности самоотношения среди молодежи, а также в анализе различий между теми, кто занимается танцами, и теми, кто не вовлечен в этот вид активности. Спортивные бальные танцы в контексте формирования самоотношения представляют собой уникальный феномен, поскольку предполагают сочетание физической активности с эмоциональным и социальным взаимодействием, что может существенно повлиять на восприятие индивидом себя и окружающих [2].

Целью данного исследования является изучение особенностей самоотношения у студентов, занимающихся и не занимающихся спортивными бальными танцами. Объектом исследования являются молодые люди в возрасте от 17 до 21 года, а предметом – самоотношение как важный компонент их самосознания. В рамках работы ставятся следующие задачи: уточнить понятие самоотношения в современной литературе, исследовать особенности взаимодействия занятий спортом с личностью, а также выявить различия в проявлениях самоотношения у спортсменов и неспортсменов.

Гипотеза исследования предполагает, что между молодыми людьми, занимающимися спортивными бальными танцами, и теми, кто не занимается этим видом спорта, существуют качественные различия в проявлениях самоотношения, что может отразиться на уровне уверенности в себе, самооценке и социальной адаптации.

Методы исследования

В рамках данного исследования для диагностики и анализа уровня самооценки и самоотношения личности использовались несколько психодиагностических методов, которые позволяют глубоко исследовать различные аспекты самосознания и самовосприятия личности [3]. Все выбранные методики являются проверенными и широко используемыми в психологии, что гарантирует их достоверность и валидность для проведения качественного анализа [4] [5].

1. Тест самооценки Будасси С.А.

Первым методом исследования была использована методика теста самооценки, разработанная С.А. Будасси, которая позволяет количественно измерить самооценку личности. Данный тест построен на основе классификационного подхода, что предполагает оценку качеств личности через выбор и ранжирование 20 характеристик, которые наиболее точно отражают представления человека об идеальной личности. Испытуемые должны были выбрать 20 наиболее значимых для себя личностных характеристик из списка 48 слов, каждое из которых обозначает те или иные черты личности. Важно отметить, что некоторые из выбранных характеристик могут быть как положительными, так и негативными, что позволяет исследовать не только позитивные, но и негативные аспекты самооценки.

Далее испытуемые должны были расположить эти качества в порядке значимости, где первое место занимают наиболее важные качества, а последнее — наименее значимые. Это позволяет проанализировать, как человек расставляет приоритеты и какие характеристики личности для него наиболее важны в контексте идеала. Также важно, что методика предполагает исключение повторений — каждый из выбранных пунктов имеет уникальное место в шкале.

Ключевым аспектом данного теста является исследование соотношения «реального» и «идеального» образа «Я». Это позволяет оценить уровень адекватности самооценки, а также выявить возможные дисбалансы между представлением о себе в реальности и идеализированном образе. Адекватная самооценка предполагает, что человек способен правильно оценить свои реальные достижения и способности, в то время как чрезмерно высокая или заниженная самооценка может свидетельствовать о несоответствии между реальностью и самооощущением [6] [7].

2. Тест-опросник на общую самооценку Г.Н. Казанцевой

Вторым методом, использованным в исследовании, является тест-опросник на общую самооценку, разработанный Г.Н. Казанцевой. Этот опросник специально предназначен для подростков, но может использоваться и для взрослых в контексте диагностики самооценки. Методика позволяет оценить общий уровень самооценки испытуемого, а также выявить закономерности и особенности самооценки в различных контекстах.

Опросник включает в себя ряд утверждений, на основе которых испытуемые должны оценить, насколько эти утверждения соответствуют их восприятию себя. Важно, что методика учитывает динамичный процесс формирования самооценки, который, согласно Казанцевой, может изменяться под влиянием внешних факторов и условий, таких как успешность деятельности, социальное окружение и межличностные отношения.

Кроме того, Казанцева рекомендует при неудовлетворительных результатах самооценки подключить психолога, который поможет глубже разобраться в личностных особенностях индивида и предложит пути для корректировки самооощущения. Этот аспект метода важен, так как высокий или низкий уровень самооценки может существенно влиять на личностное развитие и успешность в различных сферах жизни. Например, высоко оценившие себя люди могут переоценивать свои возможности, ставя перед собой невыполнимые цели, в то время как люди с низкой самооценкой могут занижать свои достижения и возможности, что также влияет на их мотивацию и результативность [8].

3. Методика исследования самоотношения (МИС) Столина В.В. и Пантилеева С.Р.

Третьим инструментом, использованным в исследовании, является методика исследования самоотношения (МИС), разработанная В.В. Столиным и С.Р. Пантилеевым. Эта методика является одной из самых современных и позволяет исследовать глубинные аспекты отношения индивида к себе, выявляя различные уровни самоотношения. МИС основана на иерархической модели структуры самоотчета и включает несколько шкал, которые оценивают различные компоненты самоотношения, такие как уверенность в себе, самооценка, аутосимпатия, отношение к себе и ожидания отношения со стороны окружающих.

Анкета включает в себя ряд шкал, каждая из которых оценивает конкретный аспект восприятия себя. Например, шкала «самооценка» измеряет уверенность человека в своих силах и способностях, способность объективно оценивать свои достижения, а шкала «аутосимпатия» отражает отношение человека к самому себе, включая как положительные, так и отрицательные эмоции. Важно, что методика также включает шкалы, которые помогают выявить более специфичные характеристики самоотношения, такие как самопринятие, самоуправление, самообвинение и самопонимание.

Глобальное самоотношение оценивается через шкалу, которая измеряет общий уровень гармонии или дисгармонии между внутренними представлениями человека о себе и его реальным опытом. Эти шкалы дают более глубокое представление о том, как человек воспринимает себя в различных жизненных контекстах и какие психологические барьеры могут мешать его развитию.

Важной особенностью методики является то, что она позволяет оценить как позитивные, так и негативные аспекты самоотношения, что важно для полноценного анализа самооценки. Например, низкая самооценка может быть связана с низким самопринятием и склонностью к самообвинению, в то время как высокая самооценка может быть сопряжена с завышенными ожиданиями и нереалистичными требованиями к себе и окружающим [9].

Основные положения

Особенности самоотношения студентов, занимающихся и не занимающихся спортивными балльными танцами, являются важным аспектом их личностного развития. Спортивные балльные танцы способствуют формированию позитивного самоотношения, повышению самооценки и улучшению восприятия собственной личности. Эти изменения связаны с физической активностью, творческой самореализацией и социальным взаимодействием, которые интегрированы в процесс тренировок и выступлений.

Исследование выявило статистически значимые различия между танцорами и студентами, не занимающимися спортом. У танцоров наблюдается более высокий уровень самооценки, позитивное восприятие себя и целостное самовосприятие. Эти результаты подтверждают, что спортивная деятельность оказывает значительное влияние на развитие самоотношения, подчеркивая важность интеграции спорта в образовательный процесс.

Литературный обзор

Исследование особенностей самоотношения у студентов, занимающихся и не занимающихся спортивными балльными танцами, основывается на трудах ведущих ученых в области психологии личности и спорта. Среди основополагающих работ можно выделить исследования Сарджвеладзе Н.И., который впервые ввел понятие самоотношения как компонента самосознания, а также работы Столина В.В. и Пантилеева С.Р., посвященные анализу структуры и функций самоотношения. Эти авторы подчеркивают роль самооценки, самопринятия и аутосимпатии как ключевых факторов формирования самоотношения [11].

Зарубежные исследования, такие как работы Роджерса К. и Бернса Р., посвящены изучению влияния социальной среды и межличностных взаимодействий на самоотношение личности. Они подчеркивают, что регулярное участие в социальных активностях, таких как спортивные соревнования и танцевальные выступления, положительно влияет на восприятие своего «Я» и повышение уровня самооценки [12] [13].

Использование теоретических подходов перечисленных авторов в сочетании с экспериментальными данными обеспечивает глубокое понимание механизмов формирования самоотношения и выявления различий между студентами, вовлеченными в спортивную деятельность, и их не вовлеченными сверстниками.

Результаты и обсуждение

Настоящее исследование посвящено изучению влияния занятий спортом на уровень самооценки молодежи. Для анализа были использованы методики самооценки Будасси С.А. и Казанцевой Г.А. В рамках исследования были сопоставлены показатели самооценки спортсменов и не спортсменов. Результаты представлены в виде таблиц и графиков с детальным описанием.

Результаты теста самооценки Будасси С.А.

Таблица №1

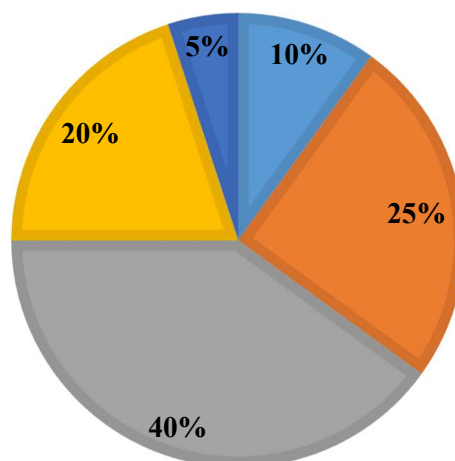
Категория	Спортсмены (%)	Не спортсмены (%)
Высокая неадекватная	10	20
Высокая адекватная	25	10
Средняя адекватная	40	10
Низкая адекватная	20	30
Низкая неадекватная	5	30

Таблица 1. Уровни выраженности самооценки по тесту Будасси С.А.

Таблица демонстрирует распределение уровней самооценки среди спортсменов и не спортсменов. Наибольший процент спортсменов имеет среднюю адекватную самооценку (40%), в то время как среди не спортсменов преобладают низкая адекватная и низкая неадекватная самооценка (по 30% в каждой категории).

ПРОЯВЛЕНИЕ САМООЦЕНКИ СПОРТСМЕНА

■ высокая неадекватная ■ высокая адекватная ■ средняя адекватная
■ низкая адекватная ■ низкая неадекватная



ПРОЯВЛЕНИЯ САМООЦЕНКИ У НЕ СПОРТСМЕНОВ

■ высокая неадекватная ■ высокая адекватная ■ средняя адекватная
■ низкая адекватная ■ низкая неадекватная

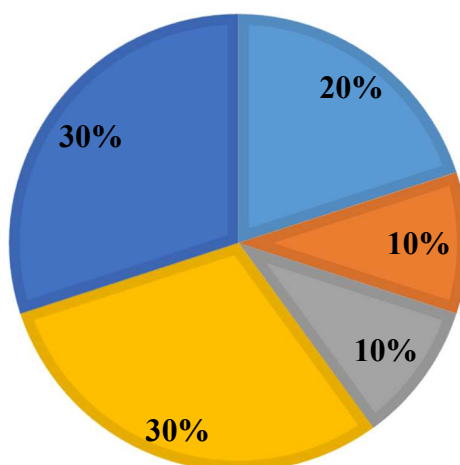


Рисунок 1. Круговые диаграммы распределения уровней самооценки по тесту Будасси С.А. среди спортсменов и не спортсменов.

Результаты теста Будасси С.А. демонстрируют яркие различия в уровнях самооценки между спортсменами и не спортсменами. Наибольший процент спортсменов имеет среднюю адекватную самооценку (40%). Этот уровень указывает на то, что данные респонденты достаточно критично воспринимают свои достоинства и недостатки, что позволяет им устанавливать достижимые цели. 25% спортсменов обладают высокой адекватной самооценкой, что говорит о сильной уверенности в своих способностях,

подкрепленной их успехами в спортивной деятельности. Напротив, только 10% не спортсменов имеют такую самооценку.

Среди не спортсменов преобладают низкая адекватная и низкая неадекватная самооценки, каждая из которых составляет 30%. Это свидетельствует о большей склонности данной группы к недооценке своих возможностей и восприятию своих неудач как значительных. Низкая неадекватная самооценка в особенности связана с недостаточной уверенностью в себе, что может быть результатом недостатка социальной поддержки или навыков саморегуляции. Эти данные подтверждают гипотезу о позитивном влиянии спортивной деятельности на самооценку.

Результаты теста общей самооценки Казанцевой Г.А.

Таблица №2

Категория	Спортсмены (%)	Не спортсмены (%)
Низкая самооценка	5	70
Средняя самооценка	55	10
Высокая самооценка	40	20

Таблица 2. Уровни общей самооценки по тесту Казанцевой Г.А.

В таблице показано, что 55% спортсменов характеризуются средней самооценкой, тогда как среди не спортсменов доминирует низкая самооценка (70%). Это подтверждает значительное влияние спорта на формирование сбалансированной самооценки.

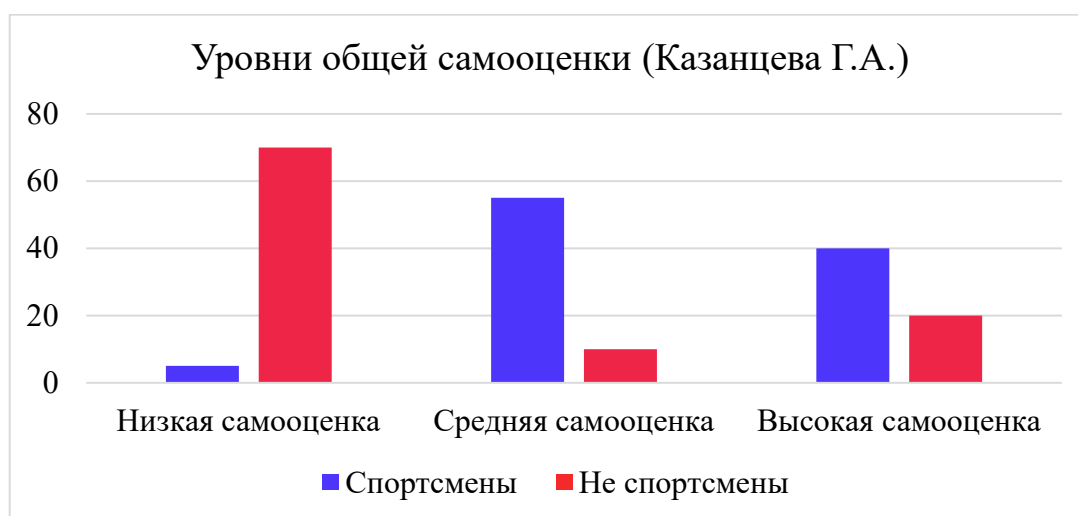


Диаграмма 2. Столбчатая диаграмма распределения уровней общей самооценки по тесту Казанцевой Г.А. среди спортсменов и не спортсменов.

Распределение общей самооценки по тесту Казанцевой Г.А. также подчеркивает различия между двумя группами. Среди спортсменов 55% имеют среднюю самооценку, которая отражает сбалансированное восприятие своих достоинств и недостатков. Высокую самооценку продемонстрировали 40% спортсменов, что в контексте их спортивной деятельности может свидетельствовать о высоком уровне мотивации и уверенности в достижении поставленных целей. Лишь 5% спортсменов характеризуются низкой самооценкой, что говорит о минимальном распространении пессимистичных установок в этой группе.

Напротив, у не спортсменов преобладающей является низкая самооценка (70%), что может быть результатом недостаточного участия в значимых для личности активностях или отсутствия положительного подкрепления. Высокая самооценка наблюдается лишь у 20% не

спортсменов, что подтверждает гипотезу о необходимости социальных и спортивных стимулов для формирования уверенности в себе.

Результаты методики исследования самоотношения (МИС) Столина В.В., Пантеева С.Р

В соответствии с результатами методики исследования самоотношения (МИС) Столина В.В., Пантеева С.Р., проведенного среди испытуемых, было выявлено несколько ключевых тенденций в самооценке и самоотношении различных групп респондентов.

Используя методику, участники исследования были проанализированы по четырем основным шкалам: I – самооценка, II – аутосимпатия, III – отношение, ожидаемое другими, и IV – самостоятельный интерес. Результаты, полученные на основе ответов респондентов, позволили выделить различия между молодыми людьми, занимающимися спортом, и молодыми людьми, не занимающимися спортом.

1. Шкала I - Самооценка:

Спортсмены показали высокие уровни самооценки, где 55-70 баллов были общими для 45-55% респондентов. Это свидетельствует о завышенной самооценке. 40% респондентов имели средние значения (45-55 баллов), что указывает на адекватное восприятие себя. Молодежь, не занимающаяся спортом, демонстрировала низкие уровни самооценки (40-45 баллов), что указывает на заниженную самооценку среди большинства (70%). Лишь 10% респондентов показали высокие значения самооценки, что указывает на значительное влияние социальной желательности в ответах.

2. Шкала II - Аутосимпатия:

Среди молодых людей, занимающихся спортом, 30% демонстрировали высокие значения аутосимпатии, что указывает на высокую степень самопринятия и позитивного отношения к себе. Средние значения аутосимпатии были у 60% испытуемых, что свидетельствует о признании своих качеств и способности ценить собственные достижения. Лишь 10% респондентов показали низкие значения, что говорит о наличии сомнений в собственной уникальности и недостаточной признанности своего "я".

3. Шкала III - Ожидаемое отношение от других:

10% респондентов, занимающихся спортом, показали высокие значения на этой шкале, что связано с отрицательным отношением к себе и ожиданием осуждения со стороны окружающих. Основная часть (90%) респондентов продемонстрировала положительный фон отношения к себе. Низкие значения по этой шкале не были выявлены.

4. Шкала IV - Самостоятельный интерес:

40% молодых спортсменов продемонстрировали высокие значения самостоятельного интереса, что говорит о их способности координировать свои действия и предсказывать последствия взаимодействия с другими. Средние значения были выявлены у 50% респондентов, что указывает на личный контроль в привычных условиях. 10% респондентов имели низкие показатели, демонстрируя слабую способность к саморегуляции и подверженность внешним обстоятельствам.

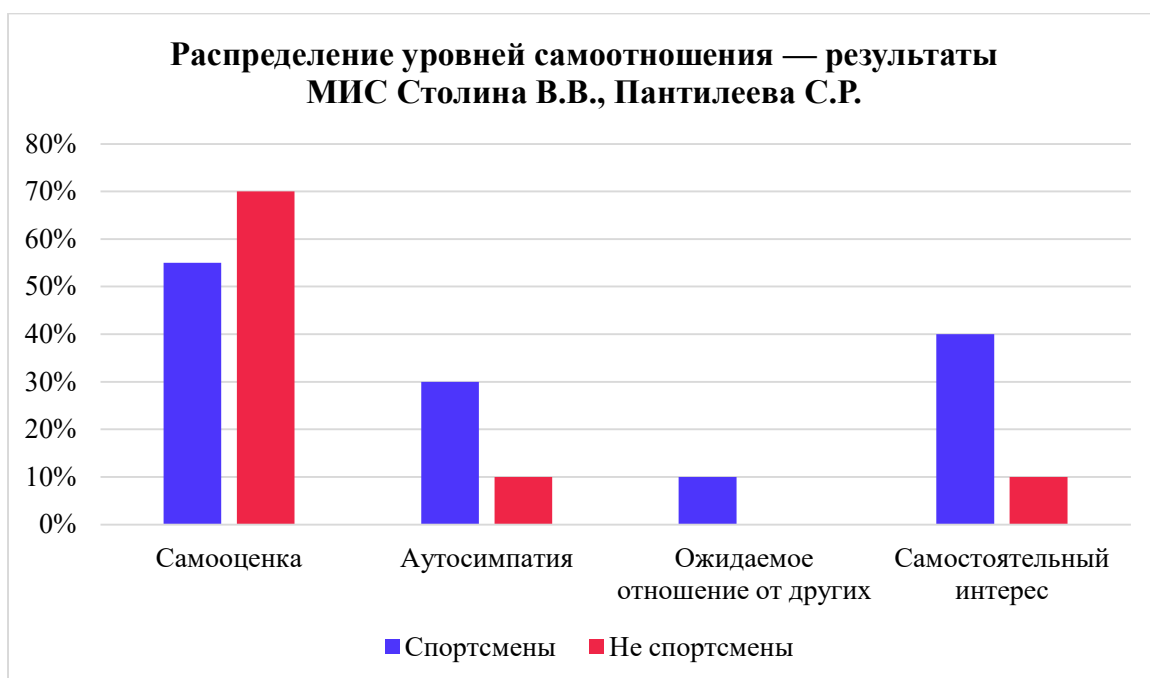


Диаграмма 3. Распределение уровней самооотношения у спортсменов и не спортсменов: различия в самооценке, аутосимпатии, ожидаемом отношении от других и самостоятельном интересе (по МИС Столина В.В., Пантилеева С.Р.)

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Historical Sciences

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Açar sözlər: *Adsorbent, bentonit, naftalan nefti, tullantı, xüsusi səth.*

Keywords: *Adsorbent, bentonite, naphthalene oil, waste, special surface.*

Biosferin əsasını təşkil edən sudur və qeyd etmək lazımdır ki, bütün hövzalar və su mənbələri onların ahata edən mühitlə sıx əlaqədədir.

Yer kürəsində baş verən sayısız hesabsız antropogen hadisələr, litosferdə və atmosferdə zərərli maddələr axır məqamda hidsorfera çatdırılır. Nəhəng hələdici və uducu sayı ilə n su əla bir universal amildir ki, onsuz təbiətdə heç bir proses əməl olunmur. Görünür, müdrik təbiət biosferdə əbəz yerə suyu bol yaratmamışdır. Canlı varlığın ilk beşiyidə su olmuşdur. Ona görə yer kürəsinin 71%-ni bərabər olan su, canlı hüceyrəsində əsas kütləsini çevrilmişdir. Bununla belə həm bol, həm də az olan su, təbii nemətlərin əsasını təşkil etməkə yer kürəsində fauna-floranın formalaşmasında başlıca amil sayılır.

Yuxarıda qeyd etdiklərimizi nəzərə almaqla Gəncə şəhərinin su təhçizatına yenidən baxmaq və müasir ekoloji baxımdan yanaşmaqla araşdırmalar aparmağa başladıq.

Azərbaycanda 8300-dən artıq irili-xırdalı çay var. Araşdırmasına görə, çay şəbəkəsinin hər kvadrat km-də şirin su ehtiyatı 0,36 km təşkil edir ki, bu da Canubi Qafqazın digər ölkələri ilə müqayisədə 2 dəfə azdır. Respublikamızda cəmi 29,7 milyard kubmetr şirin su ehtiyatı (var ki, hazırda onunda müəyyən hissəsindən istifadə olunur. Azərbaycanın ümumi su balansının həcmi 34-35 kub kilometrə bərabərdir. Bununla 72 faizi (orta hesabla 27-28 kub kilometri) qonşu dövlətlərin ərazisində formalaşır.

Bunun üçün Gəncə şəhərinə hansı mənbələrdən içməli su ilə təhçiz olunduğunun müəyyənəşdirdik. Gəncə şəhəri bir necə mənbədən su ilə təmin olunur. Azərbaycan hökuməti Almaniya inkişaf Bankı və İsveçranın SECO təşkilatı ilə birgə maliyyələşdirdiyi " Acıq kommunal infrastruktur Proqramı" Gəncə və Şaki şəhərlərinin su təhçizatı və kanalizasiya sisteminin yenidən qurulması nəzərdə tutur.

Layihəyə uyğun olaraq Göy-göl mənbəyində məhsuldarlığı saniyədə 200 litr olan drenaj sistemi barpa edilmiş, həcmi 4000 m olan bir adad su anbarı inşa edilmiş və mənbədən şəhərə qədər 24,5 km uzunluğunda magistral kəmərlər çəkilib.

Qızıl Qaya mənbəyində də barpa işləri həyata keçirilmiş, bir adad 2000 m su anbarı tikilmiş 9,5km anbarlar arası su xətləri çəkilmişdir. Ümumi həcmi 10 min m olan iki adad yeni su anbarının tikintisi isə yekunlaşmışdır.

Gəncə şəhərinin icmalı su tələbatını 60% Şəmkir çay su anbarından təmin ediləcək. Anbardan götürüləcək su 27,5 km uzunluğunda magistral yollarla Qızılqaya ərazisində inşa ediləcək və sutkalıq məhsuldarlığı 17 min m olan su təmizləyici qurğuya ötürüləcək. Layihəyə əsasən 576 km uzunluğunda paylayıcı su şəbəkəsi yaradılacaq.

Şəhərdə tikintisi nəzərdə tutulan 582 km uzunluğunda kanalizasiya xəttinin 43 km-lik işləri başa çatdırılmışdı. 2021 bəxış quyusu tikilib. Tullantı suların təmizləyici qurğuya özəxımlı rejimə ötürülməsi üçün 45 km uzunluğunda kanalizasiya kollektorunun tikintisi nəzərdə tutulur. Gələcəkdə

Gəncə şəhərində yaranacaq tullantı suları yeni tikilə cək çirkab su təmizləyici qurğuda təmizlənəcək.

Aldığımız rəsmi məlumatla müəyyən etdik ki, Gəncə şəhərində bir ildə 22 mın m su ilə təhçiz olunur .

Respublikamızda bir nəfərin bir sutkada su sərfı norma olaraq 240 litr götürülmüşdür. Hesablamalardan belə nəticəyə gəlinmişdir ki, Gəncə şəhərində kommunal su təchizatı sistemlərindən adam başına verilən suyun həcmı bir sutkada 200 litr təşkil edir.

Aparığımız araşdırmalardan belə nəticəyə gəlmək olar ki, Gəncə şəhərində vahid su təchizatı sistemi yaratmaq və şəhəri şirin içməli su ilə təmin etmək iqtisadi cəhətdən böyük şamara verə bilər. Vəhid su təchizatı sisteminin olması su itkisinin qarşısının alınmasına və böyük xərclər hesabına yaradılacaq bu sistemdə sudan səmərəli istifadə etməyə imkan verəcəkdir.

Qərb regionunda mövcud olan su mənbələrinin fiziki-kimyəvi parametrləri araşdırılmışdır. (Cədvəl 1) .

Suyun fiziki-kimyəvi parametrləri

No	Su mənbələri Parametrlər	Ağ-su	Qızıl-Qaya	Şəmkir çay	Subartezian
	İyi 20 °c	0	0	0	0
	İyi 60 °c	0	0	0	0
	Dadı 20 °c	0	0	0	0
	Rəngi	0	0	0	0
	Bulamqlığı	-	-	-	-
	pH	7.0	7.0	7.0	7.0
	Ammonyak	-	-	-	-
	Nitratlar	-	-	-	-
	Nitritlər	-	-	-	-
	Dəmir	-	-	-	-
	Oksidləşmə	1,28	1,36	2,80	1,60
	Xloridlər, mq/dm ³	14,4	24,0	19,2	54,0
	Qolovilik, mq.ekv/dm ³	2,7	3,4	3,3	3,6
	Hidrokarbonatlar, mq/dm ³	164,7	207,4	201,3	219,0
	Sulfatlar, mq/dm ³	72,0	184,0	312,1	280,0
	Kalsium, mq/dm ³	40,0	80,0	46,0	170,0
	Maqnezium, mq/dm ³	12,2	26,8	30,5	40,26
	Codluq, mq/dm ³	3,0	6,2	4,8	
	K ⁺ , Na ⁺ mq/dm ³	36,8	37,12	35,8	30,82
	Quru qalıq, mq/dm ³	220,0	410,0	300,0	800,0

2015-ci ildə şəhərin su hövzələrindən 20,87 milyon kubmetr su götürülmüşdür. Suyun faktiki istehlakı 20,82 milyon kubmetr olmuşdur. Onun 8,0 faizi suvə rma, 1,5 faizi istehsalatda və 89,8 faizi məişət- içməli məqsədlər üçün istifadə edilmişdir. Su obyektlərinə axıdılən təmizlənməmiş çirkab suların həcmi 8,5 milyon kubmetr olmuşdur. 2014-cü ildə müqayisədə təbii mənbələrdən götürülən su və istifadə olunan su faiz azalmış, o cümlədən məişət-içməli məqsədlərə istifadə olunan su 11,8 faiz çox, istehsalata sarf olunan su 3,9 dəfə az, suvə rmayə sarf olunan su 13,0 faiz, su obyektlərinə axıdılən təmizlənməmiş çirkab suların həcmi isə 0,4 faiz azalmışdır.

Araşdırmalara görə bizim yerüstü su ehtiyatımız orta illik 32,3 mird kubmetrdir. Quraqlıq illərdə isə bu göstərici 23 mird m-ə qədər azalır. Ölkədə adam başına orta illik 3800 m su düşür. Yeraltı içməli su mənbələrində isə 23764,28 mın m gün su ehtiyatı vardır.

Yer üstü su ehtiyatlarının əsas hissəsi və mənbəyi Kür çayı və onların qollarıdır. Azərbaycanın su ehtiyatların 58%-i yəni 6 min m səthi su ehtiyatlarına aiddir.

Kür çayı: Cənubi Qafqazda ən uzun çay olan Kür öz mənbəyini qardaş Türkiyənin dəniz səviyyəsindən 2270 m hündürlükdə olan Qızıl-Qadak yaylasından götürərək 1515 km masafə qat edərək Xəzər dənizinə tökülür.

Gəncə çayı: Kiçik Qafqazın Murovdağ silsiləsinin şimal yamacından axmağa başlayır. Çayın dəniz səviyyəsindən 2814 m yüksəklikdədir. Çayın uzunluğu 99 km, hövzəsinin sahəsi 752 km²-dir.

Gəncə çayı yaz gursulu rejim fazalı çay qrupuna aiddir. Adətən bu hal mart ayından iyul ayına kimi da və m edir.

Çayın su ehtiyatlarından suarmada istifadə edilir.

Regionun yeraltı su ehtiyatları: Azərbaycan ərazisində 3500-a qədər təbii bulaq və qaynaqlar vardır ki, onların ümumi su ehtiyatları 2,25 kub km³-ə bərabərdir. Bulaqlar yəni bulaq suları respublikanın dağ və dağətəyi zonalarındadır. Hal-hazırda etibarlı və qiymətli su ehtiyatı sayılan bulaqqaynaqların istifadəsinə, mühafizəsinə nəzarət çox zəifdir. Təbii qaynaqlar xeyli hissəsi (1000-dən çoxu) mineral su bulaqları təşkil edir. Respublikamızın səmərəsiz itirilən su ehtiyatlarının çox hissəsi mineral və geotermaldir.

Yeraltı sular öz tərkibinə görə bu cür qruplaşdırılır:

- 1.Şirin sular (su təhizatında istifadə olunur)
- 2.Mineral sular (müalicə əhəmiyyətinə malikdir)
- 3.Sənaye əhəmiyyətli sular.

Minerallaşma dərəcəsi 1-15 q/l olan sular isə və nnalar şəklinə istifadə olunur. Regionun dağlıq ərazisində 8465 km² olan arazıda 55 mineral su mənbəyində debiti sutkada 660000 litr olan bulaqlar Gəncə-Qazax düzənliyində sahəsi 2500 km² olan arazıda 12 mənbədə debiti sutkada 1268000 litr olan bulaqlar məlumdur.

Gəncə Bozdağının ətəyində yerləşən yodlu bulaq, Gəncə şəhərinin cənubunda Hacıkənd istiqamətində çıxan müalicəvi əhəmiyyətli "Nurud 6 bulaq, Daşkəsən və Gədəbəy rayonlarında yerləşən " Narzan" tipli bulaqlar, iqtisadi cəhətdən öz əhəmiyyətlərinə görə çox mühüm yer tutur.

Maraqlıdır ki, Narzan tipli qaynaqların illik debiti 10 milyard 800 litrə çatır. Lakin hal-hazırda bu sərvətin 0,5-0.7% istifadə olunur.

Gəncə şəhərindən şərq istiqamətində Goranboy rayonunun ərazisində "Qazan bulaq" termal müalicəvi suyu şəhərin şimal-şərq istiqamətində "Şəmsizadə" termal müalicəvi suyu, qərb istiqamətində Sərkər kəndində "Sərkər" termal müalicəvi suyu yerləşir.

Gəncə-Qazax düzünün qərb hissəsində hidrokarbonat kalsium tərkibli şirin sular, şərq hissəsində minerallaşma dərəcəsi 13 q/l-a çatan sulfat natrium suları yayılmışdır. Çoxillik müşahidələr sübut etmişdir ki, Gəncə düzündə suarmada istifadə edilən suların 58%-i yeraltı mənbələrin hesabına.

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Art History

Псевдодокументальное кино как инструмент критического анализа в эпоху искусственного интеллекта

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Abstract

Mockumentary is a cinematic genre that's been underestimated for a long time due to its mixed and unclear concept, which composes documentary and fiction filmmaking. This article explores the key features, narrative techniques, and structural principles of the “mockumentary” genre. Moreover it analyzes its relevance in the context of the fast development of artificial intelligence (AI) technologies. Drawing on theoretical frameworks by Yuri Lotman and Michel Foucault, as well as comparative analysis of films such as *Triumph of the Will* and *Man Bites Dog*, this study explores how the concepts of truth and authenticity are constructed and consumed in the media.

This research uses techniques like bibliographic analysis, case studies, internet research, and narrative analysis to study both documentary and mockumentary films. It argues that documentary images are not unquestionably reliable, but are shaped by cultural context, the filmmaker's intent, and cinematic techniques. In turn, the “mockumentary” exposes these mechanisms and critically reflects on them, imitating the form of documentary film while presenting fictional content, thereby provoking viewers to reflect on the boundaries between reality and fiction.

The article draws parallels between mockumentaries and AI-generated media content, highlighting their shared ability to mimic reality and obscure underlying ideological frameworks. The study positions mockumentaries as an important tool for analyzing and deconstructing both

traditional documentary practices and AI-driven media. In conclusion, it is argued that in the age of post-truth and digital disinformation, mockumentary film continues to hold a significant cultural and theoretical value as a form of reflective criticism.

Keywords: Mockumentary, documentary, perception, critical analysis, concept of truth, deception, AI, objectivity.

Аннотация

Мокьюментари — это кинематографический жанр, долгое время недооценивавшийся из-за своей неоднозначной и гибридной концепции, сочетающей в себе элементы документального и игрового кино. В данной статье рассматриваются ключевые особенности, нарративные приемы и структурные принципы жанра «мокьюментари». Кроме того, анализируется его актуальность в контексте быстрого развития технологий искусственного интеллекта (ИИ). Опираясь на теоретические концепции Юрия Лотмана и Мишеля Фуко, а также на сравнительный анализ таких фильмов, как «Триумф воли» и «Человек кусает собаку», данное исследование изучает, как концепции правды и подлинности конструируются и потребляются в медиа.

В исследовании используются такие методы, как библиографический анализ, исследование ситуаций, интернет-исследования и нарративный анализ, для изучения как документальных, так и псевдодокументальных фильмов. Утверждается, что документальные образы не являются бесспорно достоверными, а формируются культурным контекстом, замыслом режиссера и кинематографическими приемами. В свою очередь, мокьюментари вскрывает эти механизмы и критически осмысливает их, имитируя форму документального фильма, но представляя вымышленное содержание, тем самым побуждая зрителей задуматься о границах между реальностью и вымыслом.

В статье проводятся параллели между мокьюментари и медиаконтентом, созданным с помощью ИИ, подчеркивая их общую способность имитировать реальность и скрывать лежащие в её основе идеологические рамки. Исследование позиционирует мокьюментари как важный инструмент для анализа и деконструкции как традиционных документальных практик, так и ИИ-контента. В заключении утверждается, что в эпоху постправды и цифровой дезинформации мокьюментари продолжает сохранять значительную культурную и теоретическую ценность как форма рефлексивной критики.

Ключевые слова: мокьюментари, документальный фильм, восприятие, критический анализ, понятие истины, обман, ИИ, объективность.

Введение

Мокьюментари как жанр на протяжении длительного времени оставался недооценённым в сфере кинематографа вследствие своей неоднозначной, гибридной природы. Являясь предметом активных дискуссий среди теоретиков и практиков кино, мокьюментари по-разному интерпретировался: как поджанр документального кино и одновременно как разновидность художественного кинематографа. Подобная двойственность не является случайной. Истоки жанра восходят к ранним рефлексивным документальным фильмам, таким как «Нанук с Севера» (1922), которые уже тогда допускали манипуляцию реальностью в пользу драматургической выразительности. Со временем мокьюментари эволюционировало, превратившись в культурный феномен, критикующий способы восприятия реальности через игровую имитацию документальной формы (Омар, Рамазанова, 2025)

Используя характерный для документального кино стиль повествования, ручную камеру и импровизированные диалоги, псевдодокументальное кино создаёт убедительную иллюзию подлинности происходящего, тем самым провоцируя зрителя сомневаться в

границе между правдой и вымыслом. На данном аспекте представляется важным остановиться подробнее: проблематика иллюзорной реальности и разграничения истины и фикции приобретает особую актуальность в контексте XXI века и стремительного развития технологий искусственного интеллекта (ИИ).

Мокьюментари можно рассматривать как своеобразную реакцию на фальшивую документалистику - форму критического высказывания и протеста против эпохи, в которой дезинформация становится инструментом выгоды. С развитием генеративного ИИ проблема фальсификации медиаконтента выходит на качественно новый уровень, что придаёт жанру мокьюментари дополнительную теоретическую и культурную значимость. Возрастающая реалистичность созданных ИИ материалов и то, как ИИ преподносит и систематизирует данные все больше и больше размывают грань между реальностью и вымыслом, правдой и ложью. Именно в связи с этими тенденциями критическое отношение к реальности, которым характеризуется жанр мокьюментари, становится крайне важным для изучения.

Данная статья исследует отличительные черты, приемы, сущность, структура жанра мокьюментари и взаимоотношения между данным жанром и искусственным интеллектом как источником формирования правды в современной эпохе.

В ходе исследования применялись методы библиографического исследования, анализа конкретных случаев, интернет-исследования, нарративного анализа, и теоретико-концептуального анализа понятий «правды» и «истины» на основе работ Ю.М. Лотмана и М. Фуко. Интернет-ресурсы и библиографические источники послужили основными средствами для поиска и систематизации информации о жанре мокьюментари, а также о современном состоянии технологий искусственного интеллекта. Сравнительный анализ был проведен на материале фильмов «Триумф воли» Лени Рифеншталь и «Человек кусает собаку» Реми Бельво с целью выявления ключевых дифференцирующих черт документального кино и мокьюментари. Кроме того, был выполнен нарративный и художественный анализ фильма «Дракула» Раду Жуде, рассматриваемого в качестве примера ранних попыток имитации характерных черт искусственного интеллекта в кинематографе. Также в исследовании были учтены результаты работ Павао (2024) и Шина (2025), указывающие на неизбежную предвзятость в системах определения «правды» искусственным интеллектом и на связанные с этим потенциальные риски.

Научная новизна данной статьи заключается в рассмотрении жанра мокьюментари в контексте стремительного развития генеративного ИИ. Впервые мокьюментари анализируется как форма критического осмысления ИИ-сгенерированных медиаматериалов и феномена "пост правды". Целью исследования является выявление взаимосвязи между художественной имитацией документальности и алгоритмической симуляцией реальности, расширяя представление о границах истины и фикции в современном аудиовизуальном искусстве. Для достижения поставленной цели предполагается решение следующих задач:

Углублённое изучение кинематографического восприятия в целом, документального и псевдодокументального кино в частности, включая анализ его формальных критериев и ключевых отличительных особенностей на основе источников;

Разбор на основе источников и сравнительный анализ конкретных примеров документальных и псевдодокументальных кинокартин для прояснения различий и сущности данных направлений;

Исследование феномена генеративного ИИ и его влияния на восприятие информации, (в частности в контексте «постправды» и фабрикации медиаматериалов);

Анализ параллелей между природой истины в мокьюментари-повествовании и ИИ-сгенерированным аудиовизуальным контентом;

Составление финального вывода о взаимоотношениях псевдодокументальной стилистики и ИИ-контента.

Основная часть

Кинематограф находится в сложных отношениях с реальностью, которую он изображает на экране, и с самими понятиями «достоверности» и «правды», которые часто приписываются кинематографу, в частности, документальному. Хакимов (2019) отмечает, что документальное кино оперирует фактами, «кусками действительности» для создания образа реальности – такими, как использование хроники, освещение реальных событий, появление реальных людей и материальных объектов в кадре, и так далее. Однако, это не обязательно значит, что документальное кино прямо и беспристрастно отображает действительность на экране, даже если авторы представляют повествование в фильме как нечто объективное, непредвзятое и носящее исключительно информативный характер. Они скорее являются частью художественного взгляда на действительность, а не простыми средствами для передачи информации о реальном мире на экран.

Ю. М. Лотман (1973) утверждает, что восприятие кинематографического изображения как "достоверного" обусловлено не столько правдивостью самого изображения, сколько культурными факторами, влияющими на художественный выбор автора и зрительское восприятие. Так, Лотман приводит пример послевоенного движения итальянского неореализма в кино, построенного на противостоянии театрализованности и искусственности жанрового, массового кино того времени – это противостояние выражалось в отказе от искусственных декораций, профессиональных актеров, использования музыки, насыщенных и ярких цветов и четко определенного, "железного" сценария. Такие фильмы итальянского неореализма, как "Похитители велосипедов" Витторио де Сика, "Земля дрожит" Лукино Висконти, "Земляк" Роберто Росселлини, являясь по своей природе игровыми, стремились к максимально точной приближенности к реальности. Однако, вышеописанные приемы не воспринимались бы как нечто достоверно отображающее правду окружающей действительности без существования противоположного кино – красочных и театральных исторических эпиков, вестернов и прочих жанров того времени, которые не стремились к изображению достоверности и могут быть названы скорее эскапистскими, чем приближающими зрителя к реалиям жизни. Впрочем, данные наблюдения касаются не только документального кино и кинематографа в целом – Лотман указывает на то, что документы, газетные репортажи, фотография, тоже воспринимались в свою эпоху как нечто, что не несёт в себе лжи и является объективным, но данные представления менялись с изменением контекста и развитием технологий.

Следовательно, киноизображение не всегда является достоверным само по себе – эффект правдивости зависит от конкретных используемых в фильме приёмов, направленных на воссоздание реальности и от широкого социально-культурного контекста, окружающего фильм и аудиторию. К примеру, фильм «Нанук с Севера» Роберта Флаэрти являет собой один из самых ранних примеров фальсификации элементов нарратива в документальном кино. Фильм про жизнь североамериканского инуита активно использует постановочные элементы – постройка жилья для главного персонажа, использование фиктивного имени главного героя фильма (в действительности его звали не Нануком, а Аллакариаллаком) для создания образа примитивной жизни охотника (Омар, Рамазанова, 2025). Тем самым, фильм, воспринимаясь без должного анализа, может быть принят как абсолютно правдивый, что в корне не верно.

Чтобы распознать манипуляцию зрительским восприятием и ложь, стоит подвергать документальные работы тщательному анализу с точки зрения режиссуры, истории и восприятия. Претендующий на правдивость медиум, будь то журналистика или кино, может лишиться абсолютной монополии на объективность, если критически проанализировать контекст его времени и автора, и его конкретные стилистические особенности. В рамках кинематографа важным элементом критического анализа правдивости изображения

становится жанр псевдодокументального кино. Как отмечают Омар и Рамазанова (2025), для псевдодокументального кино характерны сатиричность, рефлексия зрительского восприятия, жанровых границ и самого понятия правды, а также намеренное разрушение границ между истиной и фикцией. Мокрыментари, с одной стороны, использует приемы документалистики, такие как наблюдение за объектом исследования фильма, ручная съёмка, интервью, отсутствие заранее написанного сценария и импровизацию, а с другой стороны - ведет повествование о вымышленных персонажах и событиях в документальной стилистике. Все это позволяет псевдодокументальному кино поставить под сомнение господствующие представления об истинности документалистики, обратить внимание на относительность и сконструированность истины и открыть возможности для анализа того, как правда в современном мире создаётся через медиа и искусство.

Различия между такими фильмами как «Триумф воли» Лени Рифеншталь и «Человек кусает собаку» Реми Бельво, Андре Бонзеля и Бенуа Пульворда позволяет яснее отследить различия между документальным кино и мокрьментари. «Триумф воли» - пропагандистский фильм Лени Рифеншталь, повествующий о съезде НСДАП в 1934 году. Фильм, фиксируя в реальности происходивший съезд, тем не менее, транслирует определенную идеологическую точку зрения - кинематография фильма явно создает благоволящую картину нацистского режима и Адольфа Гитлера, использование поэтических, иконических образов (облаков, флагов, немецкой архитектуры, массы людей в стройных шеренгах), намеренное редактирование речи Гитлера для того, чтобы убрать оттуда потенциально «неудобные» для международной аудитории фрагменты, по типу антисемитских высказываний. Сама Рифеншталь, однако, отрицала политическую ангажированность фильма и утверждала, что он является не более, чем фиксацией истории (Горячок, 2022). Таким образом, здесь имеет место быть явный обман зрительского восприятия - попытка выдать крайне политическое и идеологическое выступление, зафиксированное на камеру за нечто нейтральное и объективное, но на деле помогающее распространять и поддерживать нарративы системы насилия.

Как может показаться с первого взгляда, «Человек кусает собаку» - совсем иного рода история, чем «Триумф воли». Псевдодокументальная сатира про молодого серийного убийцу, который встречается с семьей и друзьями, ведет длинные монологи на камеру о интересующих его темах, и с крайней жестокостью, но довольно рутинно, настигает своих жертв под камерами неизвестных зрителю репортёров, явно критикует лицемерие буржуазного образа жизни героя и общества, в котором он живет и показывает абсурдное и страшное сочетание обыденности и скрытого насилия в его повседневности (Коулман, 2009). Эта картина совершенно не такая масштабная, как «Триумф воли», и, в отличие от последней, имеющая чувство саморефлексии и юмора. Но в этом и строится главное различие - заимствуя приемы документалистики, на ручную камеру снимая фиктивные акты насилия и цинизм главного героя, фильм не обманывает зрителя так, как «Триумф воли». Он показывает вымышленные события и насилие совершенно искренне - так, как будто бы они реальны, делая зрителя соучастником действия.

Джепали (2024) выделял два уровня обмана зрительского восприятия - перцептивный и интеллектуальный. На уровне перцептивного обмана зрителя пытаются заставить поверить в реальность чего-то искусственного (Джепали приводит пример восковых статуй, максимально похожих на живых людей). В данном случае само восприятие зрителя, в частности визуальное, оказывается обмануто. Интеллектуальный обман же всего лишь заключает зрительское восприятие в скобки, и работает на уровне нарратива, а не восприятия. Рифеншталь, с её «Триумфом воли», обманывает перцепцию зрителя, показывая сильно ангажированное и, в реальности, постановочное событие, как нечто объективное. «Человек кусает собаку» обманывает зрителя интеллектуально и провоцирует

его анализировать сам медиум кино, ставить под вопрос и одновременно верить реальности происходящего, и задуматься о скрытой жестокости и двойственности общества, в котором живет зритель. Хочется отметить, что далеко не всё документальное кино занимается перцептивным обманом, а только то, что выдаёт интерпретацию за факты, не предоставляя критического анализа и режиссерской саморефлексии.

Исходя из вышесказанного, можно утверждать, что для критического анализа документалистики требуется понимание ее киноязыка как со стороны автора, так и со стороны зрителя. Документальное кино построено на интерпретации реальных событий автором с помощью кинематографических приёмов, а псевдодокументальное - на том, чтобы вскрыть, «подсветить» и критически осмыслить механизмы документалистики и то, как она занимается репрезентацией реальности. В обоих случаях требуются определенные навыки интерпретации - для того, чтобы избежать перцептивного обмана необходимо не просто показывать фактически произошедшие вещи на камеру, но и уметь критически анализировать их.

Тем не менее, в современную эпоху развития искусственного интеллекта, отличить правду от вымысла и критически анализировать природу истины становится все труднее - как минимум из-за того, что всё чаще используемые ИИ-инструменты понимают “правдивость” совсем иным способом, нежели человек. ИИ-системы тренируются на разного рода больших базах данных, и, определяя истинность или ложность определенной информации, они ориентируются скорее на количественные данные, чем на интерпретацию. Модель определения истины ИИ основывается на распознавании повторяющихся паттернов, вероятностях, формальных характеристиках, доступности данных и алгоритмической консистентности, но не на понимании конкретного контекста, сложностей и нюансов, альтернативных точек зрения (Шин, 2025).

Как отмечает Палезе (2026), ИИ конституирует совершенно новые формы истины, которые, под видом нейтральности и объективности, могут продвигать определенные привилегированные точки зрения и корпоративные интересы - так, при поиске информации ИИ часто основывается на данных авторитетных западных организаций, таких, как Snopes и PolitiFact, а также на государственных и научных базах данных и статистике (Тибо и др., 2025), которые сами по себе ангажированы, и отражают точки зрения, политические взгляды и культурные особенности обеспеченных стран Глобального Севера. Эта информация становится частью базы данных нейросети и позже определяется как нейтральная и фактологическая, тем самым все сильнее воспроизводя алгоритмическую предвзятость и выдавая ее за истину.

Мишель Фуко утверждал: «Каждое общество имеет свой режим истины, свою «общую политику» истины: то есть, типы дискурса, которые оно принимает и которые оно считает истинными; механизмы и примеры, позволяющие различать истинные и ложные утверждения, средства, с помощью которых каждое из них санкционируется; методы и процедуры, которым придается ценность при обретении истины; статус тех, кто отвечает за то, что считается истиной.» (Фуко, 1977, ст. 131). Следовательно, предвзятость изначально присутствует в той информации, которая находится в базе данных ИИ - по той простой причине, что она написана конкретными людьми в конкретный период времени и сильно зависит от точек зрения и взглядов людей, культурных особенностей и широкого контекста определенного общества, которые определяют его “режим истины”.

Исходя из сказанного выше, можно провести параллель между тем, как обходится с восприятием и пониманием истины документальное изображение и искусственный интеллект. Между фальшивой документалистикой, против которой направлен жанр мокьюментари и тем, как LLM-модели представляют информацию, есть важное сходство - и то, и другое маскирует определенную идеологическую точку зрения и взгляд за фасадом

нейтральности, непредвзятости и объективности. Проблема касается в том числе и генеративного ИИ - в исследовании, проведенном Павао (2024), только 54% участников смогли отличить реальное изображение от сгенерированного ИИ, что лишь незначительно выше процента случайного угадывания.

Эти данные показывают, что инструменты мокьюментари, использовавшиеся с целью рефлексии о понятии истины, обретают новую актуальность в современном мире. Не являясь мокьюментари в прямом смысле слова, некоторые фильмы уже начинают имитировать и пародировать характерные черты ИИ через игровую форму. Фильм «Дракула» Раду Жуде, в котором неудачливый режиссер пытается сгенерировать ИИ-фильм про Дракулу является ярким примером рефлексии на тему ИИ в современном кино. Актеры играют и произносят реплики так, будто бы они - искусственный интеллект, сценарий намеренно утилизирует ошибки, неточности и воспроизводящиеся ИИ паттерны. «Дракула» Жуде разделен на 14 глав, каждая из которых, по сути, построена вокруг нового промпта, который режиссер дает ИИ и его результата, где реальные актеры имитируют поведение нейросетей с вкраплениями кадров, действительно сгенерированных ИИ (Элефтериу, Пфайфер, 2025). Как говорит сам режиссер фильма - «Фильм называется «Дракула», потому что Дракула всё высасывает. Так что, в некотором смысле, искусственный интеллект и Дракула — одно и то же.» (Салаи, 2025).

Псевдодокументальные фильмы прошлого намеренно указывали на социальную сконструированность правды, обман зрительского восприятия и предвзятость, скрывающуюся даже за самыми подлинными, нейтральными и похожими на реальность изображениями. В нынешнее же время мокьюментари и иные гибридные формы игрового кино могут схожим образом указывать на предвзятость уже иного рода - на те идеологические нарративы, обман восприятия или предвзятость, которые кроются в работе нейросетей. Если ранее мокьюментари были ответом на фальшивую документалистику, оперирующую реальными изображениями ради продвижения определенной точки зрения, то теперь они, возможно, станут ответом на ИИ-контент, оперирующий уже сгенерированными изображениями, которые выдают себя за нечто реальное. Меняются формы обмана восприятия - от манипулирования реальностью режиссером до полного воссоздания реальности нейросетью, но мокьюментари, как жанр, направленный на имитацию, сатиру, критический взгляд и продуктивная интеллектуальная игра со зрителем может стать ответом на новую волну алгоритмической дезинформации.

Заключение

Исследование документального и псевдодокументального кино на основе источников, а также исторический анализ фильмов итальянского неореализма и “Нанука с севера” позволили выяснить, что кинематограф сам по себе, как вид искусства, не всегда является прямым отражением реальности. Чаще всего “истинное изображение” в кино воспринимается и конструируется через художественные и культурные механизмы, сильно зависящие от социально-культурного контекста времени. Документальное кино не может воспроизвести реальность событий, показываемых на экране, непредвзято и нейтрально, и зрители всегда видят их через призму авторского восприятия. Данное авторское восприятие выражается в использовании конкретных художественных приёмов, таких, как использование хроники, интервью, ручной камеры и так далее. Без отсутствия саморефлексии документальное кино может намеренно обманывать восприятие зрителя и становится пропагандой, выдающей идеологические позиции за объективную правду, что подкрепляется анализом фильма «Триумф воли» Лени Рифеншталь и его сравнением с мокьюментари «Человек кусает собаку».

Мокьюментари имитирует документальную реальность и заставляет зрителя поверить в правдивость происходящего. В то же время, псевдодокументалистика - это не обман восприятия, а всего лишь вскрытие механизмов, создающих "правду" в кино. Псевдодокументальное кино способствует рефлексии на тему власти медиа, природы истины и объективности документального изображения. Однако, в наше время понятие «истины» меняется из-за развития искусственного интеллекта. Утверждения, подаваемые нейросетями как истинные, на деле возникают из огромного массива данных, написанного людьми и сильно зависящего от паттернов, формальных черт и прочих факторов, которые могут давать предпочтение определенным привилегированным точкам зрения и идеологическим позициям, представляя их нейтральными. В этом - сходство фальшивой документалистики и искусственного интеллекта.

Истина в медиа - это не абсолютная правда, а лишь результат интерпретации, власти и контекста. Изображения, созданные ИИ, требуют такого же критического анализа, как и кадры, срежиссированные человеком. Мокьюментари, занимаясь критикой и анализом господствующих представлений о правде и их искусственности, может точно так же быть обращено в сторону ИИ. Имитируя и заимствуя черты, присущие ИИ-изображениям, пародируя и переосмысляя их, жанр псевдодокументального кино может продолжать оставаться орудием критического мышления в век цифровой дезинформации. Можно предположить, что в будущем роль мокьюментари и критического искусства будет только расти.

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Chemical Sciences

COMPOSITIONS BASED ON MODIFIED PHENOL-FORMALDEHYDE OLIGOMERS

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Abstract: The synthesis, structural characteristics, and performance properties of composite materials based on modified phenol-formaldehyde oligomers (PFO) and polyvinyl chloride (PVC) were investigated. The functionalization of the phenol-formaldehyde oligomer was carried out to enhance its reactivity and compatibility with the PVC matrix. The physicochemical, mechanical, and thermal properties of the resulting compositions were characterized using Fourier-transform infrared spectroscopy (FTIR), thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), and mechanical testing. The research results demonstrated that the synergistic use of modified PFO with PVC significantly improves the thermal stability, mechanical strength, and chemical resistance of the composite material. The synthesized composites hold significant potential for applications in various fields, including construction, electrical and electronics, transportation, and the coatings industry.

Keywords: phenol-formaldehyde oligomer, PVC, modification, functionalization, composite, thermosetting polymer.

Although phenol-formaldehyde oligomers (PFO) were among the first synthesized macromolecular compounds, research focusing on their synthesis, chemical transformations, and applications remains highly relevant today. Products resulting from the interaction of phenol and its derivatives with formaldehyde are of significant practical importance, serving as antioxidant additives for mineral oils and fuels, corrosion inhibitors, stabilizers for polymeric materials, and surfactants, among other applications.

The successful application and high performance indicators of PFO in numerous sectors of the national economy are primarily attributed to the composition and structure of these compounds. For instance, the presence of phenolic hydroxyl and methylol groups, as well as aromatic rings with a delocalized six-electron cloud, positively influences adhesion properties on metal surfaces, thereby enhancing the coating-forming and inhibitory characteristics of PFO. To improve these properties, the modification of oligomers with nitrogen-containing compounds—such as amines, amides, triazines, and amino alcohols—is of great interest. Nitrogen-containing functional groups with high polarity amplify the attraction effect of oligomeric macromolecules toward the metal surface, consequently strengthening their protective properties.

Although phenol-formaldehyde oligomers (PFO) were among the first synthesized macromolecular compounds, the continued development of new methods for their modification underscores the ongoing relevance of this field. The availability of actual raw material reserves, the absence of technological complexities, and the extensive modification possibilities due to the high reactivity of PFO drive the interest in this area. Phenolic oligomers are of great practical importance; their applications in the production of coating-forming compositions, paints and varnishes, as well as anticorrosive additives and demulsifiers, play a crucial role, which is directly related to their protective properties. Furthermore, the modification with nitrogen-containing

compounds to obtain materials with a required set of properties is of particular significance [1-8].

The primary objective of this study was the sulfonation of an environmentally friendly oligomer by introducing a sulfo group into the benzene ring to obtain an ion-exchange compound for use in technical water treatment. The dynamic exchange capacity of the synthesized ion exchanger ranged from 0.74 to 0.98 meq/g, the static exchange capacity from 1.25 to 3.22 meq/g, and the bulk density varied within the range of 1189 to 1206 kg/m³.

The investigation of the optimal parameters for the synthesis of an ion exchanger (sulfocationite) based on urea-phenol-formaldehyde oligomers was conducted using the multifactorial experiment planning method. The optimal values of the technological parameters were determined, with the output parameter reaching an optimal value of 78.13%. A 250 ml laboratory reactor equipped with a stirrer and a reflux condenser was charged with the urea-modified phenol-formaldehyde oligomer and 95% sulfuric acid, then heated to 140 °C. The reactor was maintained at this temperature until the oligomer was completely melted, after which the reaction mass was cooled to room temperature. Immediately following the cooling process, 30 ml of a 37% aqueous formaldehyde solution (formalin) was added to the mixture. Subsequently, the reaction mass was transferred to a specialized vessel and placed in an oil bath at 110 °C for two hours to undergo the curing process. After solidification, the product was washed with water until the effluent became completely clear, dried, and ground into particles with a size of 1–2 mm. The resulting sulfocationite is a black, solid substance, insoluble in both water and hydrocarbons [9-11].

The rapid growth in the global production of polymeric materials is attributed to their valuable properties, such as mechanical strength, adhesion, dielectric characteristics, as well as thermal and corrosion resistance. Although phenol-formaldehyde oligomers (PFO) were among the first synthesized macromolecular compounds, they remain a subject of current research interest due to their capacity for chemical interaction—facilitated by reactive functional groups and fragments—their flexibility in controlling the curing process during operation, and their potential for use in various composite materials, adhesives, and coating agents. Analogous studies primarily focus on exploring methods for the synthesis of PFOs with novel compositions and structures, characterized by low toxicity, high yield, and simple synthesis technologies [12].

The thermal properties of benzylamine-functionalized phenol-formaldehyde oligomers were investigated, focusing on the correlation between the oligomer composition, their transformation products, and their thermal behavior. Thermogravimetric (TG) and differential thermal analysis (DTA) were conducted in both inert (nitrogen) and oxidative (air) atmospheres, from which corresponding conclusions were drawn. The extensive application range of phenol-formaldehyde oligomers (PFO) has established them as one of the most promising macromolecular compounds. PFOs are frequently incorporated into formulations for coatings, binders, thermal insulation materials, adhesives, sealants, and impregnating compounds. The enhancement of their properties through various production methods, as well as modification with a range of organic compounds—including nitrogen-containing derivatives—is attributed to the high reactivity of PFOs, defining the ongoing relevance of research in this field. Among the characteristics of phenol-formaldehyde oligomers, thermal stability is of particular significance, as it serves as a primary indicator of a material's serviceability in many applications.

Based on the preliminary discussions, research was conducted on the thermal properties of benzylamine-functionalized phenol-formaldehyde oligomers. These modified oligomers were synthesized using a specifically selected method; the resulting products subsequently underwent secondary polycondensation in a solvent medium, followed by etherification with n-butyl alcohol. The objective of this study was substantiated in previous publications. For this investigation, resol-type oligomers with a phenol to formaldehyde to modifier molar ratio of 1:1.2:(0.2–0.4) were selected, as these compositions demonstrated the most satisfactory physical and mechanical

properties in epoxy composites. To evaluate the thermal properties of the modified oligomers, thermal analysis techniques, including DTA and TG, were performed using a Jupiter STA449F3 thermal analyzer (NETZSCH, Germany) [13-16].

The synthesis of nitrogen-containing alkyl (C_8 – C_{12}) phenol-formaldehyde oligomers grafted with vegetable oils was investigated to develop new materials with protective coating properties. Soybean and linseed oils were utilized as the vegetable oil components. A reaction mechanism was proposed, involving functional groups formed through oxidation processes at the α -position carbon atoms relative to the double bonds. The probable structure was elucidated using Infrared (IR) and Nuclear Magnetic Resonance (NMR) spectroscopy, and the physicochemical properties of the synthesized products were characterized. It was hypothesized that the interaction between the phenol-formaldehyde oligomer and the vegetable oil occurs via the functional groups formed during oxidation at the α -position of the double bonds and the methylol groups of the oligomeric macromolecules. Consequently, it was concluded that a higher degree of unsaturation is a favorable factor, with preference given to more highly unsaturated oils.

The probable structure of the nitrogen-containing monoalkyl (C_8 – C_{12}) phenol-formaldehyde oligomer grafted with soybean oil was studied using Fourier-transform infrared (FTIR) spectroscopy. To understand the process mechanism, a spectral-kinetic study was conducted. The IR spectra of both the starting components (nitrogen-containing monoalkyl (C_8 – C_{12}) phenol-formaldehyde oligomer and soybean oil) and the reaction mixture were recorded at 0.5-hour intervals during the second stage of the process for comparative analysis. In the spectra of the initial oligomer, the following absorption bands were observed: 750 cm^{-1} for methylene groups; 1370 cm^{-1} (def) and 2872 cm^{-1} (str) for methyl group bonds; 1456 cm^{-1} (def) and 2957 cm^{-1} (str) for methylene group bonds; and 1508 cm^{-1} (def) and $3027, 3060\text{ cm}^{-1}$ (str) for benzene rings [17-19].

The molecular weight distribution of benzoguanamine-modified monoalkyl (C_8 – C_{12}) phenol-formaldehyde oligomers and their products of high-temperature interaction with oleic acid esters and aliphatic alcohols was studied using gel permeation chromatography (GPC). The dependence of the weight-average molecular weights and polydispersity of both initial components and final products on the ester composition was investigated. Regularities regarding the processes occurring during the interaction of oligomers with esters were identified, and relevant hypotheses were proposed. Chemical modification of phenol-formaldehyde oligomers with various compounds, as well as their use in formulations containing different resins and oils, enhances their reactivity and properties, optimizes the process, and in many cases, reduces the cost of the final product.

To detailedly investigate the structure of the synthesized oligomers, the process mechanism, and the influence of additives on product properties, research was conducted on the synthesis of nitrogen-containing monoalkyl (C_8 – C_{12}) phenol-formaldehyde oligomers grafted with full and partial esters of individual fatty acids—specifically oleic acid with aliphatic alcohols such as glycerin, ethylene glycol, and ethanol. The analyses were performed on a high-performance liquid chromatograph (HPLC) equipped with a refractometric detector, manufactured by "Kovo" (Czech Republic). The initial component, monoalkyl (C_8 – C_{12}) phenol-formaldehyde oligomer, consists of two fractions, each exhibiting low polydispersity values. The high-molecular-weight fraction, comprising 22% of the oligomer, has a polydispersity of 1.17, while the second, low-molecular-weight fraction, comprising 78%, has a polydispersity of 1.24. In other words, the high-molecular-weight fractions possess low polydispersity. The interaction of oligomers with esters is confirmed by the average molecular weight values of the high fractions. These high-molecular-weight fractions exhibit high reactivity, which is attributed to their elevated functionality [20-21].

The physicochemical properties of phenol-formaldehyde oligomers modified with imidazolines based on distilled natural petroleum acids and diethylenetriamine, as well as

polyethylenepolyamines, were investigated. The solubility of the synthesized oligomers in various polar and non-polar solvents was determined. Their thermal properties were studied, and corresponding conclusions were drawn. The advantages of analogs containing other heteroatoms compared to nitrogen-containing compounds as modifiers for phenol-formaldehyde oligomers (PFO) define the prospects for research aimed at developing newly modified PFOs. Such compounds can be effective as additives for the production of coating-forming materials and protective liquids. This is attributed to the influence of heteroatoms and the high polarity of nitrogen-containing functional groups, which ensure effective adhesion to metal surfaces and exhibit protective properties.

Among the synthesized oligomers, samples based on monoalkyl (C_8 – C_{12}) phenol-formaldehyde oligomers are infinitely soluble in non-polar solvents, including oils. The solubility of other oligomeric compounds in oils does not exceed 30%. To study the thermal characteristics, a thermogravimetric analysis of phenol-formaldehyde oligomers modified with various imidazolines was conducted in comparison with unmodified oligomers. The analyses (TG/DTG, TG/DTA) were performed using a Jupiter STA449F3 thermal analyzer (Germany) in an inert (nitrogen) atmosphere, within a temperature range of 25–650 °C at a heating rate of 10 °C/min; the dependence of thermal properties on the composition of the selected oligomers was investigated. Analysis of the TGA curves revealed that at temperatures below 300 °C, phenol-formaldehyde oligomers modified with imidazolines exhibit higher thermal stability compared to unmodified ones. For instance, at 200 °C, the weight loss for the PFO modified with diethylenetriamine-based imidazolines was 2%, while for those modified with triethylenetetramine and polyethylenepolyamine-based imidazolines, it was 11% and 1%, respectively. In contrast, the weight loss for the unmodified phenol-formaldehyde oligomer was 13% [22-26].

Glyoxal (G), phenol (P), ionic liquid (IL), and maleic anhydride (MA) were utilized to modify lignin. The modified lignins were employed to substitute phenol (50% by weight) in phenol-formaldehyde adhesives. The prepared resins were subsequently used in the production of particleboards (PB). The physicochemical properties of the synthesized LPF (lignin-phenol-formaldehyde) resins were characterized by standard methods, including gel time, solid content, density, and viscosity. Furthermore, the dimensional stability, formaldehyde emission, modulus of elasticity (MOE) in bending, bending strength, and internal bond (IB) strength of the board panels were measured.

The lignin-based resin modified with maleic anhydride (MA) exhibited the lowest curing temperature compared to the unmodified, ionic liquid-modified, phenolated, and glyoxal-modified resins. LPF resins containing lignin treated with maleic anhydride demonstrated a shorter gel time, higher viscosity, and higher solid content compared to other modification methods. Simultaneously, particleboards prepared with LPF resins synthesized using maleic anhydride or ionic liquids showed the lowest formaldehyde emission and the highest mechanical strength among all synthesized resins. No significant difference was observed in the dimensional stability indicators among all boards bonded with the modified lignin LPF resins [27-31].

The substitution of phenol in phenol-formaldehyde resins is dictated by the well-known low reactivity of lignin toward aldehydes. A brief summary of the most recent innovations regarding the use of lignin in the more traditional field of lignin-phenol-formaldehyde (LPF) adhesive resins is provided. However, this review chapter focuses primarily on modern alternative approaches employed to bypass the barrier of lignin's low reactivity with aldehydes, which have yielded encouraging results.

Accordingly, approaches based on the demethylation of lignin coupled with specific oxidation, cross-linking of pre-glyoxalated lignin-dialdehyde starch via urea, lignin-based non-isocyanate polyurethane (NIPU) adhesives and resins, lignin-amine coatings, lignin-triethyl phosphate cross-linking as bio-hardeners for both wood surface coating and metal/Teflon

bonding, and finally, direct wood bonding through the esterification of lignin with citric acid are described [32-34].

Conclusion: As a result of the conducted research, high-quality and competitive new polymeric materials were developed through the modification of phenol-formaldehyde oligomers (PFO). It was determined that the modification process significantly enhances the physicomechanical indicators of the material, particularly its elasticity and impact resistance. The high thermal stability and chemical resistance of the synthesized product against aggressive environments expand its application range, opening broad opportunities for use in strategic sectors such as the automotive industry, construction, electrical engineering, and the defense industry. Thus, the proposed modification method is evaluated as an effective technique for obtaining more durable and long-lasting composite materials.

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