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CONTENTS

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GLOBAL TRENDS IN THE INTRODUCTION OF AI (ARTIFICIAL INTELLIGENCE) IN HIGHER EDUCATION: COMPARATIVE AND SOCIOLOGICAL ANALYSIS

Abstract: The article presents a comparative sociological analysis of global trends in the introduction of artificial intelligence (AI) in higher education programs in journalism. Political initiatives from different regions, the level of accessibility of artificial intelligence technologies and digital inequality, ethical aspects of the use of artificial intelligence in teaching, as well as pedagogical practices and platforms used to teach journalism through artificial intelligence are considered. The study relies on relevant scientific literature, international reports and statistics as of 2020. General trends have been identified-the desire to provide graduates with skills in working with AI and the integration of AI tools into the educational process – in the face of significant differences between regions (Kazakhstan, Europe, USA, China, Japan) in public policy, resource provision and regulatory and ethical approaches. Conclusions were drawn about how the specific conditions of each region affect the introduction of AI in the knowledge of journalists, recommendations were proposed to take into account best practices and overcome digital inequality.
Keywords: artificial intelligence, journalistic Education, Higher Education, digital transformation, ethical aspects, comparative analysis.

Introduction

The rapid development of artificial intelligence technologies in recent years has significantly affected the higher education system worldwide. Universities are revising curricula, including courses on working with AI and using data, to prepare students for the digital economy of the future.These changes are particularly noticeable in the fields of media communications and journalism, where AI technologies are already transforming professional practice, from automated news generation to data mining and content personalization. In this regard, an urgent scientific task is to study global trends in the introduction of AI into educational programs in journalism and compare the experience of different regions (Babacan et. al., 2025).

The relevance of research. The integration of AI into education has become particularly relevant after 2020, when, on the one hand, machine learning and natural language processing technologies (including large language models like GPT) reached a new level of maturity (Babacan et. al., 2025)

and on the other, the COVID 19 pandemic stimulated a massive transition to digital learning formats. National AI development strategies have emerged in many countries, which also affect education (Schiff, 2022)

The analysis of scientific publications from 2020-2025 allows us to identify several areas of research in the field of AI and higher education. The first group of papers (Kasneci et al., 2023; Jin et al., 2024) focuses on the pedagogical potential of generative models and their impact on academic integrity and personalization of learning. The second group (Schiff, 2022; European Commission, 2022) analyzes national training strategies for the AI economy. The third group of studies examines the transformation of journalism as a profession in the context of automation (Tejedor et al., 2024; Babacan et al., 2025).

At the same time, a systematic comparative sociological analysis of the introduction of AI specifically into journalism education in different political and cultural contexts is presented in fragments. Existing research lacks an integrative model that allows comparing government policy, infrastructural conditions, regulatory and ethical framework, and pedagogical practices in a single analytical framework.

Thus, the research gap lies in the lack of elaboration of a comparative sociological approach to the

analysis of the integration of AI into journalism education.

The purpose of the study is to develop a comparative sociological model for analyzing the introduction of artificial intelligence in journalism education and to identify regional differences in strategies, institutional conditions, and pedagogical practices.

To achieve the goal, the following tasks are set:

1) To analyze modern scientific approaches to the study of AI in education.
2) Compare the government strategies for the introduction of AI in higher education in Kazakhstan, the EU, the USA, China and Japan.
3) Assess the infrastructural readiness of the regions (Internet penetration, prevalence of AI programs).
4) Analyze the regulatory and ethical framework for the use of AI.
5) Compare pedagogical practices of integrating AI into journalism programs.

The scientific novelty of the research lies in the development of a comparative sociological approach to the analysis of the introduction of artificial intelligence in journalism education. The work takes into account the political, infrastructural, ethical and pedagogical aspects of digital transformation.

The paper also offers an original model of comparative analysis of Kazakhstan with the world's leading regions within the framework of a single analytical model. This ensured comparability of the data and increased the validity of the conclusions. The analysis revealed a connection between the model of public education management and the nature of the introduction of AI. The results obtained clarify the understanding of the factors of digital reforms in the higher education system and expand the theoretical understanding of this problem.

Literature Review

Recent scholarship shows a clear shift from “classic” educational AI applications (e.g., adaptive systems, learning analytics, administrative automation) toward generative AI and large language models as a new layer of higher-education infrastructure. While optimistic accounts emphasize personalization and productivity, the more careful strand of research stresses that educational value depends on pedagogical design, learner agency, and institutional governance rather than tool availability alone. Evidence from experimental syntheses suggests that ChatGPT-based interventions can improve performance and higher-order thinking indicators, but results are highly sensitive to research design choices (e.g., short-term effects, assessment type, lack of power analysis), which limits the validity of broad claims about “transforming education” without specifying conditions. Together, these findings motivate a literature review that treats AI not as a single innovation, but as a bundle of socio-technical practices whose effects vary across contexts and disciplines (Vincent-Lancrin & R. van der Vlies, 2020)

Many countries have adopted national strategies for the development of AI, which set the framework for the field of education. For example, in the European Union, the digital transformation of education is enshrined in the EU's Digital Education Plan 2021-2027, and in 2022 the European Commission issued special ethical guidelines on the use of AI and data in education for teachers. These guides aim to debunk popular misconceptions about AI, explain the risks and benefits of technology for schools, and provide practical advice on the ethical and effective use of AI in the classroom. In addition to soft regulation, Europe is moving towards legislating the use of AI: within the framework of the upcoming EU Artificial Intelligence Act (AI Act), AI systems used in education (for example, to assess academic performance or select students) are classified as high-risk and will have to meet strict requirements for transparency, reliability and non-directional discrimination (European Commission, 2022)

The European agenda focuses on ensuring trust in AI in education and preventing potential harm (violation of student privacy, increased algorithm bias, etc.).

There is no single national program for introducing AI into education in the United States, but significant efforts are being made at the state level in line with federal recommendations and by individual universities. In 2023, the Office of Educational Technology of the US Department of Education (OET) published the report "Artificial Intelligence and the Future of Teaching and Learning", which outlined the principles of responsible AI implementation. Among the priorities are: centering the role of the teacher (a person in a crucial role is “human–in-the-loop”), ensuring equal access and taking into account the principles of fairness, guaranteeing the security of student data, transparency of algorithms and their accountability to teachers.

The report emphasizes that interest in AI among American educators is growing rapidly – teachers are increasingly experimenting with new tools (from voice assistants to text generation tools) and at the same time are aware of the risks associated with them (U.S. Department of Education, Office of Educational Technology, 2023)

In Japan, generative artificial intelligence is also becoming the subject of active discussion in higher education. The analytical review shows that in 2023, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) published an official guide on accounting for generative AI in universities and technical colleges, aimed at supporting educational institutions in effectively integrating AI technologies and managing associated risks. The reaction of universities includes the development of their own recommendations and frameworks: for example, Osaka University has prepared comprehensive guidelines on the use of generative AI, including basic educational programs, teacher support and attention to ethical issues, reflecting the desire to combine technological innovation with academic values (Enkhtur & Li, n.d.)

Thus, generative AI should be interpreted not as a homogeneous technological breakthrough but as a socio-technical phenomenon embedded in regulatory frameworks, institutional cultures and disciplinary contexts. The literature increasingly emphasizes that the impact of AI differs significantly depending on governance models, ethical safeguards and the degree of integration into curricula.

Government policy plays a key role in the development of artificial intelligence in China. Within the framework of the "Strategy for the Development of Next-generation Artificial Intelligence" (2017), education is considered as a strategic tool for building national human resources and strengthening the country's technological leadership.

As noted by Fu and Ji (2024), the Chinese model of training AI specialists is based on close cooperation between the state and universities in the format of the so-called "triple helix" (state – university – industry). Government agencies not only form the regulatory framework and strategic guidelines, but also actively encourage universities to open new educational programs on AI, create research centers and introduce specialized disciplines into curricula.

As a result, there is an accelerated institutional development of AI trends in higher education, reflecting the centralized nature of China's educational policy and its close relationship with national technological priorities (Fu & Ji, 2024)

Such an impressive large-scale government campaign in the educational field is accompanied by major investments in infrastructure (AI research centers, supercomputing facilities are being created) and support for private EdTech initiatives. In particular, adaptive AI-based learning platforms for schoolchildren are actively developing in China China has also witnessed the rapid development of AI-driven adaptive learning platforms, supported by strong state industry collaboration and large-scale educational data ecosystems (Huang & Gadavanij, 2025).

A key factor in the success of AI implementation in modern education is the access of educational institutions, teachers and students to modern technologies. There is a gap both between rich and poor countries, and within countries, between resourced universities and others. According to the International Telecommunication Union (ITU), in 2023, an average of 79% of young people (aged 15-24) globally used the Internet, compared to just 65% of individuals over the age of 24 used it. In highly and medium-developed countries, the level of youth connectivity is already close to universal (over 95%), while in low–income countries there remains a significant gap - young people there are almost twice as likely to have access to the network as other groups of the population (International Telecommunication Union, 2023). For higher education, this means that new applicants, as a rule (which is natural), are much more literate in the digital issue of previous generations, but there remains unevenness in the basic digital infrastructure between countries and regions.

Digital inequality also manifests itself in another dimension the availability of advanced AI tools and knowledge about them. For example, the world's leading universities have the opportunity to attract expensive commercial AI-based solutions and develop their own experimental systems, while less affluent universities depend on publicly available or free resources. At the same time, the proliferation of open online platforms and MOOCs (massive open online courses) with AI elements somewhat smooths this problem, enabling students from different countries to gain access to best practices. The research literature emphasizes that without targeted measures, the gap can widen: elite institutions are rapidly implementing AI to improve

the quality of education, while peripheral ones may lag even further behind (Jin et. al., 2024). Therefore, many international organizations (UNESCO, the World Bank, etc.) are calling for the integration of the principle of accessibility in the digital transformation of education providing schools and universities with the necessary infrastructure, training personnel, localization of AI systems for different languages and contexts, subsidizing access for vulnerable groups. For example, the Republic of Kazakhstan, claiming to be a regional digital hub, is investing heavily in infrastructure development: data centers are being built, and by 2027 it was planned to increase Internet coverage to 100% of settlements, which creates the foundation for the introduction of AI tools throughout the country (Official website of the Prime Minister of the Republic of Kazakhstan, 2025).

In general, overcoming digital inequality is seen as a necessary condition for the successful integration of AI into education, otherwise new technologies and digital innovations will only strengthen existing social and economic differences and the gap between countries.

Importantly, digital inequality extends beyond basic internet connectivity. A second-order digital divide is emerging in relation to access to advanced AI systems, computational resources, high-quality datasets and institutional expertise. Even in contexts with high internet penetration, unequal access to premium AI tools and technical infrastructure may stratify learning opportunities and reinforce academic hierarchies. Without coordinated policy intervention, the integration of AI risks amplifying existing structural inequalities within and between higher education systems.

With the increasing use of AI in the educational process, a set of ethical issues arises that are widely discussed in the literature (U.S. Department of Education, Office of Educational Technology, 2023).

The debate on academic integrity intensified following the public release of Chat GPT in late 2022. Early institutional responses included restrictive or precautionary measures, such as temporary bans and modifications to grading policies. However, subsequent discussions increasingly emphasized the development of balanced regulatory frameworks that permit the use of generative AI under clearly defined conditions, including mandatory disclosure requirements, transparent attribution practices, and revised assessment strategies designed to preserve academic standards (Bittle & El-Gayar, 2025).

Secondly, data privacy. AI systems (for example, adaptive platforms or learning analytics) collect large amounts of data on students' academic performance and behavioral patterns. The task is to ensure reliable protection of this data and transparency of how it is processed in order to prevent violations of confidentiality or discrimination based on hidden grounds. European documents explicitly emphasize the need to comply with GDPR and other standards when implementing AI in education (European Commission, 2022; European Commission, n.d.-a).

Thirdly, the bias and fairness of algorithms: if AI is used to select applicants or evaluate papers, it is necessary to ensure that there is no built-in bias (for example, on linguistic, gender, or cultural grounds) (Schiff, 2022)

Fourth, the role of the teacher and trust. An ethical dilemma arises: how much can one rely on recommendations generated by AI (whether it's evaluating an essay or choosing a learning route), and how does this affect the teacher's role? The concept of “Human-in-the-loop” suggests that AI solutions should be considered only as auxiliary, and the final word remains with the teacher (U.S. Department of Education, Office of Educational Technology, 2023). This is necessary in order to maintain pedagogical responsibility and avoid situations where an opaque algorithm categorically determines the student's academic fate.

At the same time, empirical research on generative AI and academic integrity remains methodologically fragmented. Many studies rely on perception surveys, institutional guideline analysis or short-term experimental interventions, while longitudinal evidence on learning outcomes and equity effects is still limited. As a result, public debates about risks and benefits often outpace robust causal evidence, complicating cross-regional comparison and systematic evaluation.

In parallel with politics and ethics, researchers analyze specific practices of using AI in the educational process. Works on pedagogy highlight the potential of Intelligent Teaching Systems (ITS) to personalize student learning. Even before the current wave of generative AI, numerous studies have demonstrated the effectiveness of ITS in various disciplines – from mathematics to language learning – by adapting the complexity of tasks to the student's level and providing instant feedback. Such tools are also emerging in journalism education: for example, systems that help students practice the skills of writing news articles with

automatic indication of stylistic errors or deviations from the structure of the news. Another class of practices is automated assessment systems (for example, algorithmic assessment of essays). Until recently, their accuracy left much to be desired, but with the improvement of language processing models, they are beginning to be used to relieve teachers when reviewing large amounts of work. At the same time, as Kasneci et al. point out. (2023), new large language models open up other possibilities: personalized assistants for students who are able to explain the material and answer questions in an interactive mode (Babacan et. al., 2025; Kasneci et al., 2023). Such approaches are beginning to be reflected in the practices of Kazakhstani universities. So, in 2025 at the private university "Q University" (Almaty) A seminar was held for journalism students on the topic "Journalism and Media in the age of AI", where cases of using neural networks in the media sphere and future skills required from graduates were discussed (Kazakh university, n.d.). Thus, the process of adapting pedagogical approaches is underway everywhere: from purely lecture-based learning towards a more interactive, project-based approach using digital platforms.

Although international literature provides substantial normative guidance and an expanding body of empirical findings, cross-regional comparisons remain analytically inconsistent. Studies rarely apply shared indicators encompassing governance structures, accessibility conditions, ethical safeguards and pedagogical adaptation. Consequently, it remains difficult to explain how socio-political contexts shape AI implementation in journalism-oriented higher education across different regions.

Therefore, the present study seeks to develop a comparative sociological framework for analyzing AI integration in higher education across Kazakhstan, the European Union, the United States, China and Japan, with particular attention to governance models, infrastructural capacity, ethical regulation and curricular adaptation in journalism-oriented programs.

Research methods and organization

To achieve these goals, a strategy of comparative sociological analysis was used, combining qualitative and quantitative methods. The object of the analysis is the process of introducing AI into journalism education programs in higher education, and the subject is its features in various socio-cultural and institutional contexts (Kazakhstan, Europe, USA, China, Japan).

The research is interdisciplinary in nature and is based on the following methods: (1) analysis of documents and literature, national strategies and programs have been studied (for example, the concept of AI development in Kazakhstan until 2029, the EU Digital Education Action Plan, reports of the US Department of Education, etc.). (2) Integrated comparative case analysis, each of The five selected regions was treated as a separate case, after which they are compared according to uniform parameters. (3) Secondary analysis of statistical data international indicators are used (the level of Internet penetration, investments in AI, the number of educational programs on AI, etc.), as well as survey and research data reflecting the perception of AI by students and teachers. These quantitative data are used to illustrate similarities and differences between regions.

It should be noted that direct measurement of the degree of AI implementation in educational programs is a complex task, since qualitative changes are not always reflected by quantitative metrics. Therefore, within the framework of the methodology, it was decided to rely on expert assessments and indirect indicators (availability of strategies, examples of implemented courses, evidence from the literature), taking into account the limitations of each individual indicator. The comparative sociological approach made it possible to take into account a wide socio-cultural context: the regulatory framework, economic conditions, public expectations, and the level of digital literacy, and correlate them with the observed practices of using AI in the education of journalists.

To enhance the analytical rigor of the comparative framework, this study introduces a structured composite indicator the AI Integration Index (AIII). The index serves as an operational tool for assessing the degree of institutional integration of artificial intelligence in journalism education across different regional contexts.

The development of AIII is grounded in internationally recognized policy and governance frameworks, including the European Commission’s Digital Education Action Plan (2021-2027) and Ethical Guidelines on the Use of Artificial Intelligence in Education (European Commission, 2022), the U.S. Department of Education’s report Artificial Intelligence and the Future of Teaching and Learning (2023),

national AI strategies analyzed in comparative policy research (Schiff, 2022), infrastructural indicators provided by the International Telecommunication Union (ITU, 2023), and the state–university–industry cooperation model described in the Chinese context (Fu & Ji, 2024).

Conceptual Dimensions

The index consists of four analytically distinct dimensions reflecting the multidimensional nature of AI integration in higher education:

1) Public Policy and Strategic Commitment (P). Presence of national AI strategies, regulatory acts, measurable implementation targets, and institutional coordination mechanisms.
2) Technological and Infrastructural Readiness (T). Internet penetration rates, institutional access to AI platforms, computational infrastructure, and systemic digital investment.
3) Ethical and Regulatory Framework (E). Existence of formal AI ethics guidelines, academic integrity policies related to generative AI, data protection standards, and adherence to "human-in-the-loop" principles.
4) Curricular and Pedagogical Integration (C). Inclusion of AI-related courses in journalism programs, integration of data journalism modules, intelligent tutoring systems, AI-assisted assessment, and faculty training initiatives.

Scoring Procedure

Each dimension is evaluated on a five-point ordinal scale:

1 - Minimal or declarative presence
2 - Fragmented and experimental initiatives
3 - Structured but limited implementation
4 - Coordinated and systemic integration
5 - Advanced, institutionalized, and scalable integration

Scores are assigned based on documented policy documents, statistical indicators, and peer-reviewed academic sources referenced in this study.

The composite index is calculated as:

$$AIII = \frac{P + T + E + C}{4}$$

where P, T, E, and C represent the respective dimension scores.

This balanced approach reflects the sociological premise that AI integration is a multidimensional institutional transformation rather than a purely technological process.

The application of the index is presented in the Results section.

The analysis was carried out in stages. At the first stage, a reference profile was compiled for each region, including: an overview of government policy in the field of AI and education, current initiatives at universities, problems noted in the literature (for example, resistance from teachers, lack of resources, ethical dilemmas), examples of specific journalism programs or faculties implementing AI. In the second stage, all five profiles were compared according to the specified categories. The matrix mapping technique was used: the data weresummarized in a table, where the analysis categories (politics, accessibility, ethics, pedagogy) were arranged along the rows, and the regions were arranged along the columns. A fragment of the summary table is presented in the "Results" section. At the final stage, the interpretation of the comparative data obtained from the standpoint of the sociology of education was carried out: historical, cultural, and economic differences affecting the perception and implementation of AI were taken into account.

The limitations of the study are related, firstly, to the fact that the available data may not fully reflect the actual practice on the ground (especially if changes have occurred recently, the literature may be late). Secondly, the focus on journalism education narrows the field of analysis – the conclusions apply mainly to this field and related humanities specialties, although many trends are typical for other disciplines. Nevertheless, the chosen methodological approach provides a sufficiently broad and reliable overview to identify key global trends and regional specifics.

The results of the study and their discussion

The results are presented in two stages: first, brief characteristics of each of the regions under consideration are given in terms of the introduction of AI in higher education (especially in the field of journalism), then summarized in a comparative table.

To complement the qualitative comparison presented above, the AI Integration Index (AIII) was applied to the five regions under consideration.

Table 1.

AI Integration Index (AIII) Scores by Region

Region	Policy (P)	Technology (T)	Ethics (E)	Curriculum (C)	AIII Score
Kazakhstan	4	3	3	3	3.25
European Union	4	4	5	4	4.25
USA	3	4	4	4	3.75
China	5	4	3	5	4.25
Japan	4	4	4	3	3.75

The index reveals differentiated models of AI integration rather than linear developmental hierarchies. China demonstrates the highest level of centralized strategic mobilization (P = 5) and large-scale curricular expansion (C = 5), reflecting its state-driven model of coordinated AI development and institutional scaling. However, ethical governance remains embedded primarily within national regulatory discourse rather than decentralized institutional frameworks, which explains its moderate ethical score (E = 3).

The European Union combines a strong regulatory architecture (E = 5), supported by the AI Act and ethical guidelines, with high infrastructural readiness and systematic curricular reforms. Its integration model is characterized by normative consolidation and regulatory coherence.

The United States exhibits strong technological capacity and innovative pedagogical practices (T = 4; C = 4), but the absence of centralized coordination results in a moderate policy score (P = 3), reflecting a decentralized bottom-up model.

Japan represents a hybrid approach, balancing state guidance with university autonomy. While technological readiness is high, curricular integration progresses cautiously, consistent with Japan’s incremental innovation culture.

Kazakhstan demonstrates proactive strategic commitment (P = 4) with ambitious targets for AI integration. However, infrastructural capacity and pedagogical implementation remain in a developmental phase, which explains the composite score of 3.25. The results suggest a transitional model characterized by policy acceleration and gradual institutional adaptation Kazakhstan. In recent years, Kazakhstan has demonstrated high activity in promoting AI at the state level. In 2024, the Government of the Republic of Kazakhstan adopted a Concept for the development of artificial intelligence until 2029, which provides for the formation of a full-fledged AI ecosystem in the country and accelerated technology adoption in all sectors, including education (Government of the Republic of Kazakhstan, 2024). The identical composite scores of China and the European Union do not indicate institutional similarity, but rather reflect different pathways toward high-level integration centralized mobilization in China and regulatory-normative consolidation in the European context.

Separately, Kazakhstan relies on international cooperation and the involvement of expertise. Partnerships have been concluded with major global companies, for example, Google Corporation in 2023-24 helped launch courses on generative AI for students of 15 Kazakhstani universities, reaching ~12 thousand students (Sakenova, 2024).

The availability of technology in Kazakhstani universities is gradually increasing thanks to government projects on the digitalization of education. According to official data, 92.9% of the country's population is using the Internet by 2023 (Trading Economics, n.d.) and large universities have established competence centers in the field of AI and big data.

The ethical aspects of the use of artificial intelligence (AI) in Kazakhstan are beginning to receive increasing attention at both the state and academic levels. One of the key steps was the approval in 2024 of

the Concept for the Development of Artificial Intelligence until 2029, which specifically emphasizes the importance of observing moral and legal norms in the implementation of AI. The concept involves the development of ethical standards that take into account national cultural and spiritual values and are aimed at protecting human rights, non-discrimination and ensuring justice in the process of digital transformation (Digital Rights, 2024). In general, the ethical policy at the university level is still being formed. Some include warnings about the prohibition of unjustified use of generative AI in educational work, but there are no uniform rules. However, awareness-raising activities are underway: for example, in 2023, Satbayev University hosted a seminar of the Ministry of Education and Science of the Republic of Kazakhstan on the ethics of AI application in education (Ministry of Science and Higher Education of the Republic of Kazakhstan, 2025).

As for pedagogical practices, Kazakhstani universities are at the beginning of the path of AI integration. New educational programs are being formed: in 2022, Astana IT University launched the bachelor's degree program "Digital Journalism" with the study of AI tools (Astana IT University, n.d.). Journalism teachers are being retrained in the use of digital tools. Nevertheless, traditional teaching methods still prevail, and one of the tasks is to prepare the teaching staff for the use of AI in the classroom. Extracurricular activities are organized for journalism students: media technology hackathons, meetings with practitioners using AI in the media. Table 1 provides a summary for Kazakhstan along with data for other regions.

Europe (the European Union and European countries). The European experience of introducing AI into higher education is characterized by a balance between innovation and regulatory measures. EU policy sets the general direction: the digital transformation of education is considered as part of the implementation of the concept of "Europe in the Digital age". At the supranational level, the aforementioned Digital Education Action Plan 2021-2027, the Horizon Europe initiative with funding for EdTech and AI research, and draft ethical standards have been prepared. Many EU countries have developed their own AI strategies, which also reflect educational aspects. For example, back in 2018, France noted in the Villani Report strategy the need to introduce AI courses at all universities and create centers of excellence in this field; Germany, as part of the KI-Campus program, funds an online platform for teaching AI to both students and the general public. In the Scandinavian countries (Finland, Estonia), national programs have been implemented to teach the basics of AI (free online courses such as Elements of AI), which have reached hundreds of thousands of citizens, this increases the overall level of literacy, including among students of humanities. Thus, Europe's strategic focus is on massively increasing AI literacy and training, while simultaneously developing AI research in education and introducing standards for safe use (European Commission, n.d.-b; European Commission, n.d.-c; European Commission, n.d.-d; KI-Campus, n.d.; Reaktor & University of Helsinki, n.d.)

The availability of technology in European universities is generally high, especially in Western Europe. In the field of journalism, European universities often cooperate with the media industry: the BBC, Reuters, Deutsche Welle and other major media participate in educational projects (for example, joint courses, internships), bringing their best practices in the field of media technology, including AI, to universities. As a result, journalism students in Europe often have the opportunity to work with cutting-edge tools, whether it's analyzing big data for investigative journalism or using algorithms to monitor social media.

In Europe, issues of AI ethics in education are being addressed at the institutional and national levels, with an emphasis on transparency and security. In addition to the pan-European principles, ethical committees are being established at the university level, and guidelines on the use of AI are being issued.

Teaching practices in European journalism schools are very diverse. Many universities are revising their curricula: they are introducing new courses (for example, "Algorithms and Automation in Media", "Data for Journalists"), updating existing disciplines ("Multimedia Journalism" now includes work with neural network tools for creating content, etc.). The example of Spain described in the Tejedoretal study is illustrative. (2024): After analyzing the curricula of 37 journalism faculties, the authors found that over the past 5 years there has been a significant increase in the number of subjects related to AI and big data (Tejedor et. al., 2024)

Similar processes are underway in Italy, Germany, and the Scandinavian countries. European teachers

are actively involved in international projects on innovation in education: for example, the Erasmus+ program implements online courses on data journalism with the participation of universities from different countries, which use online platforms and AI modules for data analysis.

USA. Higher education in the United States is characterized by decentralization, so the introduction of AI depends on the initiatives of specific universities and states. The policy at the national level is advisory in nature. However, in 2022-2023, AI issues in education have firmly entered the agenda of national pedagogical associations and accreditation bodies. In 2023, the Association of Universities and Colleges (ACE) issued a statement calling on universities to adapt their rules to the era of AI and share practices that enhance the quality of education. Some states are promoting legislative initiatives: for example, California is discussing funding programs to develop open AI tools for public universities to compete with commercial ones. But still, the main drivers are the universities themselves, especially the large and wealthy ones.

The leading universities in the United States have high-tech infrastructure, although the level of equipment varies between large universities and less well-funded colleges.

Ethical and regulatory aspects in American universities are addressed through the updating of internal codes. Universities include provisions on the inadmissibility of presenting someone else's (including machine) work as their own, in fact, expanding the concept of plagiarism to cases of AI generation. Interestingly, some universities (such as the University of Michigan) have officially allowed the use of AI, provided they specify which tools were used and how, thereby incorporating transparency. At the same time, difficulties were discovered: AI text detection tools (for example, GPTZero) turned out to be unreliable, which gave rise to a discussion about the presumption of innocence of students. Courses on professional ethics and algorithmic transparency are widely available in American journalism schools. Modules on algorithmic ethics are now being added there: cases where news algorithms have led to distortions (as in the case of the Facebook news feed scandals) are being considered, and the role of a journalist in correcting such situations is discussed.

Teaching practices in the United States are very diverse, from traditional to innovative. Since 2019, New York University has been offering the course "Algorithmic Responsibility for Journalists", which teaches algorithm auditing. The University of Texas has opened an automated journalism lab where students create programs for sports news. In 2022, Northwestern University (Illinois) launched the Medill AI for Local News project, in which students, along with engineers, develop bots for local media, combining study and research. Data journalism and Python skills are becoming the standard in training journalists. However, in some traditional schools, especially those focused on creative writing and broadcasting, AI is perceived more as a topic for discussion rather than a practical tool. Student communities and external organizations, such as the Knight Foundation and Mozilla, which finance training programs and competitions, play an important role. In general, the introduction of AI into journalism education in the United States is developing from the bottom up: initiatives come from universities and communities, which creates diversity, but also heterogeneity in the training of specialists.

China.China has a large-scale centralized government program to integrate AI into education. The main goals are to train approximately one million AI specialists by 2030 and create more than 50 advanced AI centers at worldclass universities. By 2024, over 500 universities have opened AI specialties, covering almost all major educational institutions in the country (Fu & Ji, 2024).

The government is actively investing in equipping universities with modern digital equipment, while large private companies as Alibaba, Tencent, Baidu also support universities with cloud technologies and software. For example, iFlytek has implemented a voice assistant system in Chinese at pedagogical universities to help students (Zhejiang University, 2025). In 2025, a program to support the western regions was launched with the creation of branches of technical universities and the supply of modern equipment (Central China Normal University, 2024).

In journalism, leading faculties such as the University of Communications of China work closely with state media. The Xinhua news agency and TV already use AI-robot presenters and automatic news production, which gives students the opportunity to learn based on advanced technologies (UNU Macau, 2024). Ethical regulation of AI in China is being formed within the framework of the state digital development strategy. In 2021, the national ethical principles for the development of artificial intelligence were published, emphasizing the priority of social stability, social responsibility and controllability of

technology. Research shows that the Chinese model of AI regulation combines the normative consolidation of value orientations and centralized control by the state, which distinguishes it from Western models focused on individual rights and transparency of algorithms (Fu & Ji, 2024).

Pedagogical practices in Chinese higher education are large-scale and focused on the integration of AI. Online platforms are widely developing in the country, allowing millions of students to access courses from leading professors using AI systems that monitor progress and answer questions. The educational programs include technological modules aimed at developing digital competencies and working with big data, which is especially important for journalism and the media sphere. Students gain practical skills in working with digital tools through projects and internships, which increases their competitiveness in the labor market.

Japan. Japan, with its advanced economy and technology, is introducing AI into education more cautiously, focusing on preparing the ground and studying the effects. The policy is formed by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). In 2022-2023, MEXT issued a number of recommendations for schools and universities: for example, the "Guide to the Use of AI in Education" (2023), which calls for combining AI tools with the development of students' critical thinking and understanding where AI is useful and where it is harmful (Fu & Ji, 2024). AI education occupies an important place in the national strategy "Society 5.0": it is assumed that AI will help solve the problem of labor shortages (including teachers) in the aging population of Japan, as well as individualize education for different students. MEXT funds pilot projects in a number of schools, testing them before widespread implementation.

Technology accessibility: Japanese universities are well equipped, and connectivity is excellent even in remote areas (due to the country's compactness and investments). However, until recently, Japanese teachers were in no hurry to switch to digital methods, Japan was lagging behind in educational digitalization (before Covid, most universities made little use of online learning). The pandemic has pushed for change, and now the infrastructure is ready to accept AI tools. The advantage of Japan is the high level of technical literacy of students compared to many countries (almost all young people know how to use various applications and gadgets). Journalism faculties use both global tools (English-speaking) and local Japanese developments: for example, there are Japanese speech recognition systems that are used in media schools to transcribe interviews (which saves students time).

In 2023, the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) published an official notification on the treatment of generative AI at universities and colleges. The document highlights that the use of generative and independent intellectual work by a student is "unable to deepen their own understanding" and is generally considered as an appropriate practice in the educational process (Kaneko, 2023)

At the same time, Japan actively participates in the development of international principles of “Human-Centered AI” through the OECD organization, and these principles are also being implemented in domestic policy: AI is only an assistant, it should not replace humans, it is necessary to maintain human control and understanding. The ethical education of students includes discussions about the impact of AI on society (for example, on the employment of journalists, on the quality of information), which is part of a more general medialitacy course.

Pedagogical practices: Japanese universities are starting to use AI for educational purposes, often relying on robotics. There are known cases of using mentor robots in elementary and secondary schools (robots that teach English in rural schools). Of course, robots are not used in journalism universities, but they can be used to demonstrate technology: for example, at Waseda University, the journalism faculty held a lecture with a robotic TV presenter, after which students discussed whether he could replace a human. Practically, Japanese NLP tools are used in the educational process: systems that check articles for compliance with stylistic norms can offer headlines (analogous to Western ones, but in Japanese). Teachers encourage students to check the facts found by AI, teaching them not to trust blindly. Japan has a strong tradition of group learning, and they are currently experimenting with peer-learning: groups of students work together on projects, and the AI system provides hints and ratings of the ideas they generate. Such a project was implemented at the University of Tokyo for a course on digital media: an AI analyzer evaluates the proposals of news startups from students, highlighting the most promising ones - this stimulates discussion and refinement of ideas.

The results of a comparative analysis of the introduction of artificial intelligence technologies into higher education (using the example of training journalists) are systematized and presented in Table 2.

Table 2.

Comparative characteristics of the introduction of AI in higher education (journalism) by region

Aspect	Kazakhstan	Europe	USA	China	Japan
Government policy	AI concept 2024-2029, top-down, goals of 20% of universities by 2025, 60% by 2029, support for international cooperation (Google, KazLLM), budget 650 billion tenge.	Digital Education Plan 2021-2027, Horizon Europe, national strategies, support for research and AI literature.	Decentralized, initiatives come from universities and communities; advisory recommendations at the national level (ACE); some states are considering funding open resources.	Centralized strategy, training of ~1 million specialists by 2030, >50 AI centers, mass implementation in universities and the media, support for the private sector.	Gradual implementation, Society 5.0 strategy, hybrid approach: the state sets the framework, universities are autonomous, emphasis on critical thinking.
Technologies	AI platform, supercomputer, competence centers, 92.9% Internet coverage.	High level of equipment, cooperation with the media (BBC, Reuters, DeutscheWelle)	High-tech infrastructure of leading universities, the gap between large universities and colleges.	Mass equipment, online platforms for millions of students, support for the public and private sectors.	Well-equipped universities, excellent communications, and infrastructure are ready after the pandemic.
Ethics and legal aspects	The concept and draft law "On AI", the formation of university rules, seminars and conferences on AI ethics.	EU recommendations, university committees, transparency of algorithms, data protection.	Internal codes of universities, expanding the concepts of plagiarism on AI, courses on ethics of algorithms.	Code of Ethics for AI, emphasis on the public good, honesty, data accuracy, human control.	Prohibition on the replacement of human AI, internal rules, participation in international principles of Human-Centered AI, discussion of social consequences.
Pedagogical practices	New AI and digital journalism courses, teacher retraining, hackathons and projects. Examples: Bachelor's degree program in Digital Journalism (Astana IT University, 2022), seminars on AI ethics (Satpayev University, 2023).	Project courses, collaboration with EdTech, EDX and Coursera platforms, AI literature for humanities and technical students. Examples: Elements of AI (Finland, Estonia), courses on algorithmic skills (Spain, Tejedoretal, 2024).	Online courses, IT specialists, hands-on practice with popular bots, Python, and data journalism. Examples include Medill AI for Local News (Northwestern University, 2022) and Algorithmic Accountability Reporting (New York University, 2019)	Massive online courses, AI mentors, projects and internships, an emphasis on Big Data and digital competencies. Examples: iFlytek voice assistants, internships with Xinhua and TV News, online platforms for millions of students.	Robotics for demonstration, Japanese NLP systems, critical thinking, group projects with AI tips. Examples: Waseda University's mentor robot, an automatic review system for articles and headlines at the Faculty of Journalism.
Critical analysis and features	An active strategy, limited resources, the initial stage of integration, flexible borrowing of international experience.	Strong integration into digital strategies, differences between EU countries;	Flexibility and innovation, fragmentation and the gap between universities, the predominance of the bottom-up	Large-scale implementation, systematic approach, strict control limits creative application, high centralization. Features: training	Slow implementation, emphasis on ethics, critical thinking and inclusivity, a combination of top-down and university autonomy. Features:

Features: a combination of a top-down approach with the adaptation of global practices, attention to the Kazakh language and cultural peculiarities (KazLLM).	high degree of university autonomy while respecting ethical standards. Features: massive increase in AI literature, collaboration with the media industry, student project work.	approach. Features: wide variability of practices, participation of student communities and external funds, development of applied skills through laboratories.	specialists for economics and startups, integration of AI at the mass level, practical ethics.	attention to the social role of AI, support for remote and special schools, and the gradual introduction of new technologies through pilot projects.

A comparative analysis of the introduction of artificial intelligence into higher education (using journalism as an example) shows both universal trends and significant regional differences.

General trends. All countries recognize the need to adapt educational programs to the age of AI: new courses are being created on working with data, learning digital tools and improving AI literature. Ethics is taking on an increasing role: university and national rules for the use of AI, especially generative systems, are being developed. The teacher remains a key participant in the process: AI is perceived as an auxiliary tool, not a substitute for humans.

Regional differences. China and Kazakhstan demonstrate a systematic, top-down approach: high investment, centralized management and large-scale implementation. The difference in emphasis is that China is focused on economic impact and mass training of specialists, while Kazakhstan is focused on adapting international experience and cultural and linguistic peculiarities (KazLLM).

The USA and a number of European countries are implementing initiatives mainly from below: universities, research centers, EdTech companies. This creates innovation and diversity of practices, but also fragmentation. In these countries, the main focus is on developing students' analytical and research skills.

Japan demonstrates a hybrid approach: the state sets the framework and ethical standards, universities maintain their autonomy. The emphasis is on critical thinking, inclusivity, and the social function of AI.

Recommendations for Kazakhstan include the development and adaptation of ethical standards for the responsible use of AI in the educational process, as well as the creation of open educational resources in the Kazakh language to overcome language barriers and ensure equal access to learning opportunities. It is also important to introduce a system for monitoring the effectiveness of implemented AI courses, including the assessment of their impact on graduates’ career paths. In addition, Kazakhstan should continue retraining teachers and support the development of projects aimed at integrating AI into various academic disciplines.

In order to complement the qualitative comparison presented in Table 1, selected quantitative indicators reflecting infrastructural readiness, scale of AI implementation, and policy commitments are summarized in Table 2. These indicators do not aim to provide exhaustive statistical measurement but serve as analytical proxies allowing structured cross-regional comparison.

Table 2.
Selected Quantitative Indicators of AI Integration in Higher Education (Journalism Context)

Indicator	Kazakhstan	European Union	USA	China	Japan
Internet penetration (%)	92.9%	89–95% (varies by country)	~92%	~76–80%	~94%
Universities offering AI-related programs	Target: 60% by 2029	Widespread integration	Institution-driven	>500 universities	Expanding
National AI Strategy	Yes (2024–2029)	Yes (AI Act, Digital Plan)	Advisory federal guidance	Yes (2017 Plan; national targets)	Yes (Society 5.0)
Target number of AI specialists	Expanding programs	Not centralized	Not centralized	~1 million by 2030	Not centrally quantified

The quantitative indicators reveal important structural asymmetries. China demonstrates the highest degree of centralized scaling and measurable expansion targets, while Kazakhstan reflects ambitious strategic planning combined with ongoing infrastructural development. The European Union shows high digital penetration but emphasizes regulatory harmonization rather than numerical mobilization. The United States displays strong infrastructural capacity without centralized coordination, whereas Japan combines high technological readiness with gradual, non-quantified implementation.

Thus, statistical proxies confirm that AI integration models differ not only in policy rhetoric but also in measurable structural commitments and infrastructural capacity.

In all the countries studied, there is a recognition of the need to adapt journalism education to the era of AI. The curricula include new courses on working with data, mastering digital tools, and improving AI literacy. The importance of training graduates who are able to adapt to the transforming media and technological landscape is emphasized. In addition, attention to ethics is increasing everywhere: universities are developing regulations on the use of AI, especially generative systems (ChatGPT, etc.), which has become especially relevant since 2023. There is also a common understanding of the role of the teacher as an indispensable participant in the educational process, AI is everywhere perceived as an auxiliary tool, not an alternative to humans.

Regional differences are caused by political and administrative traditions, economic resources, cultural attitudes, and educational priorities.

China has a centralized education digitalization strategy that ensures high-speed AI adoption and coordination between levels. On the contrary, in the United States, Great Britain, and a number of European countries, initiatives often come from "below" from universities, research centers, and EdTech companies. This leads to fragmentation, but it also promotes innovation.

Kazakhstan occupies an intermediate, but strategically advantageous position: it actively borrows and adapts international best practices, taking into account national realities, cultural characteristics and linguistic specifics. Despite the objective limitations in resources compared to developed countries, the state demonstrates a consistent and purposeful policy in the field of digital transformation of education. Kazakhstan shows an example of flexible integration of innovations, in which digitalization is not perceived as an end in itself, but becomes a tool for modernizing and increasing access to education.

Japan demonstrates a hybrid approach: the state sets the framework, but universities retain their autonomy. The ethical aspects and social function of AI are more prominent here, with an emphasis on supporting remote schools and students with special needs.

Cultural differences manifest themselves in the perception of AI. In Western countries, the risks and benefits of technology are actively discussed, and students are involved in these discussions. In Asian schools, innovations are introduced more consistently and hierarchically, and students are more likely to demonstrate their willingness to adopt technology. However, the language barrier remains a problem: English-language resources dominate, and this limits the availability of AI tools. Localized language models

are being developed in China and Japan, and steps are also being taken in this direction in Kazakhstan (for example, KazLLM).

In the USA and Europe, the main focus is on improving the quality of education and analytical skills of students (for example, in journalism, conducting investigations using AI). In China and Kazakhstan, the focus is on the economic impact: graduates should be able to develop AI products and launch startups. In Japan, it's about equality and inclusivity.

Teachers' willingness to integrate AI varies: in China, it happens with strong government support, in Europe and the United States more flexibly, with an emphasis on digital autonomy and the development of a culture of innovation. Professional development programs are being implemented in Kazakhstan. In Japan, innovation is introduced through gradual reflection, supported by academic traditions.

The level of trust in government and technology is higher in China and Kazakhstan, which accelerates digital transformation. In Western countries, on the contrary, caution and criticality prevail due to concerns about privacy and transparency of algorithms.

Practical recommendations include the development and adaptation of ethical standards for the use of AI in the educational process, ensuring that new technologies are applied responsibly and transparently. It is also important to create open educational resources, including materials in the Kazakh language, in order to provide equal access to AI-related learning opportunities and reduce language barriers. In addition, regular performance monitoring should be introduced: after several years, the impact of AI courses on graduates' career trajectories should be assessed to determine their practical effectiveness and relevance to the labor market.

Future work may focus on interdisciplinary differences, quantifying the level of AI integration (for example, through the creation of the AI Integration Index), as well as examining students' perceptions of AI in different countries. It is promising to conduct a case study on specific universities, allowing for a deeper understanding of barriers and successful practices.

Conclusions

By the mid-2020s, the integration of artificial intelligence into higher education in journalism had become a global phenomenon, but it proceeds in different ways depending on regional conditions. Global trends include an accelerated revision of curricula taking into account digital skills and AI, the search for the optimal combination of technology and traditional teaching methods, as well as increasing attention to issues of ethics and equal access. Comparative sociological analysis has shown that each region, as well as each country, has its own unique "ecosystem" of AI implementation.

In Kazakhstan, there is a proactive government strategy and the desire to quickly catch up, as in other CIS countries, through large-scale effective initiatives, while the challenges remain the lack of practical experience among teachers and logistical resources among some universities, the need to localize content (taking into account the use of Kazakh as the main language in working with AI) and the formation of a high culture of academic integrity in the new digital environment.

In Europe, there is a gradual but thorough integration, framed by strict ethical standards and regulations; European journalism programs focus on improving analytical skills and critical thinking, using AI as a tool, but at the same time limiting it if it contradicts values (transparency, fairness).

In the USA, there is a mosaic of approaches: outstanding innovations are juxtaposed with conservatism; market demand and initiatives of universities themselves play a key role. The American experience is valuable as examples of successful practices emerging from below, but there is a lack of uniformity, the gap between leaders and laggards may grow.

China has an unprecedented large–scale integrated AI development in the shortest possible time, based on centralized management and resources; students gain access to technology from an early age. China demonstrates the high results that can be achieved by comprehensive, clear and systematic mobilization of all levels of higher education.

In Japan, there is a moderate, prudent path: Japanese universities modernize education, carefully analyzing the effectiveness of innovations. Combining advanced technologies with a traditional educational culture takes time to adapt, but in the long run, Japan is able to quickly scale successful solutions (for example, the use of robots or AI assistants) to the national level thanks to the unity of standards and

government support.

Summing up, we can conclude that the successful implementation of AI in higher education is a multifaceted process that requires a balance between technical innovation and social and moral values. The experience of different regions teaches that not only the technologies themselves are important, but also the context of their application: politics, culture, and people's willingness to change. In the context of journalism education, this means educating a new generation of professionals who not only possess AI tools for creating and distributing information, but are also aware of the responsibility for their use. International exchange of experience plays a key role: globally, countries should learn from each other how to integrate AI into education as effectively and ethically as possible. Such cooperation and comparison of approaches will help to develop best practices that ensure the quality and inclusivity of education in the digital age.

In conclusion, we note that the introduction of AI is not a one–time event, but a phenomenon that is increasing its presence in an increasing number of areas of our lives. Undoubtedly, AI technologies will continue to evolve, so the modern higher education system must remain flexible, operational and adaptive. Keeping a human being – a teacher, a student, an editor – at the center of the educational process, with all the growing influence of artificial intelligence (AI), will ensure that higher education is not only high-tech, but also humanistic, aimed at modern comprehensive civilizational development of the individual and society.

Conflict of Interest Statement

The authors declare no potential conflicts of interests regarding the research, authorship, or publication of this article.

Author Contributions

The authors affirmed that there is no conflict of interest in this article. Nurbanu A. Abueva carried out the conception and investigation. Aliya M. Zhusupova overlook the writeup of the whole article and prepared the relevant literature. Saltanat S. Massakova wrote the research design and conducted the data entry, revised critically the article for intellectual content. Anna S. Buzelo carried out the data analysis. Unerbek A. Abuev prepared the interpretation of the results, contributed to drafting and revising the article.

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DEVELOPMENT OF PROFESSIONAL-CREATIVE COMPETENCES OF FUTURE BIOLOGY TEACHERS THROUGH THE DIGITAL ECOSYSTEM

Abstract. The study evaluated the effectiveness of developing professional and creative competence of students enrolled in the 6B01505 Biology, 6B01508 Chemistry-Biology teacher training programs through a digital educational ecosystem. A pedagogical experiment was conducted across diagnostic, formative, and control stages with the participation of 127 students. The instructional model incorporated virtual laboratories, 3D anatomical visualization, AR/VR simulations, digital biosimulations, analytical AI modules, and interactive design platforms. A mixed-method assessment approach was employed, integrating standardized tests, self-assessment questionnaires, observation checklists, and semi-structured interviews. Data analysis using SPSS Statistics 27 confirmed a statistically significant increase in competence indicators at $p < 0.01$. The motivational-value component improved from 2.84 to 4.19, cognitive-intellectual from 2.91 to 4.37, operational-technological from 2.76 to 4.45, and reflexive-evaluative from 2.63 to 4.22. Growth rates ranged from 47.5% to 61.2%, demonstrating substantial progress across all developmental dimensions. Qualitative findings indicated enhanced research initiative, analytical reasoning, and digital literacy among participants. The results support the transition to a modular educational structure, integration of digital research projects, and adoption of competence-oriented assessment strategies. The practical value of the study lies in strengthening professional identity formation of future teachers through reflective practices and competence monitoring tools.

Key words: oat, salt tolerance, project-integrative learning, biology teacher, research skills, practical experience, genetic analysis.

Introduction

The concept of "competence" was introduced into the field of education as a result of research in psychology. From a psychological point of view, competence is the ability of a specialist to act correctly in unexpected situations, use new approaches to communication, solve complex tasks, effectively use conflicting information, and plan the course of the process in advance. Professional creative competence is the ability of a specialist to master the knowledge and skills necessary for performing professional activities at a high level and to effectively apply them in practice. It requires mastering not individual knowledge and skills, but a generalized system of actions. A competent specialist must be able to continuously supplement his knowledge, search for, process, and implement new information in his activities.

Creativity requires interest, knowledge, diligence, risk-taking, internal motivation, and imagination. Interest, enthusiasm, and passion are recognized as important personal qualities. Knowledge, hard work, perseverance, and willingness to take risks are also identified as necessary qualities for creativity. Hard work and perseverance are of particular importance, as they contribute to the development of students' creative abilities. Intrinsic motivation and imagination are also mentioned as factors necessary for creativity in the classroom. According to research, there are pedagogical strategies aimed at developing creativity in biology. Research-based teaching methods allow for the development of skills in conducting experiments, collecting and analyzing data. The use of digital resources and virtual laboratories expands the possibilities for visualizing complex biological processes and research. Project tasks and 3D modeling ensure that students can clearly express their ideas and improve their creative thinking skills.

Cross-disciplinary approaches linking biology with computer science, mathematics or art disciplines allow students to come up with new solutions and apply ideas in different contexts. Tasks aimed at solving creative problems develop analytical thinking. Group and joint work contribute to increasing creative potential through cooperation. The assessment system should be based not only on the result, but also on the creative process, the ability to generate new approaches and ideas. The systematic introduction of strategies

into the lesson allows for the effective development of creativity in the professional practice of biology teachers, improving cognitive and research skills.

Krauss (2024) notes that the advantage of a competency-based approach is that it focuses on students applying their knowledge to real-life situations. In biology, there are many opportunities to use theoretical knowledge in practical work and analysis of environmental problems. It has been shown that integrated teaching of subjects creates a holistic approach to the natural sciences.

Tomlinson (2014) shows that adapting the content and methods of learning to the individual needs of each student allows for their independent development.

Nogerbek, A. (2022) conducted a scientific study on the professional competencies of students preparing for the specialty of biology teacher. Scientists used a two-dimensional tool in the study. Quantitative data were collected using a special scale for assessing the competencies of creative thinking and teaching technology. According to the results of the study, it was found that the level of creative thinking and the competence of using teaching technologies of students studying in the “Preparing Biology Teachers” program is at an average level. These competencies did not differ significantly depending on gender and course of study. Qualitative data showed that the majority of students need to pay attention to personal development, participate in events such as courses, seminars, and conferences to develop creative thinking. It is important to show interest in digital tools and systematically use them in the learning process to master teaching technologies. It is recommended to develop special educational content and organize seminars at universities on the methods of forming creative thinking and teaching technology competencies.

Digital educational platforms and virtual laboratories allow for the improvement of practical and creative activities in the field of biology. It opens the way for the introduction of innovative approaches in teaching biology. The modern educational space is moving towards digitalization, raising all components of the pedagogical process to a new level. In the formation of professional and creative competencies in the field of biology, the digital ecosystem plays an important role as an innovative environment that combines virtual laboratories, interactive simulations, online platforms and artificial intelligence-based learning tools. The ecosystem allows developing research skills, increasing creative potential, and effectively using modern digital technologies in future professional activities. Salybekova, N. (2023) and other scientists in the article “E-Learning Adoption: Designing a Network-Based Educational and Methodological Course on “Humans and Their Health” set the goal of introducing a methodological model based on a digital ecosystem for teaching secondary school biology. The proposed model is aimed at effectively organizing the online learning process, increasing the active participation of students and improving learning outcomes. According to the researchers, the development of professional and creative competence of teachers through a digital ecosystem is carried out through e-learning platforms. The ecosystem approach enhances learning motivation and contributes to increasing learning achievement. The article describes a study aimed at developing and implementing a distance learning course for the subject "Man and His Health". Based on the results of the first stage, an educational and methodological ecosystem was created in a network format and the effectiveness of its use in subject teaching was tested.

In recent years, the development of professional and creative competence through a digital ecosystem has aroused considerable interest in industry and academia. Most of the research is focused on human-computer interaction and the functionality of learning platforms. In academic works, consideration of the process from the perspective of developing students' competence is still rare among Kazakhstani scientists.

Foreign scholars Beghetto (2010) argue that in recent years, developing students' creative abilities has become an important educational goal worldwide, as it provides economic, social, and personal benefits. Glăveanu, Ness, Wasson, & Lubart (2019), Loveless (2003, 2007), Lubart (2005), Mishra, Yadav, & Deep-Play Research Group (2013) argue that ecosystem models are new tools and environments for developing students’ creativity. Cachia & Ferrari (2010) show that ecosystem technologies contribute to the development of creativity.

Scott, Leritz, & Mumford (2004), Lai, Yarbro, DiCerbo, & deGeest (2018), Ma (2006), Valgeirsdottir & Onarheim (2017) show that there are few experimental studies that have examined the effects of learning activities on ecosystem technologies on creativity. Andiliou & Murphy (2010), Skiba, Tan, Sternberg, & Grigorenko (2017) show that teachers’ attitudes towards creativity directly affect the ways in which students develop their creative abilities. Bereczki & Kárpáti (2018) studied how teachers understand creativity, the

characteristics of creative learners, and the characteristics of learning environments that foster creativity. Henriksen & Mishra, Merriman, Scott (2015) write that highly qualified teachers understand creativity scientifically and can use pedagogical strategies that stimulate it. Mullet et al. (2016), Ertmer, & Ottenbreit-Leftwich (2017) show that teachers' beliefs and practices are determined only through individual research on creativity and technology. Based on these theoretical foundations, we defined the purpose of our study. It is to develop a scientific and methodological model for the development of students' professional and creative competence based on the capabilities of the digital ecosystem and to identify ways to implement it in the pedagogical process.

Accordingly, the objectives of the study were determined:

1. To analyze the theoretical foundations of professional and creative competence of students in biology, chemistry and biology.

2. To identify the impact of digital ecosystem elements such as virtual laboratories, biosimulation, digital content, artificial intelligence tools on the professional and creative development of students and to propose a learning model.

3. To verify the effectiveness of the proposed model through practical and experimental methods.

Methods and organization of research

The educational process is organized using project-based learning, research-oriented approaches, and digital modeling methods. Structural components of digital ecosystems are integrated into laboratory activities through the use of platforms such as Labster, PhET, and BioDigital Human for creating virtual models of biological processes, conducting virtual experiments, and processing experimental data. Artificial intelligence tools, including ChatGPT Edu and BioStat AI, are employed to support digital data analysis within the information and analytical module. Collaborative scientific projects are developed using interactive digital platforms such as Miro, Padlet, and Microsoft Loop, fostering a creative and communicative learning environment. Students' professional development is continuously monitored through a reflective and interactive module utilizing Mentimeter and Google Forms Analytics for self-assessment and feedback. As part of the learning process, each student develops an independent digital project and conducts a virtual investigation of a biological object. Assessment of learning outcomes and professional competencies is based on a comprehensive set of diagnostic tools, including professional and creative competency assessment cards, checklists, self-assessment questionnaires, testing, semi-structured interviews, the five-point Likert motivation scale, the Pedagogical Motivation questionnaire, the Research Interest Index adapted from P. Renzulli's model, and tests developed in accordance with Bloom's taxonomy.

Results and discussion

The study was conducted in the conditions of a pedagogical university in the subject "Human Anatomy" of the educational programs 6B01505-Biology Teacher Training and 6B01508-Chemistry-Biology. During the experimental work, an ecosystem model was introduced into the content of the 2nd year "Human Anatomy" subject. It was aimed at empirically proving the effectiveness of the process of developing students' professional and creative competence through a digital ecosystem.

Virtual laboratories, 3D anatomical images, AR/VR simulators, PhET and Visible Body platforms were used as the core of the model. Technologies increased students' participation in research activities and influenced the development of motivational-value, cognitive and action components of professional and creative competence.

The practical and experimental work consisted of diagnostic, formative, control and final stages.

1) At the initial stage of the study, the level of professional and creative competence of students was assessed using four main criteria:

2) At the motivational-value level, internal motivation for professional and creative activity, professional orientation, and research interest were assessed. To determine the motivational process, the Likert 5-point motivational scale, the "Pedagogical Motivation" questionnaire, and the research interest index based on the Renzulli model were used.

3) 2. At the cognitive-intellectual level, the integration of biological knowledge, creative thinking, and the ability to make scientific predictions were assessed using a test based on Bloom's taxonomy.

4) 3. At the operational level, the use of digital tools and the organization of practical activities were carried out.

5) 4. At the reflective-evaluative level, self-analysis and the quality of professional decision-making were assessed. The assessment was carried out in the form of an individual reflective diary in digital format.

The features of integration with the motivational-value component and the digital ecosystem model were determined. The motivational-value component of professional-creative competence is considered the main psychological-pedagogical mechanism that determines the professional development of a biologist student. The digital ecosystem model expands the content of this component and creates conditions for the formation of motivation at a new level.

Table 1

Initial level indicators of professional-creative competence of students

Competency component	Low level (%)	Average level (%)	High level (%)
Motivational-value	33	52	15
Cognitive-intellectual	40	47	13
Operational and technological	38	50	12
Reflective-evaluative	36	51	13

The data in Table 1 show that the majority of all components of professional and creative competence are at an average level. Although the knowledge and skills necessary for professional activity of future biology, chemistry and biology teachers are formed, their deep creative activity and independent research skills are not sufficiently developed. The Likert scale recorded the instability of internal professional motivation. The Renzulli index revealed that research motivation is fragmented. The survey results showed that the career orientation of students depends on external factors. In terms of the motivational and value component, 33% were low, 52% were at an average level. The indicator indicates a weak professional interest and internal motivation, but the potential for development through ecosystem tasks was high.

The cognitive and intellectual component was 40% low, 47% at an average level. The fragmentary nature of biological knowledge and insufficient ability to make scientific predictions were observed in students. The operational and technological component was 38% low, 50% at an average level. The skills of using digital tools and organizing practical activities are unsystematic. The reflective-evaluative component is 36% low, 51% is at an average level. Self-assessment and professional decision-making skills remain at an unstable level. The results clearly demonstrate the need for a purposeful and systematic introduction of the digital ecosystem in the process of professional training. The need for a purposeful and systematic introduction of the digital ecosystem in the process of professional training was identified.

Scientific organization of the formative period

The research model was based on the concept of a pedagogical digital ecosystem. It was considered as a multi-level pedagogical system that increases the cognitive activity of the learner, integrates scientific and creative activity with the digital environment. The ecosystem model served as a dynamic pedagogical environment that ensures the learner's independent action in the digital space, creative decision-making and research activity. The ecosystem environment is characterized as a set of interconnected digital elements that activate the learner's internal motivation.

The formative stage was organized on the basis of the pedagogical digital ecosystem model. The structure of the model included Labster, PhET, BioDigital Human digital laboratory space, ChatGPT Edu, BioStatAi information and analytical module, Padlet, Miro, Microsoft Loop creative and communicative environment and Mentimeter, Google Form Analytics reflexive and interactive module as a single system.

In practical lessons on the subject of "Human Anatomy", digital laboratories, performing tasks of a research-research nature through an ecosystem model called Labster, PhET, BioDigital Human increased research interest and practical activity. During the study, students in the SPE developed a small scientific research project related to the subject of "Human Anatomy". They created hypotheses about biological phenomena and proved them through experience. They participated in online communities and professional forums, strengthening their professional orientation in the field of biology. Artificial intelligence-based learning platforms, such as adaptive tests, intelligent assistants, individually monitor the student's progress,

and work with analytical tools such as Mentimeter, Google Form Analytics allows for self-assessment. Biological data visualization tools, a virtual microscope, 3D modeling increase cognitive interest, and create an emotional connection to the professional world (Table 2).

Table 2

The manifestation of the motivational-value component in the ecosystem context

Indicators	View through ecosystem elements
Intrinsic motivation and professional interest	It is observed during the independent implementation of a research project in virtual laboratories and simulation platforms.
Professional orientation	Participation in online conferences and scholarly communities is strengthened by maintaining a digital portfolio.
Research interest	Data analysis, supported by artificial intelligence, is evolving in the process of creating numerical models of biological processes.
Value relationship	It is formed in the process of solving environmental, biotechnological, and ethical problems within the digital ecosystem.

The results showed that most students were at an average level, and some were at a low level. The ability to use digital technologies in the performance of professional and creative tasks was insufficient, and research and modeling skills were formed in a fragmentary manner.

The learning process was carried out using project-research and digital modeling methods. Each student completed an individual digital research project for a specific biological object, modeling anatomical processes based on AR/VR and 3D visualization. Such integrated activities enhanced the cognitive activity of students and combined professional and creative experience.

Table 3

Dynamics of components of professional and creative competence

Competency components	**Diagnostic period (%)**	**Formative period (%)**
Motivational-value	Low-33	Low-14
	Medium-52	Medium-41
	High-15	High-45
Cognitive-intellectual	Low-40	Low-15
	Medium-47	Medium-41
	High-13	High – 44
Operational and technological	Low-38	Low-16
	Medium-50	Medium-38
	High-12	High- 46
Reflective-evaluative	Low-36	Low-17
	Medium-51	Medium-41
	High-13	High-42

Comparative results in Table 3 showed positive dynamics in all components of professional and creative competence:

During the period of formation of the effectiveness of the cognitive and intellectual component, the indicator increased to 45%, and an almost threefold growth rate was recorded. During the diagnostic period, the share of high-level students was 15%. Such growth proves that the digital ecosystem modules contributed to the transformation of internal professional motivation into a stable motivational process. Digital laboratories, AR applications, and integration with scientific communities ensured that students recognized themselves as subjects of the scientific environment. As a result, professional goal-setting skills were strengthened, the perception of scientific research as a personal value was stable, and the desire to join the scientific community as a professional member increased. The component identified the ability to integrate biological knowledge, creative thinking, and scientific forecasting. Using the ecosystem model, students were able to connect anatomical structures with data from physiology, cytology, genetics, and molecular biology at an interdisciplinary level. Complex topics such as "Tissue", "Musculoskeletal System", "Nervous System", "Internal Organs" of the subject "Human Anatomy" were mastered on the basis of 3D

visualization and simulation models, and subject knowledge was integrated at the level of systematic scientific integrity. At the end of the experiment, the ability to analyze the interrelationships of biological systems, make scientific predictions, and draw substantiated conclusions significantly increased compared to the diagnostic stage.

The digital ecosystem formed professional and creative development as a natural, dynamic, and self-regulating process. The model provided an environment that not only developed the student's subject knowledge, but also strengthened his research activity and professional self-determination. Motivational and value orientation increased significantly, and students began to strive to apply theoretical material in practice and perceive the realization of their professional potential as a personal mission. The 45 percent increase recorded in the formative period proves the high effectiveness of the digital ecosystem in the formation of professional and creative competence.

In terms of the cognitive-intellectual component, students demonstrated the ability to spatially represent complex anatomical structures, system analysis, and explain functional relationships. The level of understanding of the interrelationships of tissue, bone, muscle, and joint systems through digital visualization increased. The ecosystem model allowed students to creatively apply their biological knowledge. The results of the cognitive-intellectual component were at a high level of 13% in the diagnostic period. In the formative period, it reached 44%, demonstrating a clear increase in cognitive transformation. Interactive modeling and digital simulations allowed for the analysis of structural-functional relationships of complex biological systems. Students were systematically involved in intellectual activity aimed at making scientific predictions and proving hypotheses. At the end of the experiment, the level of intra- and interdisciplinary integration increased, and the skills of multi-level analysis of biological processes were consolidated.

The results of the operational-technological component showed that students' skills in conducting research, modeling, working with digital data, and interpreting results improved. Tasks such as determining the morphological features of tissues using a virtual microscope and AR technologies, and modeling bone and muscle movement on the Complete Anatomy platform were performed. As a result of such activities, the ability to work independently increased by 46 percent, and the ability to analyze and draw conclusions by 42 percent. Using the PhET, Visible Body, and BioDigital Human platforms strengthened students' skills in modeling biological processes, planning experiments, and implementing them in a digital environment. The ability to process data, work with digital tools, and independently organize biological experiments significantly increased. The ecosystem environment was identified as the main catalyst for technological competence that forms research independence. In the operational-technological component, the use of digital tools and practical activities were organized. Ecosystem elements such as virtual laboratories, 3D models, AR applications, and biological simulators contributed to the improvement of students' practical skills. During the experiment, they created models of “Chemical composition of bones”, “Microscopic structure of muscle tissue”, “Joint movement”. They modeled breathing and blood circulation using BioDigital, Visible Body, Anatomy VR. They allow you to predict the consequences of changes in the body and determine cause-and-effect relationships. Students were able to independently organize the research process using digital tools such as PhET, Visible Body, BioDigital Human. They performed tasks such as digitally recording the results of laboratory experiments and presenting interactive assessment tools. They increased their efficiency and independence in practical activities. The quality of processing experimental data and interpreting results improved. The component, forming the core of professional and creative competence, increased the research skills and digital literacy of future biology, chemistry and biology teachers.

The high level in the diagnostic stage for the reflective-evaluative component was 13%, and in the formative stage it increased to 42%. The systematic use of feedback tools allowed students to assess their own actions and improve the quality of professional decision-making. Digital reflection platforms, such as online portfolios and self-assessment modules, established a culture of personal professional reflection and increased the student's internal responsibility for engaging in science. The weak professional motivation, superficial nature of cognitive processes, and passivity in practical activity observed during the diagnostic period underwent significant changes during the formative period. The ecosystem model became a natural and dynamic mechanism for professional and creative development. The reflective-evaluative component assessed the quality of self-analysis and professional decision-making. At the end of the study, students'

abilities to self-analyze, make professional decisions, and evaluate learning outcomes significantly increased. In the digital ecosystem, comparisons of their own and others' results, analysis of achievements were carried out through Google Classroom, Padlet, and Mentimeter feedback tools, and the level of critical assessment of their own actions increased. In professional decision-making, they were oriented towards relying on scientific justification and substantiating experimental data. Reflective-evaluative development strengthened the internal professional position of students, increased their responsibility, and formed a culture of qualitatively assessing the results of creative activity.

Analyzing the results of the study, it can be seen that the digital ecosystem model strengthened the interconnection of all components of professional and creative competence. The motivational and value component increased cognitive activity, while cognitive development contributed to the improvement of action skills.

The results of the experimental study proved that the use of the digital ecosystem model in the preparation of biology, chemistry and biology undergraduates in pedagogical universities is an innovative and effective method of developing professional and creative competence. Ecosystem-based learning raised professional adaptation, research thinking, cognitive autonomy and creative activity to a new qualitative level.

The results of the study showed that the culture of thinking, action and reflection increased qualitatively when the development of professional and creative competence was carried out on the basis of a digital ecosystem. The content and quantitative changes of each component are analyzed below.

When working in a digital environment, intrinsic motivation and creative thinking activity increased, and the ability to make scientifically sound decisions, work with data, and interpret results increased. The results showed that the interconnection and consistency of all components of professional and creative competence were strengthened. Motivational-value development increased cognitive activity, while cognitive maturity ensured the effectiveness of operational and reflective actions. The interconnection proved the integrative nature of the digital ecosystem model.

3. At the end of the experiment, the data obtained with the participation of 127 students were processed using the SPSS Statistics 27 program to produce the results of the control-final stage.

Table 4

Results of the control-final period

Competency indicators	Initial average score	Final average score	Difference (t-test)	Significance level (p)
Motivational and value-based	2.84	4.19	6.12	< 0.01
Cognitive and intellectual	2.91	4.37	6.48	< 0.01
Operational and technological	2.76	4.45	7.03	< 0.01
Reflective and evaluative	2.63	4.22	5.89	< 0.01

The results in Table 4 showed a highly reliable statistical difference at the $p < 0.01$ level. The presence of t-criterion values in the range of 5.89–7.03 for all competency components scientifically proves that the digital ecosystem has a highly effective impact on the formation of professional and creative competencies of students. The qualitative growth observed in the formative period became quantitatively stable in the final period, indicating that a deep transformation took place in the structure of students' competencies as a result of the systematic impact of the ecosystem digital modules.

The observation showed that in the motivational-value component of the final period, the initial low level of motivation was almost completely eliminated, and the final average score increased to 4.19. The indicator indicates that the internal value orientation of students aimed at professional choice has stabilized, personal activity has increased through the digital ecosystem, and they have begun to perceive science as an important component of their future professional activity. According to the motivational value, cognitive activity and professional motivation have significantly increased through the digital ecosystem. 47.5% of

students were able to combine their personal interest in studying biology with digital tools.

The increase in the average score from 2.91 to 4.37 in the cognitive intellectual component proved that students were not limited to mastering biological knowledge only at the reproductive level, but also acquired the ability to conduct interdisciplinary integration, make scientific predictions, and analyze the logical connections of complex biological systems. The 30% increase recorded in the formative period turned into a stable cognitive level in the final period. In terms of cognitive-intellectual competence, 50.2% of students developed their ability to make scientific predictions and analytical thinking through digital laboratories and artificial intelligence-analysis modules.

In the operational-technological component, the increase from 2.76 to 4.45 showed that students were able to freely use virtual laboratories, 3D simulators and biological platforms such as PhET, Visible Body, BioDigital Human as professional-technological tools. The ability to plan research activities, analyze digital data, and independently organize experiments reached a high level, and research independence was established. 61.2% of students strengthened their applied biological skills through practical digital experiments and the Labster, BioDigital Human modeling platforms.

In the reflective-evaluative component, the increase from 2.63 to 4.22 showed that students completely got rid of dependence on external evaluation and formed an internal reflection mechanism. The ability to analyze their own actions, make professional decisions, and consciously evaluate the results has become a stable skill. The dynamics of the development of this component proves the pedagogical effectiveness of digital feedback systems. 60.4% of students raised their self-assessment culture and professional reflection to a new level using Mentimeter and Google Form Analytics. The digital ecosystem had a systematic, multi-level and transformative effect on the development of professional and creative competence of students.

The low-level indicators identified during the diagnostic period improved. We empirically consider the results as an effective digital ecosystem and an innovative pedagogical paradigm in teaching biology. Professional self-realization and reflective culture rose to a qualitatively new level. The digital ecosystem model demonstrated its systematic, integrative and transformative potential as a tool for developing professional and creative competence in the training of biology specialists.

Conclusion

The results of the study supplemented the conceptual basis for creating a digital educational environment in pedagogical universities. An innovative elective course entitled “Digital research and creative modeling in biology teaching” was developed and tested. The results of the study proved that the digital ecosystem is not only a didactic tool for the development of professional and creative competence of students of biology, chemistry-biology, but also a whole pedagogical transformation system. It allowed us to consider it as a scientifically based mechanism for the formation of cognitive autonomy, creative potential and innovative professional consciousness of the student.

A comprehensive analysis of the study results comprehensively proved the high effectiveness of the process of developing professional and creative competence of biology, chemistry-biology students through a digital ecosystem in the conditions of a pedagogical university.

The digital ecosystem model in the preparation of biology, chemistry-biology, and biology has been scientifically substantiated as a mechanism for the comprehensive development of professional competence. The methodology developed as a result of the study made a practical contribution to the development of academic digitalization, creative research and scientific integration in pedagogical universities. During the observation period, the cognitive index of students was at the level of 2.52, and after the formation period it increased to 5.22, which proves that learning motivation, self-assessment system and striving for personal development have increased. A significant increase in indicators at the disciplinary-reflective level has revealed that the formation of competence is a mechanism dependent on personal self-awareness. Positive changes were also observed in the reflective-communicative dimensions. The ability to express one's own opinion and make decisions has increased. Empirical data confirmed the effectiveness of the pedagogical influence system. The main mechanism for developing competence is to improve the student's "I Concept" at the personal-evaluative level.

Conflict of Interest Statement

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Author Contributions

B.B. Dildabekova led the conceptualization, data collection, formal analysis, and preparation of the original manuscript. M.B. Amanbayeva contributed to the study design, methodology, supervision, critical review, and editing of the manuscript. B.U. Dildabekova participated in data collection, analysis, interpretation of the findings, and manuscript preparation. All authors reviewed and approved the final version of the manuscript.

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DESIGN, IMPLEMENTATION, AND EVALUATION OF AN INSTRUMENTAL AND METHODOLOGICAL PLATFORM FOR TEACHERS' PROFESSIONAL COMPETENCY DEVELOPMENT

Abstract. The rapid digital transformation of education requires new approaches to supporting teachers' professional development and strengthening their ICT competencies. This study aimed to design, implement, and evaluate an instrumental and methodological platform intended to provide comprehensive methodological support for teachers in secondary education. The platform integrates regulatory documentation, teaching resources, professional development planning, webinars, coaching, collaborative communication, competency monitoring, and analytical feedback within a unified digital environment. A quasi-experimental research design was employed involving 160 teachers of Geography and Computer Science from public secondary schools in Astana, Kazakhstan. Participants were divided into an experimental group (n = 80) and a control group (n = 80). Professional competencies were assessed using psychological-pedagogical diagnostics, questionnaires, observations, expert evaluation, and statistical analysis based on Fisher's angular transformation criterion. The findings demonstrated that teachers using the proposed platform achieved higher levels of ICT competence, communication skills, professional motivation, and creative engagement than those in the control group. The comparison between the experimental and control groups revealed statistically significant differences ($\varphi^* = 2.41$, $p = 0.016$), confirming the effectiveness of the platform. The integrated digital environment also facilitated continuous methodological support, improved collaboration among teachers, and enhanced opportunities for individualized professional development. The study concludes that the proposed instrumental and methodological platform represents an effective solution for developing teachers' professional competencies in the context of digital education. The findings contribute to the modernization of teacher professional development systems and may serve as a practical framework for educational institutions implementing digital transformation strategies.

Keywords: Instrumental and methodological platform, support, educational organizations, ICT, competencies.

Introduction

Teachers should be ready to use new technologies in the educational environment (Zulpykhar et al., 2025) to ensure effective learning and development of students. In the process of modernization of education related to the development of information and communication technologies, new opportunities for the educational process are opening up. Teachers should apply the skills and competencies that become necessary in the conditions of the informatization of society and education (Baydjanov, 2021). The authors describe several skills and competencies that teachers should possess:

1. Digital literacy: the ability to effectively use information and communication technologies to search, evaluate, analyze, and process information.
2. Computer thinking: ability to formulate and solve problems using concepts and methods of computer science.
3. Information security: awareness of possible threats to information security and the ability to protect your information.
4. Critical thinking: the ability to analyze information, evaluate its reliability, and make informed decisions.
5. Communication skills: the ability to communicate and collaborate effectively in virtual environments (Mukasheva et al., 2023).

6. Creativity and innovation: the ability to generate new ideas, develop innovative solutions, and find non-standard approaches to solving problems.

7. Self-organization and self-motivation: the ability to plan your activities, work independently, and motivate yourself to achieve your goals (Zulpykhar & Azamat, 2025).

This will help make the learning process more interactive, accessible, and effective (Karelkhan et al., 2024). Teachers with ICT skills can effectively use online resources for self-education and professional development. They can study new teaching methods, get access to up-to-date scientific and methodological literature and lectures, and exchange experiences with colleagues around the world.

Thus, teachers who can apply the new didactic potential of ICT are in demand in the modern information society as specialists who can effectively use modern technologies for the education and development of students. At the same time, despite the indisputable importance of the conducted research, the problem of using modern means of informatization for teacher training, in particular, for the formation of their ICT competence, has not yet been completely solved. One of the main reasons for this problem is the lack of time and resources to master the necessary skills in the field of information technology (Seitakhmetova et al., 2022). To solve this problem, it is necessary to provide teachers with access to modern means of informatization and create special educational programs that would help them master the necessary skills. In addition, it is important to change the approach to teacher training by including mandatory courses in information technology (Kopeyev et al., 2020) in the curriculum.

The analysis of scientific and pedagogical research and the current situation in the practice of the formation of professional competence of teachers through an instrumental and methodological platform allows us to identify the following contradictions:

1. Despite the proliferation of educational platforms, access to them and the quality of equipment may vary significantly in different regions and educational institutions. This creates an inequality in the ability of teachers to develop their professional skills.

2. Teachers have limited working hours and may face difficulties in finding time to learn new pedagogical approaches and methods. This may reduce their motivation and opportunities for professional development.

3. Teachers may feel apprehension and resistance before introducing new technologies into the educational process, especially if they do not have sufficient support and feedback. The purpose of methodological support is the systematic creation of organizational, educational, technical, and informational conditions for systematic self-development. The development of an integrated system of methodological support should be based on the principles of scientific character, predictability, flexibility, mobility, and continuity. Taking into account these principles, the process of teacher development becomes an interaction of a creative laboratory of joint searches and the introduction of educational innovations into the system of pedagogical activity.

Among the functions of methodological support for the pedagogical development of teachers, we define the following: educational, advisory, service, coaching, adaptation, expert, moderation, corrective-reflexive, and others.

Methods and means of organizing such activities can be used: modern learning technologies, including information and communication technologies, distance learning, games, dialogue, focus groups, tutoring, team building, and others. These methods must include a basis for reflection as a necessary element and as an indicator of the quality of interaction in the system of continuous pedagogical development.

In addition, forms of methodological support for teachers include:

organizational methods of support (consultations, coaching, assistance in the work of creative teams, school-wide seminars, pedagogical council). This is the essence of information transmission, they are divided into active (discussions, business games, training, etc.) and passive (speeches at pedagogical councils, meetings; questionnaires (other forms of public opinion polls); acquaintance with printed information (books, textbooks), etc.);

the creation of organizational (resource room or work information center) and methodological (consulting) conditions for teachers' participation in various events: courses, conferences, methodological associations, round tables, seminars, workshops, etc.;

providing methodological support (mentoring) for teachers conducting research activities and pedagogical experiments;

Provide information support to teachers to participate in various training events (conferences, master classes, professional skill competitions) to present and summarize their experience.

Therefore, we believe that the organization and methodological support of pedagogical activities are indispensable, systematically organized activities create conditions for the professional growth of teachers and the development of professional and pedagogical abilities of teachers in this process.

The dictionary definition of the concept of "escort" presents its content as "following along with someone, being nearby, leading somewhere or following someone; to accompany, accompany, go."

The founder of the idea of pedagogical support was Gazman (2018), who identified a special direction in the theory and practice of education – "pedagogy of self-awareness", according to which pedagogical activity was considered to stimulate the processes of independence in the pupil with the help and support of the teacher.

By analyzing the scientific literature, it is possible to assess the need to support teachers in general education organizations based on an integrated and differentiated approach. These methods include the following (Abylkassymova et al., 2020): to provide an opportunity to adapt the educational and methodological space of the school to the personality and interests of the teacher; to give them freedom of choice and change in the context of educational institutions; to form a desire for self-education and self-improvement, to solve individual problems of personal development in connection with the needs of society in the context of modernization of the education system.

To generalize the experience, pedagogical events are organized in Astana, scientific and practical conferences, seminars, methodological landings, round tables for secondary education organizations and preschool educational institutions, methodological days of practical training, and master classes are held.

Methodological support is understood as helping the teacher in the formation of the orientation field of professional self-development, and responsibility for the actions for which he is responsible (Salmon, 2012).

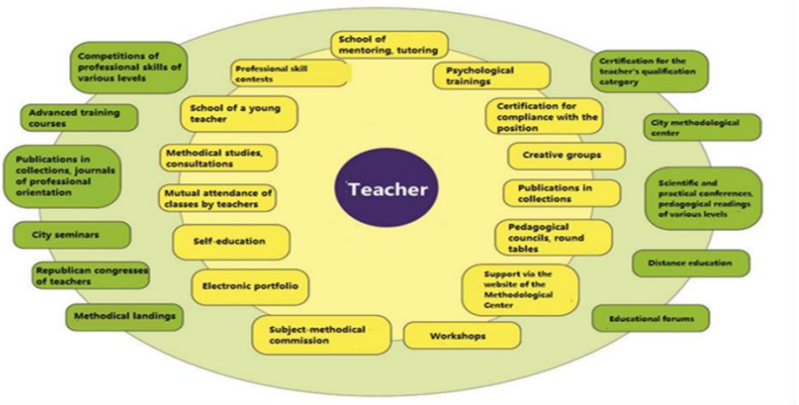
We consider the organization and methodological support of pedagogical activity in general and systematically organized activities, which creates conditions for the professional development of teachers, the development of the pedagogical profession, and pedagogical abilities. As a management technique for organizing the interaction of academic disciplines (Higueras-Rodríguez et al., 2020).

So, let's consider the implemented model of organizational and methodological support of teaching staff in Astana.

Figure 1 describes a model of methodological support for teachers of Astana city (hybrid, personalized), which provides for the individualization of methodological support, that is, provides a positive position for teachers, since in the practice of working with teaching staff this is a traditional mode. Individualized transition of the professional development system.

Figure 1

A model of instrumental and methodological support of teaching staff in the city of Astana has been developed



This model combines forms of online support and offline methods, which are mixed, since resource management is carried out through an instrumental and methodological platform developed by the authors of the study. The main content of the resources is implemented to provide advice to teachers, conduct practical psychological and pedagogical seminars, trainings, webinars, round tables and master classes.

Unlike general-purpose learning management systems such as Moodle, Google Classroom, or Microsoft Teams, the proposed instrumental and methodological platform was specifically designed to support teachers' professional development rather than student learning. The platform integrates regulatory documentation, methodological resources, professional development planning, webinar management, coaching activities, collaborative communication, monitoring of competency development, and analytical feedback within a single environment. This integrated approach enables continuous methodological support throughout teachers' professional activities and reduces fragmentation caused by the use of multiple independent digital services.

The scientific novelty of the study lies in the development and implementation of new methodological tools, techniques, and technologies aimed at improving the quality of education. These tools expand the possibilities for organizing teachers' professional development and provide more structured support for the formation of their ICT competencies.

Another important aspect of the study is the transition to digital resources hosted on an instrumental and methodological platform. Within the framework of methodological support for teachers' activities, this platform serves as a unified environment for accessing educational materials, methodological recommendations, and digital tools necessary for professional growth.

In addition, the study ensures the combination of online and offline forms of methodological support. This approach was implemented in the context of the priority national project "Quality Education: Educated Nation" and allows for a more flexible, accessible, and practice-oriented system of professional support for teachers.

Research methods and organization

The purpose of the experimental work is to evaluate the effectiveness of the implementation of an instrumental and methodological platform for accompanying teachers in the development of the discipline "Geography" and "Computer Science". The study involved 160 teachers from public secondary schools in Astana, Kazakhstan. Participants included teachers of Geography and Computer Science. Their teaching experience ranged from 3 to 25 years. Teachers voluntarily participated in the study and provided informed consent. The sample included 80 teachers assigned to the experimental group and 80 teachers assigned to the control group. The authors analyze how the instrumental and methodological platform can be used taking into account the specifics of subjects, curricula, and a group of teachers. Teachers were assigned to the experimental and control groups according to comparable characteristics, including teaching experience, subject specialization, and initial ICT competency level. Baseline testing confirmed that no statistically significant differences existed between the two groups before the intervention ($p > 0.05$).

Approaches to using the platform may vary depending on the subjects, as each subject has its own specific requirements and learning objectives. In many cases, teachers require methodological support and training to effectively use new knowledge and skills in their practice. When choosing teaching methods using an instrumental and methodological platform, it is important to take into account their convenience and effectiveness for specific groups of teachers and their ability to successfully integrate these technologies into the educational process (Zhang et al., 2022). Salmon (2012) points out that platforms can significantly strengthen and improve methodological support in learning by providing students with access to extensive information, interactive resources, and learning tools. They emphasize that methodological support using the educational platform makes it possible to diversify educational materials, attract students to active participation, and stimulate their academic achievements. Higueras-Rodríguez et al. (2020) speak about the importance of methodological support with the use of an instrumental and methodological platform in the context of teaching teachers. He points to the potential of the platform that helps teachers develop their professional skills and improve the quality of education. Dessart L. et al., considers methodological support using the online platform in the context of the development of media education. He notes that the instrumental and methodological platforms allow students to actively interact with a variety of media resources (for example, video, audio, and graphics) and develop critical thinking, communication skills, and the ability to cooperate.

The implementation of the concept of pedagogical effectiveness on methodological support with the use of an instrumental and methodological platform for teachers was carried out in a contingent of organized groups. Experimental work was carried out to assess the effectiveness and usability of the platform for methodological support of teachers. Within the framework of this concept, teachers received support and support in using the instrumental and methodological platform in their teaching activities. Special webinars, seminars, and training were developed and conducted, which helped teachers to master new technologies and effectively apply them in the educational process. Organized groups of teachers started using the educational platform in their pedagogical practice, which allowed them to significantly improve the quality of education and make the learning process more interesting and accessible to students. New methodological materials, lessons, and programs adapted for teachers were developed and implemented. Teachers actively used computer programs, multimedia presentations, interactive whiteboards, and other ICT tools in their work. This allowed teachers to make the learning process more visual, interactive, and accessible to all students. The results of the implementation of the concept of pedagogical efficiency using the instrumental and methodological platform were positive . Teachers have become more confident and motivated in their work, which has led to an improvement in their professional skills and student learning outcomes. Students have become more active and interested in the learning process thanks to the introduction of new technologies.

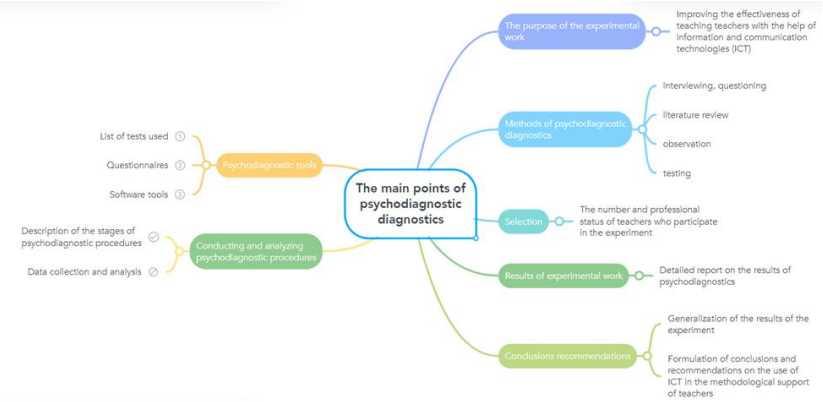
The purpose of this study is to assess the professional competence of teachers using a diagnostic complex that includes quantitative and qualitative assessment methods. The diagnostic procedure is designed to identify the level of knowledge, skills, and abilities of teachers in the professional field. The quantitative assessment is based on the calculation and analysis of quantitative data, such as the number of correct answers to test tasks, the time spent on completing tasks, etc. This makes it possible to determine the numerical indicator of the professional competence of teachers. Qualitative assessment includes an analysis of qualitative characteristics, such as the level of depth of understanding of the material, the ability to apply knowledge in practice, the flexibility of thinking, and a creative approach to problem-solving. These parameters are evaluated subjectively, with the help of expert evaluation or by analyzing the quality indicators of completed tasks.

Psychological and pedagogical diagnostics includes the following methodological tools:

- general scientific method: observation, interview;
- psychological and pedagogical method: questionnaires, tests, documentation analysis, analysis;
- products of students' activities;
- socio-psychological method: sociometry, rating;
- method of mathematical statistics: methods for assessing the reliability of the shift of values
- feature, cluster analysis methods (Figure 2).

Figure 2

The main points of psychodiagnostic diagnostics of experimental work on methodological support of teachers using an instrumental and methodological platform

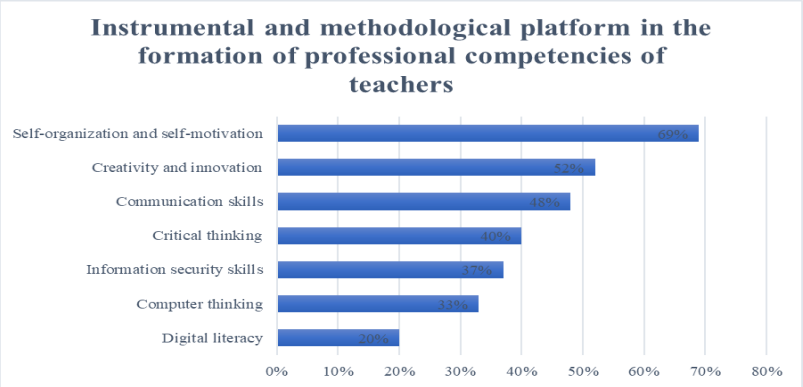


To select questions for teachers, a modification of the "professional competence" tests was used,

which allows for assessing the level of training and professional skills of teachers, as well as identifying their potential problem areas that require further training or development. The method aimed at a comprehensive assessment of these connections involves the use of various tools and tests to assess cognitive functions and activation processes. This may include tests on memory, attention, problem-solving, logical thinking, and other cognitive skills. It can also be used to measure reaction time, information processing speed, and other instrumental indicators. This method can help in making decisions about professional development opportunities, mentoring programs, and other resources that will help teachers improve their skills and knowledge.

Figure 3

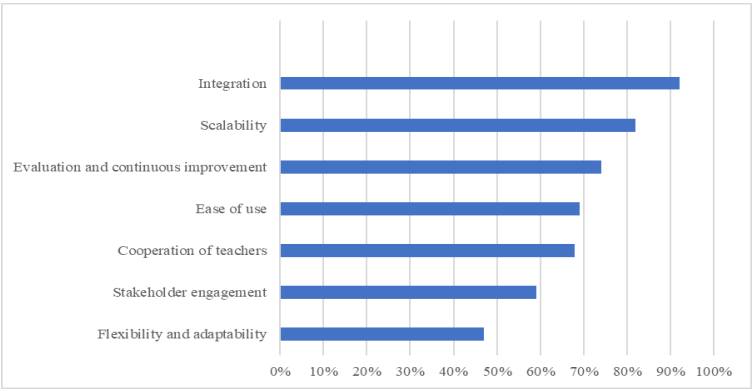
Instrumental and methodological platform in the formation of professional competencies of teachers



The most important knowledge and skills that are laid down when using the instrumental and methodological platform are identified, focused on the formation of such competencies as: "Digital literacy" 20%, "Computer thinking" 33%, "Information security" 37%, "Critical thinking" 40%, and 48% - "Communication skills", "Creativity and innovation" 52%, "Self-organization and self-motivation" 69% (Figure 3).

Figure 4

The basic principles of the formation and development of the instrumental and methodological platform



The basic indicators of the components were confirmed by the professional levels determined between the control and experimental groups using an instrumental and methodological platform. During the implementation of this platform, statistical tests of data were carried out, which were used together with the multifunctional Fisher angle transformation criterion (φ* Fisher criterion). This was done in order to confirm the homogeneity of the data, which is expressed in the lack of significant differences in the sample groups of KG (control group) and EG (experimental group) (Figure 4).

The results of the study and discussion

When discussing the formation of ICT competence of teachers, it is proposed to consider the following

components: motivational-target, organizational-content, procedural-technological and evaluative-reflexive. This helps the teacher to develop the skills necessary for the effective use of ICT in the educational process (Figure 5).

Figure 5

Comparison of the structural component of ICT competence at the stages of the formation of disciplines, ccording to the instrumental and methodological platform

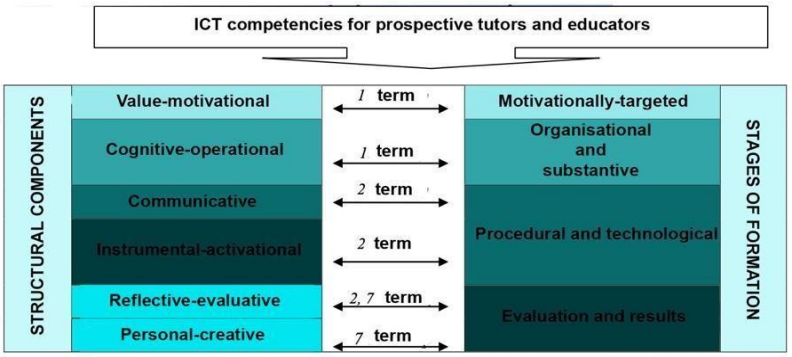


Table 1

Criteria for the formation of structural components of ICT competence in teachers

Structural component	Criteria of formation
1. Value-motivational	1. Understanding the importance of using ICT, using IMP (instrumental and methodological platform), in professional activities; 2. Motivation to carry out professional activities using ICT; 3. Network etiquette, and personal data protection in IMP.
2. Cognitive-operational	1. Understanding the essence and meaning of information; 2. Viewing, searching, and filtering data, information, and educational content for the creation and development of IMP; 3. Evaluation of data, information, and content and their management using the IMP.
3. Communicative	1. Interaction with the use of ICT in EE (information and educational environment); 2. Exchange of ICT tools and mediation in the field of EE; 3. Cooperation with the use of ICT, including IMP, in EE.
4. Instrumental-activation	1. Development of educational content using IMP; 2. Development of IMP; 3. Integration and revision of educational content using IMP.
5. Reflexive-evaluative	1. Development and evaluation of individual progress, IEM (informational and educational materials) with the help of IMP; 2. Assessment of the feasibility of using ICT; 3. Assessment of methodological support of teachers.
6. Personal-creative	1. Creative use of ICT in professional activity; 2. Identification of individual needs, and creative use of technologies with the help of IMP; 3. Identification of the lack of competence in the field of ICT.

The results were analyzed in the control and experimental groups during the period from 2021 to 2024. To do this, various methodological approaches and an instrumental and methodological platform were used. In the process of analyzing the results, the data obtained from the control and experimental groups were compared. The results of the analysis helped to understand the impact of the use of ICT on the educational process and to evaluate the effectiveness of the applied methodological approaches.

Table 2 presents the results of a study of the value-motivational components of ICT competence of teachers at the stage of EW formation (experimental work). Within the framework of diagnostics, the dominant motive of teachers' educational activity was determined.

Table 2

Criteria for the formation of structural components of ICT competence in teachers

Group	Communicative motives	Avoidance motives	Motives of prestige	Professional motives	Motives for creative fulfilment	Educational and cognitive motives	Social motives
CG1	45	69	52	39	45	42	38
CG2	45	68	53	40	46	44	39
CG3	46	67	54	40	48	44	39
CG4	48	69	55	42	49	42	40
EG1	55	60	50	52	57	50	54
EG2	58	55	51	54	56	52	55
EG3	62	50	51	55	57	56	57
EG4	78	50	50	62	65	59	64

According to the data given in Table 2, we can see the dynamics of changes in teachers' attitudes towards the learning process, taking into account the use of an instrumental and methodological platform, as well as personal and professional development. It should be noted that the dominant motive of avoiding failure, fixed at the ascertaining stage of EW, sharply decreased in all experimental and control groups. This fact may be due to the social adaptation of teachers in the educational environment of the school during the training period, including the use of IMP and other EIEE resources (Electronic Information and Educational Environment). The motives for the prestige of receiving a high assessment changed with the least dynamics in all groups participating in the EW, which may be due primarily to the professional orientation of teachers to the educational results of formal and significant achievements of non-formal education. In turn, there is a positive dynamics of educational and cognitive motives, interest in the study of the disciplines "Geography", and "Computer Science". Thus, the participants of the experimental groups EG1, EG2, EG3, and EG4, who studied these disciplines with the support of e-learning courses, webinars, seminars, round tables, forums, and coaching, noted these motives to a greater extent (for example, EG4 - 58% of respondents, and CG4 - only 41% of the respondents).

Among the most significant motives, according to the data obtained during the ER, it should be noted the motives associated with communication and interaction of teachers in the generalization and dissemination of pedagogical experience. Thus, among 77% of respondents of the EG4 group, it is defined as the most dominant, respectively, EG3 group - 61%, EG2 group - 57%, and EG1 group - 54%. In turn, among the control groups of students, the maximum indicator of this motive is recorded in CG4, and is only 47%.

The results of the study of the value-motivational component of the ICT competence of teachers allow us to note an increase in the importance of developing motivating factors among the experimental and control groups studied.

It should be noted that the category of tasks related to the assessment and analysis of information and the content of the IMP can be considered the most difficult for teachers to perform. This section of tasks presented in the electronic training course of the disciplines being developed shows the least dynamics of the formation of the cognitive-operational component of the ICT competence of teachers. This fact is primarily due to the multidimensionality and variability of the proposed tasks using the tools of the methodological platform in the e-learning course, which require not only additional operational knowledge about ICT but also the ability to use various resources in the educational process. This confirms the didactic potential of the instrumental and methodological platform for further use. In general, experimental groups of teachers demonstrated a higher success rate in solving problems in the subjects taught (71% for EG4, 69% for EG3, 65% for EG2, and 63% for EG1), which indicates increased functionality of the cognitive-operational component of ICT competence.The results of the evaluation of the instrumental activation component of the ICT competence of teachers at the formative stage of the experiment are shown in Table 3.

Table 3

Results of evaluation of the instrumental and motivational component of ICT competence of teachers at the formative stage of the experiment, %

Group	Understanding the nature and importance of educational content for the creation and development IMP	Review, search and analyse information, educational content for IMP creation and development	Evaluate, manage, analyse information and educational content through IMP	Average success %
CG1	37	45	40	41
CG2	38	45	41	41
CG3	40	46	43	43
CG4	42	48	45	45
EG1	65	66	60	64
EG2	70	67	60	66
EG3	73	70	67	70
EG4	75	72	69	72

The data presented in the table on the dynamics of the formation of the instrumental activation component of ICT competence of teachers confirm the overall positive dynamics of the success of the tasks proposed within the framework of the developed methodological support for disciplines among the experimental and control groups of teachers with a numerical predominance of the experimental group (74% of respondents in EG4 and only 42% of students in CG4). According to the diagnostic results, the average and above-average level of formation of the instrumental activation component in the studied groups was determined. It should be noted that the smallest number of respondents in the experimental and control groups demonstrated the ability to use IMP as an integrated tool aimed at the formation of ICT competencies (68% of respondents in EG4, 44% of students in CG4). First of all, this confirms the prospects of IMP and practical developments in the field of using IMP as an effective means of forming ICT competence in teaching teachers in the conditions of informatization of education and requires further study.

In general, the experimental groups of teachers compared with the control groups showed a higher average success rate of tasks (73% - EG4, 70% - EG3, 68% - EG2, 67% - % - EG1), which confirms the increased level of instrumental functionality of the activation of the ICT competence component. Table 4 presents the results of a study of the communicative component of ICT competence of teachers at the stage of EW formation, during which the leading types of behavior were identified: "dependent", "aggressive" or "competent".

Table 4

Results of evaluation of the instrumental and motivational component of ICT competence of teachers at the formative stage of the experiment, %

Group	Dependent	Aggressive	Competent
CG1	34	9	57
CG2	32	8	60
CG3	29	9	62
CG4	30	8	62
EG1	22	8	70
EG2	20	8	72
EG3	15	7	78
EG4	15	7	78

The dynamics of the assessment of the communicative component of ICT competence at the stage of EW formation showed that most teachers have a more pronounced component of the type of behavior. So, for experimental groups of teachers, this type of behavior is 77% for EG4, EG3 - 77%, EG2 - 71%, and EG1 - 69%. In turn, among the control groups, the component type of teacher behavior in communicative situations is more typical for CG4 and is 61%. The data obtained confirm the

professional orientation of teachers to partnership and interaction in communicative situations between the pedagogical community, which, of course, is one of the important professional skills for the further effective implementation of educational activities using IMP.

Let's pay attention to the almost unchanged indicators of aggressive behavior, which are 7-8% for control groups and 6-7% for experimental groups. First of all, this is due to the professional orientation of teachers to avoid manifestations of sharpness, irritation, categorical judgments, and negative evaluation of communication participants, events, and actions. A low level of aggressive behavior is a significant factor in the implementation of productive educational and professional activities of teachers. In general, the results of the study of the communicative component of ICT competence allow us to note an increase in the importance of partnership interaction between teachers of experimental and control groups using IMP, which is especially important in the conditions of professional activity in an open information and educational environment.

Table 5

Results of evaluation of the instrumental and motivational component of ICT competence of teachers

Group	Retrospective	Situational	Prospective
CG1	56	59	58
CG2	58	61	59
CG3	60	61	62
CG4	62	67	68
EG1	60	59	63
EG2	64	60	65
EG3	68	67	68
EG4	68	69	70

According to the data presented in the table, we can see similar levels of dynamics in various manifestations of reflexivity, and reflexive-evaluative components in the ICT competence of teachers, at the stages of formation of the SP and UP.

In general, the level of reflexivity of KG and EG increases throughout the entire training period, approaching a higher level of values of indicators. In turn, close and sometimes equal values (for example, the values for CG4 - 67% are equal to the data obtained, characteristic of EG3 - 67%) between the registered levels of reflexivity of teachers confirm minor differences between the levels of reflexivity of the compared experimental and control groups.

Diagnostics of the personal and creative component of ICT competence of teachers allowed us to determine the distribution of values on the scales of personal creativity among respondents at the stage of EW formation, presented in the table below.

Table 6

Results of the study of the types of reflection of the reflexive-evaluative component of ICT competence, %

Group	Personal creativity diagnostic scales for future tutors and teachers, %			
	Risk appetite	**Curiosity**	**Complexity**	**Imagination**
CG1	55	42	25	13
CG2	56	44	27	19
CG3	58	45	27	20
CG4	60	48	30	24
EG1	67	50	33	28
EG2	68	50	35	30
EG3	70	51	36	32
EG4	72	52	36	35

The maximum level of growth of indicators was recorded on the "risk appetite" scale in experimental groups (EG4 - 71%, in turn, CG4 - only 59%), which confirms the teachers' focus on goal-setting and their

focus on achieving goals with the help of IMP.

It is important to note the increase in the indicator on the "Imagination" scale of the diagnosis of personal creativity. However, a greater increase in this indicator was recorded among the respondents of the experimental groups (EG4 - 34%, EG3 - 31%, EG2 - 29%, EG1 - 27%). First of all, this is due to the use of an instrumental methodological platform in the conditions of informatization of teacher training. In addition, the use of IMP helps to increase the level of skills of independent activity of teachers, their focus on the development of an individual educational trajectory, the presence of variability in the means of achieving educational results, and the possibility of individual ways of solving professional tasks.

During the ascertaining stage of the experimental work, statistical processing of the obtained data was carried out using the multifunctional Fisher angle transformation criterion (φ* Fisher criterion). The criterion φ* allows us to determine whether one of the angles is statistically significantly superior to the other for a given sample size. The comparison between EG4 and CG4 demonstrated statistically significant differences (φ*=2.41, p=0.016), confirming the effectiveness of the proposed methodological platform.

The criterion φ* is aimed at comparing the percentages of two samples by the frequency of the studied effect and assessing the reliability of the differences between them to compare the formation of ICT competence of teachers of the control and experimental groups.

The following hypotheses were put forward as hypotheses:

H_0: the proportion of teachers with reproductive and productive levels of ICT competence in CS4 is not higher than in EG4.

H_1: The proportion of teachers demonstrating reproductive and productive levels of ICT competencies is higher in CG4 than in EG4.

It should be noted that the constructive level of formation of ICT competence of teachers was recorded in both experimental and control groups. The CG4 control group demonstrated a constructive level of ICT competence, which was characteristic of the following components of ICT competence: instrumental-activity (5.0%), reflexive-evaluative (10.2%), and personal-creative (10.2%).

During the formative stage of the experimental work, statistical data processing was also carried out using a multifunctional Fisher angle transformation test (φ* Fisher criterion).

Conclusions

In conclusion, the article summarizes the results of the study, as well as presents the main conclusions on the use of the instrumental and methodological platform. Teachers in the experimental group demonstrated significantly higher levels of ICT competence, communication skills, and professional motivation than teachers in the control group. Statistical analysis confirmed that these differences were significant, indicating that the proposed platform positively influenced teachers' professional competency development.

1. An approach to informatization of teacher training for the development of ICT competence is proposed based on the use of an instrumental and methodological platform for mastering the disciplines of the computer science and geography cycle in the information and educational environment. This platform provides teachers with the opportunity to use various information and communication technologies (ICT) in the preparation and conduct of computer science and geography lessons. It includes programs, tools, and resources that help teachers create interactive lessons, develop and review assignments, and evaluate and monitor student performance. The use of such a platform allows teachers to effectively use ICT tools, such as interactive whiteboards, software for creating and editing multimedia materials, computer programs for analyzing geographical data, etc. The use of an instrumental and methodological platform allows teachers to effectively organize work in the classroom, share materials and resources with students, as well as provide feedback and support in the learning process. This not only improves the quality of education but also helps teachers to use their time and resources more effectively.

2. The article proves that the instrumental and methodological platform is an effective means of developing the ICT competence of teachers in information education, taking into account their personal and professional development when using its methodological functions and didactic properties: Interactivity is the possibility of interaction and exchange of information between teachers. This allows you to create an active and dynamic educational environment where each participant can demonstrate their knowledge and

skills; Multimedia – the use of various multimedia materials, such as video, audio, and images, for teaching and illustrating concepts and concepts. Multimedia elements will make lessons more visual and memorable; publicity – the possibility of publishing and sharing materials, assignments, and work results between teachers and students. This allows you to create cooperation and interaction between different participants of the educational process; Non-linearity - the ability to choose the order of studying the material and performing tasks by students, depending on their individual needs and interests. This contributes to taking into account the individual characteristics of each student and adapting the educational process to his needs; Integrativity – the ability to integrate various disciplines and courses, which allows you to create comprehensive and related educational programs. This helps students to see the connections between different subject areas and apply their knowledge in different situations.

3. A model of the formation of ICT competence of teachers in the conditions of informatization has been developed and substantiated. Formation of ICT competence of teachers is an important task in the conditions of modernization (informatization) of education. The model developed for this purpose should be justified taking into account modern requirements and trends in the field of information and communication technologies. One of the main components of the model of formation of ICT competence of teachers is training. This can be both formal education (courses, training, master classes) and informal training (self-education, exchange of experience with colleagues). Training should include not only the development of specific ICT skills but also the development of pedagogical competencies that allow the effective use of information technology in the educational process. Support from the school or educational institution administration also plays an important role in the model. The administration should provide access to the necessary ICT resources and infrastructure, as well as create conditions for the exchange of experience and cooperation between teachers. In addition, the administration should support the initiatives of teachers aimed at introducing innovative ICT solutions. Another component of the model is the constant self-development of the teacher. Information technology is constantly evolving, and the teacher should be ready to be aware of the latest trends and update their knowledge and skills. It is also important to develop a teacher's conscious attitude to ICT competence and the ability to self-assess so that he can systematically analyze his strengths and weaknesses and work on their improvement. Finally, the model should take into account the context and specifics of the educational institution. Each school or educational institution has its characteristics, and the introduction of ICT should be adapted to these characteristics. The model should contain flexibility and the ability to adapt to changes that may occur in the organization. Thus, the model of formation of ICT competence of teachers should be justified based on modern requirements and trends, taking into account the educational context, and contain elements of training, support, self-development, and adaptation.

4. A platform has been developed and implemented to provide methodological support for the formation of ICT competence of teachers in the context of the implementation of the proposed approach to informatization of its formation, including work programs of disciplines, electronic educational and methodological support for their implementation, a set of educational and methodological materials that provide all types of educational activities. This is a significant step in the development of informatization of education. The presented methodological platform is a comprehensive solution that includes several components. Working programs of disciplines help to structure the educational process and determine the main goals and objectives of teacher training. They are an important tool for planning and evaluating the learning process. Electronic educational and methodological support allows teachers to access digital resources, materials, and tools for teaching. It provides teachers with the opportunity to use modern technologies and techniques in their work, making the learning process more interactive and effective. The set of teaching materials provided on the platform is a valuable source material for teachers. These materials include textbooks, lesson summaries, assignments, and examples of work that help teachers develop lessons, conduct practical classes, and evaluate students' academic achievements. The platform offers comprehensive support to teachers in the formation of ICT competence. It not only provides the necessary educational content but also creates conditions for the development of key skills and abilities of teachers in the field of information technology. By using this platform, teachers will be able to become more confident and competent in using ICT in their teaching practice. This, in turn, will help them teach more effectively, create interesting and interactive lessons, and also improve the educational process as a whole.

5. The effectiveness of the formation of ICT competence in the implementation of the proposed

approach to informatization of education, taking into account the developed methodological support, is proved. Significant positive changes in the level of formation of ICT competence of teachers in experimental groups allow us to confirm the hypothesis and solve research tasks. These results mean that the proposed approach to informatization of education and the developed methodological support have a significant impact on the formation of ICT competence of teachers. This may be especially important in the modern information society, where the use of information and communication technologies is becoming increasingly necessary in the educational environment. Research is a valuable research contribution and can serve as a basis for further development and improvement of approaches to the formation of ICT competence of teachers. This also confirms the importance and usefulness of the methodological support that was developed during the research process.

Conflict of Interest Statement

The authors declare no potential conflicts of interest regarding the research, authorship,or publication of this article.

Author Contributions

Zh.E. Zulpykhar, N.T. Shyndaliyev, R.Z. Zhilmagambetova, and D.E. Kapanova contributed equally to this work. All authors were involved in the conceptualization, methodology, data collection, analysis, and interpretation of the results. All authors participated in writing, reviewing, and editing the manuscript and approved the final version for publication.

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DIGITAL PEDAGOGICAL TECHNOLOGIES IN TEACHING A SECOND FOREIGN LANGUAGE (GERMAN) IN A BILINGUAL ENVIRONMENT: PRACTICE AND PROSPECTS FOR HIGHER EDUCATION

Abstract. The study examines the role of digital educational technologies in teaching German as a second foreign language within the bilingual higher education environment. Using a quantitative, descriptive design, data was collected from 150 university teachers through a self-developed questionnaire. Conclusions indicate that the responsible majority were mid-career teachers with 6–10 years of professional experience, providing reliable insight into class practices. Results suggest that teachers strongly confirmed the effectiveness of digital devices in increasing vocabulary, grammar, and communication skills and increasing inspiration, cooperation, and inclusion. The average score above 4.0 reflects a wide consensus on the positive impact of digital technologies on the results of student learning. Teachers also reported readiness to integrate digital pedagogy, though challenges such as infrastructure limitations and the need for continuous professional training were emphasized. Significant differences in perceptions emerged by age and experience, with younger and mid-career teachers showing greater acceptance of technology. Overall, the study highlights both the promise and conditions necessary for sustainable digital pedagogy in bilingual contexts.

Keywords: digital pedagogy, bilingual education, second foreign language, German, higher education.

Introduction

The rapid digital transformation of higher education has changed the way languages are taught and learned. Digital pedagogical technologies have become the main instruments in the modernization of curricula. The use of digital platforms in foreign language education has brought new avenues for immersion, intercultural exchanges and personal learning experiences, which are difficult to get in traditional face-to-face settings (Azadov, 2025). In bilingual academic settings, learners who shift between their mother tongue and additional language such as English will surprise that the German phenomenon has become a unique challenge as the second foreign language. Despite this, Germany still holds a country with the richest culture and the most promising career opportunities in Europe, and the use of technology will make students busier arriving, practicing with German language, which may not come into language otherwise often (Stikhina & Erofeeva, 2024). In this way, the use of digital educational devices merges not only as a mere technological upgradation, but also as an essential educational remedy to strengthen the learning of the German language at the tertiary level.

Between many others, scholars have argued that successful digital education implementation in foreign language education will rely much more on the planned framework that combines the use of technology with the participation of students through active teaching techniques. Esen (2025) reveals that digital resources can do a variety of things simultaneously, from enabling interaction among users to raising their desire to learn more, while Zhang and Zou (2022) put forward that such technologies can be classified based on their effects on one’s ability to communicate, think rationally, and feel emotionally. They are excellent tools in situations when German is delivered as a second foreign language because as they facilitate the procurement of vocabulary, the practice of grammar, and the interaction between cultures, they do not need to be bound by the walls of the traditional classroom. For example, digital storytelling and gamification have been the focus of much research, which has led to them gaining recognition as powerful tools to improve students' involvement by providing them with authentic, creative, and interactive types of environments (Monti & Raffone, 2019; Perez & Masegosa, 2022). These strategies enable learners to get over one of the obstacles to motivation that they usually meet when they learn another foreign language, thus helping them to accumulate their confidence and fluency.

Simultaneously, however, it is not possible not to take into consideration the significant changes in the teaching and administrative practices, which are required because of the digital transformation of foreign language education. Chilla et al. (2025) argue that for a digitally inclusive setting, the faculty's preparedness for teaching it is of crucial importance, as they will have to do the integration of the tools while catering to the linguistic diversity of the students.

Comparisons between different situations reveal that the level of success of institutions following international models of digital pedagogy is in their capability to adapt to the changing needs of learners (Onishchuk et al., 2020; Guimarães & Hildeblando, 2021). It is worth noting that with regard to bilingual environments, the multilingual and plurilingual views stress the potential of digital pedagogies to facilitate student empowerment through acknowledgment of their current linguistic resources as well as via the provision of well-structured routes leading to languages such as German (Oliinyk et al., 2024; Galante et al., 2023). These views locate digital technologies in the range of non-supporting but really necessary components of language learning ecosystems in higher education.

This research is motivated by the increasing need for the incorporation of German as a second foreign language subject in the bilingual higher education program while simultaneously considering the issues of limited exposure, learner motivation, and teacher readiness. Even though English tends to be the dominating language in bilingual curricula, the addition of German will widen the students' linguistic palette and develop their intercultural skills, especially in the context of European academia and the labor market (Rubio-Alcalá & Coyle, 2021; Stikhina & Erofeeva, 2024).

However, the successful feeling of the plan depends not only on the availability of digital devices, but also on the evidence-based understanding of their effectiveness, ideas and obstacles in the behavior of students and teachers. This study to evaluate the experience of second stakeholders, first to determine its role in increasing the acquisition of German language by raising the issue of digital educational technologies, and the third to investigate the future possibilities of their integration in terms of higher education. And thus, it not only becomes a witness for teaching discourse related to digital changes of language education, but also for practical and viable design of bilingual programs.

The primary objective of this study is to investigate the effectiveness of digital pedagogical technologies in enhancing the teaching and learning of German as a second foreign language within bilingual higher education settings. Specifically, the research seeks to examine how the integration of digital tools can improve students' language acquisition, engagement, and overall learning outcomes.

Furthermore, this study aims to analyze the perceptions and attitudes of teachers regarding the incorporation of digital technologies into their teaching practices in a bilingual educational environment. Understanding educators' perspectives will provide valuable insights into the factors that influence their willingness to adopt and effectively use digital tools.

Finally, the research intends to explore the key challenges associated with implementing digital pedagogical technologies in higher education foreign language curricula. By identifying these obstacles, the study seeks to propose strategies for achieving sustainable improvements in the quality and effectiveness of foreign language instruction.

Literature review

The shift of higher education to the use of digital technologies has changed the entire foreign language teaching landscape and has provided novel possibilities for personal learning and mutual engagement. The scholars consider that in addition to expanding access, digital platforms bring radical changes to the educational methods used in the language instructions (Azadov, 2025). In terms of bilingual teaching, this digital change is even more important, as learners have to deal with different languages in this digital world, while at the same time they gain their proficiency in a new language like German. The growth of technical resources not only makes the teaching and learning process more adaptive and student-centered but also allows language learners to use authentic communication and develop their international skills in the changing environment.

Research has shown that mixed education is a more efficient way to achieve the language learning objectives if it is properly designed to balance face-to-face activities and online parts. It states that mixed instructions given in digital environment open the door to become the owner of their learning through the

use of such materials for students who are interactive and provide continuous practice.

In the same vein, Gacs et al. (2020) bring the difference between planned digital integration and emergency-based online teaching to say that the presence of technology alone does not guarantee the success of the academic process, but rather makes thoughtful plans. Mixed model for German language learning in bilingual environment makes it possible to combine the knowledge of culture with the practice of language, thus facilitates the development of educational and social skills at the same time.

Investigations related to digital tools for second language learning depict the tools' use cases and their pedagogical functions. Esen (2025) concludes that the digital resources may be such platforms as those for collaboration or gaming, with each resource meeting one specific need in language learning. Zhang and Zou (2022) characterize primary functions of these tools as communicative, cognitive, and affective, and they focus on the ability of tools to motivate and engage the learners. In the case of less commonly spoken languages such as German, where there is little exposure outside of the classroom, these types of technology become an important way through which the learners may practice and immerse themselves.

One of the most effective teaching methods that has been developed in second language acquisition for higher education is digital storytelling. According to Monti and Raffone (2019), storytelling becomes a platform offering real-life experiences to the learners as they creatively use the language in practice. The use of combined text, audio, and visuals makes the students' multimodal expression possible, which resembles the actual communication in the real world. This method is mainly helpful in a bilingual environment since learners may use their first language as a support while they gradually improve their German skills.

The digitization of the field of foreign language learning is a major change that also greatly affects the preparation of teachers. It is necessary for the digitally inclusive methods that teachers individually have the skills to include various devices for individually individual teaching and intercultural communication. Teacher's readiness is most important in bilingual situations, as teachers are those who have to deal with the complications of different languages as well as digital literacy among students. Studies conclude that professional development in these areas has a direct impact on the efficiency of digital education and its stability in higher education.

Domestic researchers have made a lot of comparative analysis of foreign language education in various countries, and their conclusion is that adopting international practices can lead to a local innovation facility. According to Onishchuk et al. (2020), Ukrainian universities have taken foreign models and used them for modernization of training of language teachers and development of digital skills.

Such cross-winter borrowings of various designs reflect the importance of international cooperation for the creation of borrowing courses that use the latest technology and at the same time suit local bilingual realities. The inclusion of world best practices with local adaptation in German language teaching can greatly affect the promotion of the results of learners.

The emphasis on multilingual and plurilingual education as a new teaching method shows increased awareness that learning another language is not a separate process. It claims that knowledge of many languages trains students to become a more optimal speaker because they can move fluidly from one language to another.

In addition, Galante et al. (2023) argues that Digital Plurilingual Pedagogies offer the learners an opportunity to actively use the target languages, while drawing at the same time in the list of their entire linguistic performances. In bilingual environment, this approach allows students to maintain their linguistic knowledge, and at the same time, it creates a favorable bridge for German learning as the second foreign language.

The difficulties faced by those who teach a second foreign language at non-linguistic universities still exist even when there is digital support. Stikhina and Erofeeva (2024) point out the fact that the learners often find second foreign languages such as German more difficult than others because of the limited exposure and lower motivation compared to English. On the other hand, if digital technologies are properly integrated, they can make the learning process more interesting and accessible, and thus the barriers mentioned above will be lowered. By using authentic communicative tasks and digital interactions to contextualize German, higher education can become a location of the transformation of perceived difficulty into opportunity.

Cross-border higher education has gone global, and digital resources play a significant part in the

communication and learning process of a foreign language. Guimarães and Hildeblando (2021) consider the digital technologies as one of the most important factors in the facilitation of the intercultural exchange, which in return gives the students the possibility of being more connected, and they get prepared for the global mobility.

German, being one of the most important languages to learn academically and professionally in Europe, is definitely very helpful when combined with digital tools, as they can provide the learners with the most authentic and latest cultural content, international peers, and even professional networks, which can be just perfect to not only strengthen the language skills but also the intercultural awareness.

One more point of the up-and-coming MALL is the promising field of development. According to Puebla et al. (2022), the use of mobile technologies creates versatile and learner-friendly scenarios where learners, even those who are vulnerable to barriers in the conventional learning context, can study. Vocabulary development and micro-learning tasks are the areas in which the portability and immediacy of mobile applications make them especially effective. However, there are issues such as digital distractions and different competence levels of digital literacy that need to be managed in order to guarantee that the benefits can be fairly distributed.

Although digitization is one of the most important changes in foreign language teaching, creating a favorable environment for learning is the foundation of success. Shulgina et al. (2023) has an opinion that language digital ecosystems can not only reduce the problem of limited communication requirements, but can also expand the boundaries of mutual and professional skills. This is the same as Petrenko et al. (2020) mentioned that digital resource courses provide more flexibility in design, which is more responsible.

Thus, the environment of the culture-teaching school for bilingual learners of German provides an opportunity where academics can be real in the classroom and students are concurrently immersed in intercultural contact as well as communication capacity.

The structure is the backbone of any institution, and it is also true for the Foreign Language Department. The role of Foreign Language Centers (FLCs) in adopting digital education is really very important. In its research, Tseliga (2019) suggests that FLC is challenged when it comes to lining its resources with changing academic needs, but they are still necessary to promote innovation. Activity method proposed by Biletska et al. (2021) also goes with this claim, as it allows for the development of student-centered, interactive and active functions that can be facilitated using digital platforms. These institutional and functioning support are especially relevant to the inclusion of German as a second foreign language (L2) in bilingual courses, thus it is a viable and attractive option.

Asia's research clearly reveals how digital learning is changing the second language acquisition worldwide. Kawaguchi (2021) says that digital platforms offer language risk in places where it is very difficult to communicate directly with the native speakers of the language. While their focus is Asia, the situation in bilingual European contexts is very high, where students may have very little contact with the German language outside the school environment. Digital resources are being used to fill this void by giving students the possibility of being fully attached to the language and thus makes the experience closer to real communication as much as possible.

Gamification is another factor that has powerful energy and can attract more students in a multilingual he atmosphere. Perez and Mashegosa (2022) claim that gamified technology motivates learners to actively engage and also reduce the anxiety related to learning language.

For German learners, integration of gamification in bilingual programs is extremely beneficial, as it provides them an opportunity to work on their hard grammar and vocabulary through sports and other fun activities, which are usually low-minded, and thus learning is reinforced without loss of student interest.

The teacher's knowledge in the field of digital and ICT literacy is very important for keeping up with these changes. Konovalenko et al. (2022) state that future foreign language teachers should have various digital skills, and they must be able to efficiently use technology in their teaching. Konovalenko and Nadolska (2020) agree with that and stress the importance of information technology literacy for the preparation of the educators for the contemporary challenges. Still, without these skills, even the most advanced digital resources run the risk of being underutilized. Therefore, the training of digitally literate teachers should be considered the top priority in the progression of German language education in bilingual higher education.

New developments such as artificial intelligence and aggregative communication give us an idea of where language instruction may be headed in the future. Godwin-Jones (2025) points to AI as a tool to facilitate less commonly taught languages through adaptive learning systems, whereas Solmaz (2025) refers to apps like Duolingo for reshaping multilingual learners' experiences.

Collectively, these studies predict that digital language learning will be increasingly personalized and interactive and is a planet-sized as well as globally interconnected. As far as German as a second foreign language in bilingual higher education is concerned, these technological breakthroughs are the cause to expand the practice periodically and to move more extensively towards linguistic and cultural competence through the gradual disappearance of inclusion barriers.

Materials and methods

In order to study digital pedagogical technology integration for teaching German as a second foreign language in the bilingual higher education context, the research was carried out through a quantitative descriptive research design.

It was deemed suitable to use the quantitative approach, as it facilitated the collection of standardized data from a relatively large group of respondents and empowered the researcher to measure trends, attitudes, and practices in a systematic way. By identifying emerging challenges and future prospects alongside documenting the present state of pedagogical practices, the research accomplished its objectives.

The research sample was made of university lecturers who teach foreign languages and are especially dedicated to those schools where bilingual education programs are set up and German is taught as the second language.

Teachers have been identified as the group most central to the deployment of digital pedagogy strategy, transforming classroom practices, and positively impacting the learner's outcome; thus, they were chosen as the object of this study. Their opinions and experiences were an important source of truth regarding both the advantages and limitations of the incorporation of digital tools in higher education language curricula.

150 teachers were picked as the simple random sample from the population. The method guaranteed that every member of the target population had an equal chance of being included in the study, which minimized bias and maximized the representativeness of the results.

The size of the sample was considered enough to provide a substantial quantitative analysis of the data, as well as to detect similar behaviors among differing institutional contexts.

A self-made questionnaire was used as a data collection tool in this research, which was designed with reference to the literature and precedents in the field of digital pedagogical technology in foreign language education.

The survey instrument was intended to identify technologies' adoption, practices, and experiential aspects across different areas of technology integration. Five-point Likert scale ranging from Strongly Agree to Strongly Disagree was used to construct items, which allowed for detailed responses, and, at the same time, these responses could be quantified and statistically analyzed.

The instrument was made with quality in mind, and for this reason, validity and reliability testing was carried out. The questionnaire was given to language education and educational technology experts for them to check if the contents were valid. A pilot study was also conducted with the help of a small group of teachers, who were given the questionnaire, and their feedback was taken into consideration when necessary adjustments were made. Cronbach's alpha, which showed a high level of internal consistency, was used as a measure of reliability, and this, in turn, enabled the identification of the instrument's suitability for the main study.

Data were collected both through physical distribution and online collection. The questionnaire was in a printed version, which was handed out to selected universities, and an online version was made available as a Google Form link, which ensured that more people could have access to it and would participate. Response rates benefited from this hybrid approach, as teachers from various institutions could easily contribute to the study despite geography or scheduling constraints.

The study's data were subjected to both descriptive and inferential statistical techniques using a Statistical Package for the Social Sciences (SPSS) software program. Descriptive statistics such as

frequency, percentage, mean, standard deviation, etc., were used to summarize the data and to show the general trends of digital pedagogical practices.

While testing the connections and differences between the variables, the researcher went deeper into the field of the perceptions of the effectiveness and challenges of digital technology integration in teaching German within bilingual higher education contexts by applying inferential methods.

Results

Table 1 shows the demographic characteristics of the respondents. Out of 150 participants, females (63.3%) outnumbered males (36.7%).

Most respondents fell within the 41–50 age group (56.7%), followed by those aged 31–40 (32.7%), while only a small number were between 21–30 (1.3%). In terms of teaching experience, a majority had 6–10 years of service (56.7%), with fewer teachers in the ranges of 1–5 years (16%), 11–15 years (24%), and above 15 years (3.3%).

These demographics indicate that the data primarily represents mid-career and experienced teachers, providing reliable insights into the integration of digital pedagogical technologies.

Table 1.

Frequency distribution at the basis of demographic analysis

Title	Description	Frequency	Percentage (%)
Gender	Male	55	36.7%
	Female	95	63.3%
	Total	150	100%
Age of respondents	21-30 Y	2	1.3%
	31-40 Y	49	32.7%
	41-50 Y	85	56.7%
	51-60 Y	14	9.3%
	Total	150	100%
Experience	1-5 Y	24	16.0%
	6-10 Y	85	56.7%
	11-15 Y	36	24.0%
	>15 Y	5	3.3%
	Total	150	100%

Table 2 highlights teachers' perceptions regarding the effectiveness of digital technologies in teaching German. The majority strongly agreed or agreed that digital tools make learning interactive, support grammar understanding, and improve vocabulary practice, with mean scores ranging from 4.04 to 4.41.

The respondents also recognized the role of digital platforms in listening and increasing the skills of speaking and stated that such equipment increased inspiration and supported personal learning.

The overall tendency suggests a strong agreement that digital technologies positively affect students' performance and engagement in German learning.

Table 2.

Perceived effectiveness of digital technologies

N	Statements of questions	SA	A	UD	DA	SDA	M	SD
1	Digital tools make learning German more interactive and engaging	72	70	6	2	0	4.41	0.64
		48%	47%	4%	1%	0%	-	-
2	The use of digital technologies helps me understand German grammar more effectively.	66	79	5	0	0	4.41	0.56
		44%	53%	3%	0%	0%	-	-
3	Online resources improve my ability to practice German vocabulary regularly.	58	86	4	0	2	4.32	0.66
		39%	57%	3%	0%	1%	-	-
4	Digital platforms provide useful opportunities to practice German listening and speaking skills.	63	75	5	6	1	4.29	0.77
		42%	50%	3%	4%	1%	-	-

5	Learning German through digital technologies is more effective than traditional methods.	40 27%	84 56%	18 12%	8 5%	0 0%	4.04 -	0.78 -
6	Digital tools enhance my motivation to learn German as a second foreign language.	52 35%	73 49%	20 13%	5 3%	0 0%	4.15 -	0.77 -
7	Using digital technologies has improved my overall performance in learning German.	50 33%	81 54%	17 11%	1 1%	1 1%	4.19 -	0.71 -
8	Digital pedagogical technologies help me learn German at my own pace and according to my needs.	54 36%	84 56%	9 6%	2 1%	1 1%	4.25 -	0.69 -

The data of Table 3 reflects the attitude of the respondents towards integrating the digital tool in German language teaching.

Table 3.

Perceptions and attitudes toward digital technologies

N	Statements of questions	SA	A	UD	DA	SDA	M	SD
9	I enjoy learning German when digital technologies are integrated into teaching.	44 29%	92 61%	11 7%	0 0%	3 2%	4.16 -	0.72 -
10	Digital resources make the learning environment more student-centered.	59 39%	75 50%	10 7%	4 3%	2 1%	4.23 -	0.80 -
11	Teachers are well prepared to use digital technologies in teaching German.	49 33%	84 56%	13 9%	1 1%	3 2%	4.17 -	0.77 -
12	The use of digital tools increases my confidence in learning German.	43 29%	78 52%	21 14%	6 4%	2 1%	4.03 -	0.84 -
13	I feel that digital tools make German learning more accessible and inclusive.	45 30%	84 56%	16 11%	3 2%	2 1%	4.11 -	0.77 -
14	I believe that digital technologies encourage active participation in class.	50 33%	86 57%	10 7%	4 3%	0 0%	4.21 -	0.68 -
15	Digital learning platforms foster collaboration among students in learning German.	59 39%	77 51%	12 8%	2 1%	0 0%	4.29 -	0.67 -
16	I am satisfied with the integration of digital technologies in my German language courses.	42 28%	97 65%	7 5%	4 3%	0 0%	4.18 -	0.64 -

With average score from 4.03 to 4.29, a high level of agreement was recorded in the item. Most of the teachers believed that digital resources promote student-centric learning, cooperation, and encourage active participation. Satisfaction with integration of digital technologies was also notable, many people admit that teachers are usually well prepared to use such devices. These findings show that digital academic technologies are not only effective, but also well received by both teachers and learners in bilingual contexts

Table 4 presents insights into future opportunities and challenges in using digital pedagogical technologies.

Table 4.

Prospects and challenges of digital pedagogy

N	Statements of questions	SA	A	UD	DA	SDA	M	SD
17	Digital technologies can significantly improve future teaching of German in higher education.	48 32%	87 58%	11 7%	4 3%	0 0%	4.19 -	0.68 -
18	The integration of digital pedagogical tools ensures long-term benefits for bilingual language education.	61 41%	75 50%	12 8%	2 1%	0 0%	4.30 -	0.67 -
19	Lack of technical infrastructure is a major challenge for implementing digital language teaching.	47 31%	82 55%	13 9%	8 5%	0 0%	4.12 -	0.78 -
20	Teachers need more professional development to use digital tools effectively in teaching German.	50 33%	82 55%	11 7%	6 4%	1 1%	4.16 -	0.78 -
21	The use of artificial intelligence and new technologies will shape the future of German language education.	54 36%	78 52%	15 10%	3 2%	0 0%	4.22 -	0.70 -
22	Digital pedagogy can help overcome the difficulties of learning German as a second foreign language.	49 33%	77 51%	19 13%	5 3%	0 0%	4.13 -	0.76 -
23	I believe investment in digital resources is essential for improving German language teaching.	53 35%	83 55%	12 8%	2 1%	0 0%	4.25 -	0.65 -
24	Future prospects of digital pedagogical technologies are promising for bilingual higher education.	62 41%	65 43%	16 11%	4 3%	3 2%	4.19 -	0.88 -

Respondents largely agreed that digital tools ensure long-term benefits, improve teaching prospects, and can overcome learning difficulties, with mean values above 4.10. They also emphasized the need for teacher training and investment in infrastructure, while acknowledging the potential role of artificial intelligence in shaping future practices.

Although some concerns about infrastructure gaps remain, the overall perception is optimistic about the sustainable role of digital pedagogy in bilingual higher education.

Table 5 presents the analysis of variance at the basis of gender.

Table 5.

Analysis of variance at the basis of gender

Gender	N	Mean	Std. Deviation	df	t	Sig. (2-tailed)
Male	55	147.84	9.95	148	0.06	0.955
Female	95	147.75	8.97	-	-	-

The t-test results show no significant difference between male and female respondents in their perceptions of digital pedagogical technologies (p = 0.955). Both genders reported nearly identical mean scores, indicating that attitudes toward the use of digital tools in teaching German are consistent across gender lines.

Table 6 presents the analysis of variance at the basis of age. The ANOVA results reveal a significant difference in perceptions across age groups (p = 0.001).

Table 6.

Analysis of variance at the basis of age

Age	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1690.89	3	563.63	7.34	0.001
Within Groups	11218.85	146	76.84	-	-
Total	12909.74	149	-	-	-

This indicates that teachers' attitudes toward digital pedagogical technologies vary by age, with younger and mid-career teachers likely to show greater acceptance and confidence compared to their older counterparts.

Similar to age, teaching experience also shows significant differences in perceptions of digital pedagogical technologies (p = 0.001) (Table 7). The results suggest that mid-career teachers with 6–10 years of experience expressed stronger agreement on the effectiveness and prospects of digital tools compared to those with very limited or very extensive teaching experience.

The research results indicate that the majority of respondents belonged to the female teaching staff, which makes up 63.3% of the sample, while males were 36.7%. Most of the participants were aged between 41 and 50 years (56.7%), followed by those aged 31–40 with 32.7%.

Table 7.

Analysis of variance at the basis of experience

Experience	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1708.49	3	569.50	7.42	0.00
Within Groups	11201.25	146	76.72	-	-
Total	12909.74	149	-	-	-

The groups of under 30-year-olds and over 50s were quite small. More than half of teachers (56.7%) had a 6–10-year professional experience, while small groups were distributed less than 5 years and more than 15 years of experience in teaching. These demographic features indicate the fact that the reactions came mainly from the career level between teachers, which are exposed to digital academic practices for a long time; Thus, their insight is quite reliable.

The implementation of digital technologies in the school and the German home learning were given high status by teachers. He also admitted that it becomes easy to come with languages with digital tools, as

they provide inputs of hearing and reading, as well as they facilitate grammar and vocabulary.

With the average rating overtook 4.0, the respondents stated that digital equipment not only stimulates inspiration and provides personal learning support, but also contributes to the improvement of student's performance. Thus, this study reveals that there is a common agreement among respondents that resorting to digital academic technologies plays an important role in achieving language learning goals.

In terms of perceptions and approaches, the users of digital solutions in German language teaching were quite materials. He emphasized that the use of digital materials provokes working-based learning and promotes interaction and hence not only in class but also beyond it.

In addition, they agreed that such equipment makes good access and inclusion, while at the same time develop the confidence of learners. Most of the respondents considered their training enough, which enabled them to include these techniques, which makes us believe that along with institutional readiness, the teacher ability also plays a major role.

The purpose of research is to discover opportunities and challenges generated by technical teaching methods. They were complete sure that digital technology, in the long run, can bring a lot of benefits in the environment of bilingual education, improve the horizon of language teaching, and even make it easier to learn.

Nevertheless, the infrastructure upgrade and continuous teacher training were two main issues raised by them to achieve maximum receipt of efforts in training benefits. The AI and New Tech portion was also seen as an essential factor that would determine the future of the German language instructions. While infrastructural deficiency is still seen as a difficulty, there is an optimistic tone of general stability and innovation in the field of digital education.

The discovery of the impact of demographic factors on the study variables achieved deep insight. The penis was not considered a major factor, as the views shared by male and female teachers about digital academic technologies were more or less similar.

However, the difference in age and teaching experience occurred due to the emergence of statistically important results. When it came to use digital devices compared to older people, small and mid-career teachers looked more inclined and confident. Similarly, teachers who have experience 6–10 years, felt more positive about the efficiency and possibilities of digital technologies, which are starting or ending their teaching career. The study found that the readiness for digital education may be more generated and related to career-phase factors than the gender.

Discussion

The main results of this research work show, firstly, that digital pedagogical technologies have a crucial role in teaching a second foreign language, especially in a bilingual environment. For example, technologies work well in German language classes in universities. The survey shows that the implementation of the ICT tools leads to the involvement of the students and to the consolidation of the vocabulary and grammar. Moreover, digitalized material facilitates the listening and speaking processes of the learners since it offers a wider range of interactive activities.

These findings are consistent with Ihnatova et al. (2021), where the authors also point out that the application of digital technologies in hybrid and bilingual milieus propels the learners' autonomy, cultivates the engagement of all students, and finally, raises the quality of the course. The same is true for Azadov (2025), who, besides the emphasis on the role of technology for better learning results, talks about the modernization of pedagogical practices when digital tools are involved in higher education.

The teachers' positive experience with and openness to using digital tools are indicative of their confidence in integrating technology in their pedagogical work. Inclusion, collaboration, and autonomy, together with accessibility for diverse groups of students, are some of the pedagogical values that the participating teachers saw as being enhanced by using ICT as instructional resources.

Thus, we may refer to the conclusions of Esen's (2025) systematic review of the literature, which suggests that digital tools for second language acquisition increase student engagement by offering personalized learning experiences and that we can see this especially in higher education contexts. Furthermore, practitioners holding such views about their preparedness to use technology for teaching make us think of Chilla et al. (2025), who, in the same vein, indicate that digital language education will be

successful if teachers are trained well enough.

According to the results of this survey, notable factors are gender, age, and experience, with the latter two having a significant impact on perception. Young and middle-aged teachers are more open to saying that they can incorporate the technology successfully in their own classes. On the contrary, older teachers seemed a little skeptical about using ICT in their classrooms.

This difference between generations is a classic example of the general trend of technology adoption in the educational field. Puebla et al. (2022) also concluded that older educators and learners would struggle more to transition to mobile and digital learning environments, which underscores the significance of continuous professional development. Thus, it might be the case that training programs dedicated to senior faculty are the best way to solve the problem of the digital divide in HEIs.

Teachers' acknowledgment of the opportunities and challenges offered by digital pedagogy is another important result of the research. The respondents agreed that artificial intelligence and other futuristic gadgets will become the pillars of the bilingual method of the future, as digital tools can be a great stimulus for that.

At the same time, they also brought up problems such as infrastructure gaps and the need for continuous professional development. The issues raised here by practitioners who embrace technology are echoed in Monti and Raffone's (2019) report pointing out that a major concern regarding the sustainability of innovations is the level of institutional support provided in this direction. The above clearly suggests that we can only achieve the benefits of digital education if institutional obstacles are addressed for its full use, such as people belonging to infrastructure.

Complete discussion suggests that digital technologies not only serve as a useful support for teaching and learning, but on the other hand, are characterized by teachers as a valuable tool in a bilingual context of higher education.

However, his richness depends a lot on the organization's commitment, training, and proper allocation by various groups iconic through age and experience by various groups. Keeping the results in interaction with current educational research, this research study suggests that the implementation of digital educational technologies in second foreign language teaching is not only an essential and attainable pathway for university teaching in future, but also moves forward in the higher education sector.

Conclusion

Research has concluded that digital academic technologies are very effective in teaching Germans as a second foreign language in a bilingual higher education environment. The teachers stated that this equipment improves the learning process by enhancing student engagement and inspiration, as well as strengthening grammar, vocabulary, and communication skills.

These positive attitudes mark the use of digital resources as a means of supporting student-centered learning, inclusion, and cooperation principles. The results also suggest that most teachers are in a position to execute digital technologies competently, a suggestion of great greetings between teacher skills and institutional readiness. These results support the first two objectives of the study, showing the effectiveness of digital technologies and their use by teachers at the same time.

At the same time, the study reveals the fact that the ability of digital education is quite attainable, but there are still some difficulties in overcoming some difficulties. Among other things, the participants indicated the long-term possibilities of digital innovations, which may be the future of bilingual language education, such as Artificial Intelligence.

Nevertheless, they were still drawing attention to the needs of infrastructure and continuous teacher training, which one of the most important factors is contributing to success. In addition, differences in age and experience are also indicated in adopting technology along the lines of generational intervals. These reflections, when pieced together, align with the third research purpose, which controls our disposal ability and faces obstacles because we take steps towards digital academic practices. In the final analysis, research does not leave much space for doubt that digital equipment is already making significant changes in the way they teach foreign languages; nevertheless, how far they will succeed in the future will be contingent on the important investment of strategically teaching workforce resources, training, and equitable access to the world.

Based on the findings of the study, the authors recommend strengthening the digital transformation of higher education institutions by investing in modern digital infrastructure and ensuring equitable access to technological resources for all faculty members. Particular attention should be given to the continuous professional development of academic staff through targeted training programs aimed at enhancing digital competencies, especially among senior educators and those with limited experience in using digital technologies. In addition, universities are encouraged to integrate emerging technologies, including artificial intelligence, into educational programs and teaching practices to foster personalized, innovative, and more effective language learning experiences while supporting the development of digital skills required in contemporary education.

Conflict of Interest Statement

The authors declare no potential conflicts of interests regarding the research, authorship, or publication of this article.

Author Contributions

Gulden Tussupova: Conceptualization, Methodology, Supervision, Writing – Review and Editing, Proofreading.

Aiman Aubakirova: Literature Review, Data Analysis, Resources, Data Analysis, Final Editing.

Gulizat Nurbekova: Data Collection and Curation, Validation, Visualization, Writing – Original Draft.

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INTEGRATED USE OF CASE STUDY METHODS AND REFLECTIVE PRACTICES IN DEVELOPING PROFESSIONAL COMPETENCIES OF FUTURE CHEMISTRY TEACHERS IN AN INCLUSIVE EDUCATION ENVIRONMENT

Abstract. The article examines the impact of the integrated use of the case method and reflective practices on the development of professional competencies of future chemistry teachers in the context of inclusive education. The theoretical section substantiates the need to develop teachers' knowledge, skills, and value orientations that enable effective teaching of diverse groups of students, and proposes an approach that combines analysis of practical cases with systematic reflection. In a pedagogical experiment, students of a teacher training university were divided into an experimental group (with the use of cases and reflective tasks) and a control group (traditional instruction). The experiment lasted one semester. By the end of the course, the experimental group showed a statistically significant improvement in indicators of readiness for inclusive teaching compared to the control group ($p < 0.001$). A thematic analysis of students' reflective journals was also conducted, revealing positive dynamics in their awareness of learners' individual needs, professional self-improvement, and confidence in working with children with special needs. In the discussion section, the results are compared with contemporary research; conclusions are drawn about the high effectiveness of the combined use of case method and reflection in preparing teachers for inclusive practice, and the limitations of the study are considered. Finally, practical recommendations for teacher education programs and directions for further research are provided.

Keywords: case method, reflective practice, inclusive education, professional competencies, chemistry teacher, pedagogical experiment.

Introduction

Inclusive education, recognized worldwide as a fundamental right of every child, aims to educate all students together, regardless of their developmental differences and educational needs. Its goal is to ensure the full participation of each student in the educational process, valuing diversity and promoting social integration. Achieving this goal largely depends on teachers' willingness to differentiate instruction and create a supportive environment for all students (Georgiadi & Papazafiri, 2025). However, research shows that many teachers lack the competencies to work in inclusive classrooms. In one study, only one in ten teachers reported a sufficient understanding of inclusive teaching methods; the majority acknowledged the need for additional training in this area. Graduates of pedagogical universities often begin working without sufficient practical experience working with children with special educational needs, which leads to difficulties and a sense of insecurity early in their careers. A lack of knowledge and skills in inclusive pedagogy negatively impacts teachers' attitudes toward inclusion and the quality of education for children with special educational needs. Thus, a pressing issue is the search for effective means of developing the professional competencies of future teachers to work in inclusive education.

Modern approaches to teacher training emphasize the need to shift from predominantly theoretical teaching to active methods that develop teachers' practical skills and reflective thinking (Georgiadi & Papazafiri, 2025). In particular, the case method, a teaching technique based on the analysis and discussion of realistic situations from practice, has attracted attention. The case method originally originated in legal and business education, but in recent decades it has also become widespread in teacher training. Immersing future teachers in scenarios that simulate complex teaching situations allows them to "revive" theoretical knowledge and connect it with real-world classroom practice. Research shows that case-based learning increases student engagement and participation, develops analytical and decision-making skills, and fosters empathy and tolerance (Georgiadi & Papazafiri, 2025). Sharing and analyzing stories from practice helps develop a deeper understanding of student diversity and how to work with them in future teachers, which is

especially important in an inclusive classroom. For example, in a study, web-based case studies were used to teach 40 future teachers the principles of adapting lessons for children with special needs and demonstrated effectiveness in developing inclusive skills. Another study found that the use of case studies significantly enhanced students' reflective thinking regarding pedagogical problems, although it did not fundamentally change their initial views (Hoffer, 2020). This confirms the potential of case studies as a tool for stimulating critical reflection on their own teaching experiences.

Along with the case study method, reflection is recognized as a key component of teacher professional development. The concept of "reflective practice" involves the meaningful analysis of one's own experience with the goal of learning lessons for the future. According to the definition, reflective practice is a set of mental and emotional actions in which a specialist examines their experience to arrive at new understandings (Deniz & İlik, 2021). John Dewey noted that reflection begins with a state of doubt or difficulty and culminates in the discovery of a conclusion or solution, thereby extracting meaning from each experience for future action (Saloviita, 2020). In the context of teacher training, reflection is considered an essential component of professional learning. As researchers note, reflective practices are incorporated into all teacher education programs, following the cyclical process of "action - analysis - new knowledge - improved practice." Common forms include reflective journals, portfolios, group discussions of experiences, and others all of which help future teachers develop the habit of self-observation and continuous self-improvement (Larios & Zetlin, 2023). Reflection plays a particularly important role in inclusion settings: teachers, faced with the diverse needs of their students, must be able to critically evaluate the effectiveness of their methods and, if necessary, promptly adjust them. The review emphasizes that the reflective practice of special educators is directly linked to the successful inclusion of children with special educational needs in the general classroom (Sancar et al., 2021). Reflection allows teachers to understand what happened in the lesson and why, and, based on this experience, develop more effective teaching strategies that take into account the interests and abilities of all students.

Both the case study method and reflective practices have proven effective tools for teacher training. Moreover, the idea of their integrated application is gaining increasing support in both theory and practice (Byrd & Alexander, 2020). Analyzing pedagogical situations through case studies provides material for reflection, while reflection deepens the assimilation of this material, transforming the experience into a foundation for professional growth. It can be assumed that the combination of the case study method with targeted reflection creates a synergistic effect: future teachers not only learn about the principles of inclusive education but also experience typical situations, reflect on their experiences, and thereby develop sustainable competencies (Kelly & Barrio, 2021). This approach is consistent with modern models of inclusive teacher training, which emphasize the development of both knowledge and skills (cognitive and practical components) and values and motivation a mindset toward inclusion, empathy, and confidence (affective component). In a number of studies, such holistic preparation is described using the "Heart-Head-Hands" metaphor, implying the unity of a teacher's beliefs, knowledge, and skills for successful inclusive practice.

The aim of the study was to experimentally test the effectiveness of the integrated use of case studies and reflective practices in developing the professional competencies of future chemistry teachers for work in an inclusive education environment. The hypothesis was that integrating case studies and reflection into the educational process of future teachers would lead to a more significant increase in their readiness for inclusive education (compared to traditional training methods). To test this hypothesis, a pedagogical experiment was planned with chemistry students, comparing their competency indicators before and after training, as well as a qualitative analysis of the students' reflective materials reflecting the dynamics of their professional consciousness.

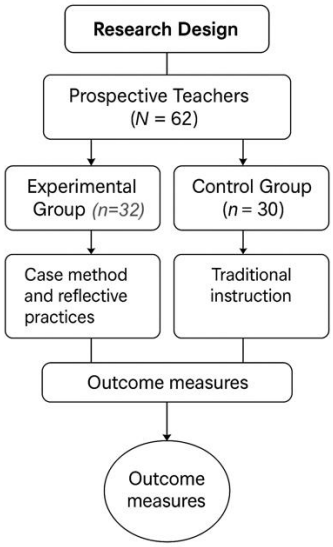
Methods and Organization of the Study

A pedagogical experimental study was conducted using a control group vs. experimental group design, with pre- and post-test measurements. The independent variable was the use of specialized teaching methods: the experimental group integrated the case study method and reflective practices, while the control group followed a traditional curriculum without an emphasis on these methods. The dependent variables indicators of the development of professional competencies for working in an inclusive environment were measured before and after the experiment (at the beginning of the semester) and after its completion (at the

end of the semester) in both groups. In addition, qualitative data (reflective diaries) were collected from the experimental group to allow for an in-depth analysis of changes in their perceptions of inclusive education.

Sixty-two fourth-year students majoring in Chemistry (Chemical Education) at a pedagogical university participated in the study. All participants had previously completed basic courses in chemistry pedagogy and teaching methods. They had not completed a separate systematic course on inclusive education before the experiment. Students were randomly assigned to two groups: experimental (N = 32) and control (N = 30). The groups were comparable in terms of age and gender and academic composition: average age was ~21 years; the proportion of girls was 68% (experimental) and 70% (control); the average grade point average at the beginning of the experiment was ~3.7 (on a five-point scale) in both groups. Participation in the experiment was voluntary, and all students gave informed consent for the processing of the obtained data in aggregate form (Figure 1).

Figure 1.
Research Design Flowchart



The experimental training program lasted one semester (15 weeks) and was implemented within the framework of the academic discipline "Chemistry Teaching Methods in an Inclusive Classroom," specially developed for the study. In the experimental group, training in this discipline included: (1) regular use of the case method: students weekly analyzed cases (descriptions of situations) from the practice of teaching chemistry related to inclusive education (e.g., conducting a chemistry experiment with a student with a hearing impairment; group work including a student with an autism spectrum disorder; differentiated explanation of a new topic taking into account the different levels of preparation of students, etc.). Cases were prepared by the teacher based on real cases and included supporting materials: student characteristics, lesson fragments, student performance. Case discussions took place in small groups of students, followed by a general discussion in class. (2) Systematic reflective practices: Students kept individual reflective diaries after each lesson and case discussion, recording their conclusions, questions, emotions, and plans for applying what they had learned in practice. In addition, reflective sessions were held in small groups every two weeks: students shared experiences and diary entries with each other, discussing what they had learned about teaching in an inclusive environment and how this changed their approach. The teacher (researcher) facilitated these discussions, asking guiding questions and encouraging in-depth analysis. Otherwise, the curriculum followed the standard: students studied the principles of inclusive education, didactic strategies for a diverse class, adapting teaching materials and assessment tools, working in teams with tutors and psychologists, etc. – but all topics were illustrated with cases and accompanied by reflective reflection. In the control group, the same course was taught using the traditional method: lectures and seminars, without a specific emphasis on case studies and reflection. Students in the control group received the same amount of theoretical information on inclusive education (definitions, principles, methods) and completed practical assignments (developing lesson fragments, tests, etc.), but did not analyze case studies or keep mandatory

reflective journals. Thus, the main difference between the groups was the teaching method.

A comprehensive approach was used to quantitatively assess the development of competencies. An integrated criterion, "readiness for inclusive education," was developed, including three components: (a) Knowledge - assessed using a specially designed 30-question test on key aspects of inclusive pedagogy (knowledge of the legislative framework, differentiation methods, the main categories of special educational needs and ways to support students, etc.); (b) Skills - assessed based on the results of completing a practical assignment: developing a chemistry lesson on a given topic for a class with two students with disabilities (hearing and cognitive impairments). The lessons were assessed by two independent experts using a developed scale (criteria: adaptation of learning objectives, variability of methods, consideration of special needs, methods of student interaction, differentiated assessment, etc.). The average score of the experts was converted into a percentage. (c) Attitudes – measured using the ATI (Attitudes Toward Inclusion) questionnaire in an adapted version containing 20 statements assessed on a Likert scale (1–5). The questionnaire revealed the degree of agreement with positive and negative statements about inclusion (e.g., “Education in a regular classroom is beneficial for children with special needs,” “The presence of a student with a disability in the classroom reduces the academic performance of the rest,” etc.). For each component (knowledge, skills, attitudes), the percentage of the maximum possible was calculated. Then, the integral indicator of competence was calculated as the average value of the three components (in %). This summary score, reflecting the student’s overall readiness for inclusive education, was used for statistical comparison of the groups. The measurement was conducted twice – before the start of the course (pretest) and after its completion (posttest). The reliability of the instruments used was pre-checked: the cognitive test had a Cronbach’s α coefficient of 0.82; The agreement between expert assessments of lessons is the agreement coefficient of ~0.75; the attitudes questionnaire is $\alpha = 0.88$.

To test the hypotheses about the differences, the parametric Student's t-test was used. Since the sample size was relatively small, the conditions for applying the t-test were preliminarily checked: the distributions of pre- and post-test scores in the groups were close to normal (Shapiro-Wilk criterion $p > 0.1$), the variances were comparable (Levene's criterion $p > 0.05$). Paired t-tests for dependent samples (to assess the significance of changes within each group before and after training) and independent t-tests (to compare the experimental and control groups with each other at the end of training) were performed. The significance level was set at $p < 0.05$. To estimate the effect size, Cohen's d coefficient was calculated. Regarding the qualitative data, thematic analysis was conducted manually using MS Excel tables; the reliability of the resulting thematic categories was ensured by coding agreement between two researchers (the agreement coefficient was ~0.8 at the coding stage). Students' quotes in the text are provided anonymously (the student's reference number is indicated).

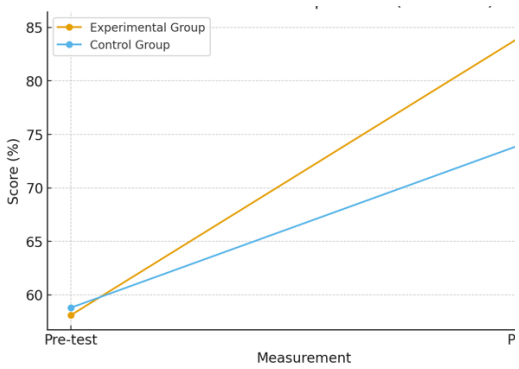
Research Results and Discussion

At the pre-test stage, no significant differences were found between the experimental and control groups in the integrated indicator of readiness for inclusive education ($M = 58.1\%$ and $M = 58.8\%$, respectively; $t(60) = -0.28$; $p = 0.78$). This indicates that the participants had comparable levels of competence prior to the experiment. In both groups, the average pre-test score indicated a moderately low level of student readiness for inclusive education (~59% of the maximum): many students lacked knowledge of terminology and methods (the procedure for developing an individualized curriculum was particularly poorly understood – less than 40% of correct answers), and the attitudes questionnaire showed some uncertainty (for example, about 30% of students agreed with the statement “in a regular class, it is impossible to pay sufficient attention to children with special needs”). Thus, the starting conditions of the groups can be considered equal and characterize the typical level of preparation of graduates, which has significant potential for development. Following the implementation of the experimental program (posttest), a statistically significant increase in the average competence score was observed in both groups (Fig. 2). In the control group, the increase was approximately 15.8 percentage points (from 58.8% to 74.6%; paired t-test: $t(29) = -7.75$; $p = 1.5\times10^{-8}$), indicating a positive impact of even traditional training on expanding knowledge and partially correcting attitudes. However, in the experimental group, the increase was significantly higher – approximately 27 percentage points (from 58.1% to 85.1%; $t(31) = -12.25$; $p = 5.5\times10^{-13}$). The final average competence score in the experimental group reached 85%, which corresponds

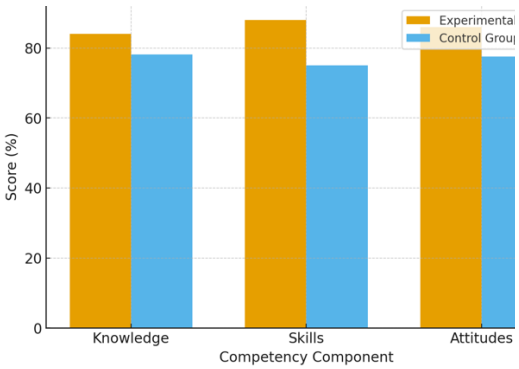
to a high level of readiness for inclusive activities (close to professional): students demonstrated a deep understanding of the principles of inclusion, the ability to develop detailed, adapted lesson plans, and expressed a predominantly positive attitude and self-confidence.

Figure 2

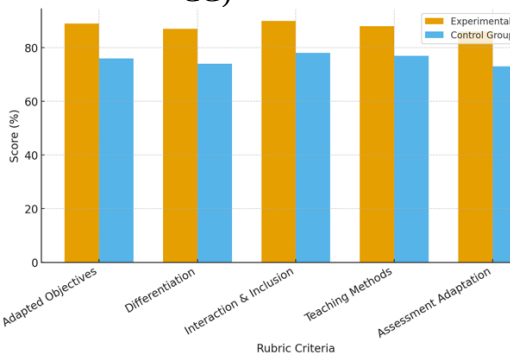
Dynamics of the integral indicator of readiness for inclusive education (as a percentage of the maximum) among students in the experimental and control groups (before and after training).



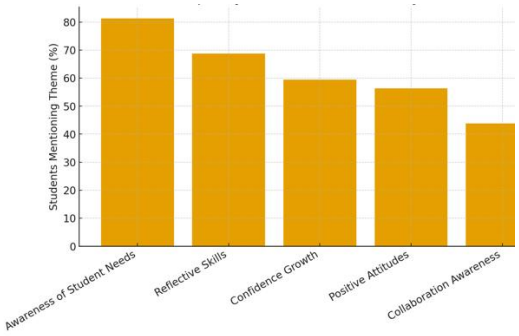
Overall Inclusive Competence (EG vs CG)



Component Scores After Training



Rubric Criteria Scores (Post-test)



Frequency of Themes in Reflective Journals

The difference between the experimental and control groups at the end of the training was statistically significant. The average post-test score in the experimental group (85.1%) exceeded that of the control group (74.6%) by approximately 10.5 points; an independent t-test showed: $t(60) = 4.94$; $p = 6.9\times10^{-6}$. The effect size (Cohen's d) for this difference was approximately 1.3, corresponding to a large effect. In other words, the experimental teaching method demonstrated a significant advantage in developing the competencies of future teachers for working in inclusive education.

A more detailed analysis of the competency components revealed that the greatest differences between the groups by the end of the experiment were observed in the "skills" and "attitudes" components. For example, in the experimental group, the average score for the practical assignment (lesson development) was 88%, while in the control group it was 75%. Experts noted that in the experimental group's work, students proposed a wider range of adaptations and differentiated techniques and demonstrated a creative approach to inclusiveness (for example, they proposed group experiments with assigning roles accessible to students with disabilities, using multisensory demonstrations, etc.). In the control group, many of the works were more general in nature and erred on the formal side (some students limited themselves to the instruction "I will pay more attention to a weak student" without providing specifics). In the attitudes component (ATI questionnaire), the experimental group achieved an average of 86% positive responses, while the control group achieved approximately 78%. The difference in confidence was particularly striking: 90% of students in the experimental group agreed with the statement "I will be able to effectively teach a class if it includes children with special needs" in the posttest, while in the control group the figure was 63%. This fact demonstrates that the combined use of case studies and reflection not only equips future teachers with

knowledge but also strengthens their self-confidence and alleviates unnecessary fears about inclusion (Machost & Stains, 2023).

Overall, the statistical results confirm the main hypothesis: the integration of case studies and reflective practices into teacher training significantly increases the effectiveness of developing inclusive competencies compared to traditional teaching (lecture and seminar model). Next, we will examine the qualitative changes that occurred in students in the experimental group based on an analysis of their reflective diaries.

An analysis of the reflective entries of students in the experimental group revealed three key themes reflecting the development of their professional thinking and attitudes during their participation in the experiment. These themes can be roughly summarized as: (1) Awareness of students' individual needs; (2) Development of reflective skills; (3) Increased confidence and readiness for inclusive education. Figure 2 presents a summary of each topic, with examples of typical student utterances and the proportion of students whose entries contained the relevant ideas.

Understanding the Individual Needs of Students. Nearly all students (≈80%) noted in their diaries that working with case studies helped them gain a deeper understanding of the uniqueness of each student and the importance of an individualized approach. While at the beginning of the course, many discussed students with special educational needs in rather general terms (e.g., "we need to pay more attention to weaker students"), by the end, they had a clear understanding of the specific needs and how to address them. Students wrote that, while analyzing the cases, they "felt like looking at the lesson through the eyes of different students." One student noted, "Now I see that two students with the same diagnosis may require completely different support" (Student E5). They realized that an inclusive approach is not a set of universal solutions, but constant attention to the unique characteristics of each child. For example, one student described, "After the case about the blind student, I wondered, how does he even experience a chemistry experiment? I hadn't even imagined before that boiling could be heard and warmth felt instead of seen." Such reflections demonstrate the development of empathy and the ability to put themselves in the student's shoes (Kaya & Öz, 2021). Students began to use the word "individualization" more frequently in their notes and to provide specific ideas (detailed differentiation of tasks, the use of different perception channels as visual, audio, kinesthetic; flexible group assignments, etc.). This qualitative shift in thinking, from a general understanding of inclusion to specific methodological solutions is directly related to the experience of case analysis and subsequent reflection.

Table 1 presents the summarized results of the thematic analysis of reflective journals, illustrating the above themes.

Table 1

Identified themes in the reflective statements of students in the experimental group (N = 32) based on the results of the pedagogical experiment

Theme	Description (content of the theme)	Example of a student statement	Percentage of students who mentioned the theme
Awareness of students' individual needs	Recognition of learner diversity, understanding the necessity to differentiate instruction and adapt methods for different abilities and needs.	"Each student is unique in their own way, and I need to adjust my teaching methods to their needs."	80%
Development of reflective skills	Ability to critically analyze one's teaching experience: identifying successful and problematic aspects of lessons, understanding causes and consequences of one's actions, and planning improvements.	"By analyzing my lessons, I learned to look at them from the outside and find what can be improved."	70%
Growth of confidence and readiness for inclusive teaching	Increased confidence in one's abilities as a teacher; positive attitude toward inclusive education and belief in the ability to implement it in practice.	"Solving practical cases and discussing them with classmates helped me feel more confident as a future teacher."	60%

The qualitative data obtained are consistent with the results of the quantitative analysis. Students in the experimental group demonstrated not only an increase in formal knowledge/skill indicators but also personal

and professional growth, reflected in changes in their attitudes and level of awareness. It can be concluded that the combination of case studies and reflection enabled the development of deeper competencies, addressing the value-motivational component (Meadows et al., 2020). Future teachers began to perceive inclusive education not as an external requirement, but as a natural part of their profession, requiring creativity and dedication. Many experienced "insight" for the first time – the understanding that the success of inclusion depends largely on their own actions and attitudes.

Thus, the qualitative analysis confirmed the hypothesis regarding the benefits of an integrated approach: it not only imparts knowledge but also transforms students' professional consciousness. Below, we discuss the significance of these results and relate them to the findings of other studies. The results of the experiment convincingly demonstrate the effectiveness of the integrated use of the case study method and reflective practices in developing inclusive competencies in future chemistry teachers. The experimental group, trained using this approach, demonstrated a significantly higher increase in readiness for inclusive education (on average +27 percentage points) than the control group in traditional instruction (+16 percentage points). A statistically significant advantage for the experimental group ($p < 0.001$, $d \approx 1.3$) was evident across all key competency components knowledge of methods, practical skills, and positive attitudes toward inclusion. These quantitative data are also reflected in the qualitative changes recorded in the students' reflective materials: the experiment participants demonstrated a deeper understanding of individual student needs, developed critical thinking regarding their own teaching practices, and increased confidence in their ability to work in an inclusive classroom.

These results are consistent with the findings of several previous studies in related fields. First, our experiment confirmed the significant benefits of case studies for teacher training. As Meadows et al. (2020) noted, case studies don't always immediately change students' attitudes, but they certainly enhance their reflective thinking. We observed a similar phenomenon: although students in the control group also learned about inclusion, students in the experimental group learned to ask "what if..." and "why..." questions through case studies, their understanding became more critical and analytical. Furthermore, our participants reported the "perspective transfer" effect noted in the literature: the case study allowed them to see the lesson through the eyes of a student with special needs, which increased empathy and a willingness to adapt instruction to different abilities. This supports Hoffer's (2020) observation that storytelling and case discussions "expand the conversation" and provide the opportunity to "see the world from different perspectives," opening the minds of future teachers to the values of inclusion. Our students noted that after the case studies, they had a clearer understanding of the challenges children with disabilities face in chemistry lessons and actively sought ways to make the subject more accessible. This is an important step in what the literature describes as the transition from the theoretical acceptance of inclusion to the practical skills for its implementation (Baxter et al., 2021).

Reflective practices played an equally significant role. They acted as a learning "accelerator," transforming case study work from a one-time activity into an ongoing process of professional self-analysis. As Kelly & Barrio (2021) note, reflection is a cyclical process of understanding experience, leading to continuous improvement in practice. In our experiment, through journaling and reflective sessions, students underwent several such cycles of self-analysis over the course of the semester. They effectively learned to learn from their own experiences, a meta-skill that is extremely valuable for teachers, whose profession requires continuous development. Interestingly, by the end of the experiment, many participants reflected not only after an activity (lesson or case) but also during discussions or assignments, adjusting their approaches on the fly. This is reminiscent of the concept of "reflection-in-action" (Szocik et al., 2021), whereby a professional is able to analyze and modify their actions directly in the process. The development of this rudimentary skill in students is evidence of the effectiveness of our approach, as it is typically acquired by experienced teachers.

The combined use of case studies and reflection also led to important changes in attitudes and motivation. Future teachers' attitudes toward inclusive education became more positive, and fears and resistance subsided, consistent with the results of international studies. For example, Sancar et al. (2021) demonstrated that specially designed inclusion courses can reduce students' anxiety and increase their self-efficacy regarding inclusive practice. In our experiment, a similar course enriched with active methods had an even more pronounced effect: many students not only felt confident but also expressed a personal

commitment to the idea of inclusion, a desire to apply their acquired knowledge in practice, and a desire to share it with colleagues. This aspect is extremely important, as the success of implementing inclusive education largely depends on the teacher's attitude, their willingness to embrace the ideology of "education for all". According to the "heart-set" concept changing a teacher's beliefs and values is the foundation for developing all other competencies. Our data show that integrating case studies and reflection can tap into this deep-seated component: through experiencing situations and self-discovery, students rethink their views on teaching and internalize inclusive values.

Conclusion

The study found that the integrated use of case studies and reflective practices is an effective approach to developing the professional competencies of future chemistry teachers for work in inclusive education settings. Students who studied using this approach demonstrated a significant increase in their readiness for inclusive learning compared to their traditionally educated peers, both in terms of mastering specific skills for differentiating and adapting instruction, and in developing a positive attitude and confidence in their ability to successfully work with a diverse student body. This finding is consistent with trends in modern pedagogical science, which emphasize the importance of active, experience-based methods in teacher training (case-based learning, experiential learning, and reflective practice). Our contribution is to empirically demonstrate the synergistic effect of combining these methods when applied to preparing teachers for inclusion.

The theoretical significance of this study lies in its enrichment of the model for developing inclusive teacher competencies. It has been shown that effective preparation must take into account a trinity: immersion in a practical context (the case as a model classroom), the development of a reflective culture (the ability to learn from experience), and the assimilation of inclusive values. The findings confirm and concretize the concepts of "reflective practitioner" and "heart-head-hands" as applied to a narrow field chemistry education in an inclusive classroom demonstrating that even in subject-specific conditions, general pedagogical principles remain valid.

Conflict of Interest Statement

The authors declare no potential conflicts of interests regarding the research, authorship, or publication of this article.

Author Contributions

Akbope Balgabaykyzy Tulegenova, Perizat Adilbekovna Abdurazova, and Kulyash Zaurbekovna Kerimbaeva contributed equally to this work. All authors contributed to the conceptualization, methodology, investigation, data analysis, interpretation of the findings, manuscript writing, review, and editing. All authors have read and approved the final version of the manuscript.

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ENGLISH TEACHERS' ATTITUDES TOWARD TRANSLANGUAGING AS A DIMENSION OF PROFESSIONAL COMPETENCE

Abstract. Translanguaging, as a dynamic use of many languages to assist learning, has been gathering attention since the rise of multilingual education. However, research on its role in enhancing teachers' professional competence is limited, particularly in southern Kazakhstani state schools. The current study examines the teacher's understanding, attitudes, classroom practices, and beliefs about institutional and personal policies of English as a Foreign Language (EFL) in 5 state secondary schools in southern Kazakhstan. 16 teachers participated in a structured written interviews, which were analysed using qualitative analysis in MaxQDA. The findings show that the majority of instructors are knowledgeable with translanguaging and have generally positive opinions about using students' native tongues to improve understanding, confidence, and cognitive development. In spite of the fact that institutional English-only policies and insufficient expertise with some languages provide problems, teachers reported strategically using translanguaging in scaffolding, brainstorming, and explanation of complex topics. The research implies the need for professional development and policy changes that balance multilingual pedagogy with institutional expectations by accentuating a discrepancy between ideal teaching philosophies and actual classroom practice.

Key words: translanguaging, teachers, teacher's attitudes, professional competence, soft skills, English as a Foreign Language (EFL), teacher development, Kazakhstan.

Introduction

English language instructors are expected to exhibit a wide range of professional soft skills, such as pedagogical flexibility, communication skills across cultures, empathy, reflective practice, and being open to innovation, in light of the digital transformation of education and ongoing professional development (Rasulova & Mukhamedov, 2025). These skills are important in multilingual classrooms where teachers must adapt to the language and cultural demands of a wide range of students. Translanguaging is one educational strategy that exemplifies these professional soft skills.

Translanguaging, in its core, is "the process of making meaning, shaping experiences, gaining understanding and knowledge through the use of two languages" (Baker, 2011, p. 288). Although a relatively new concept, it has evolved throughout time to change meaning beyond this initial concept to include students' spontaneous, everyday use of their whole language repertoire (Lewis et al., 2012). Translanguaging may be regarded as a way to facilitate learning of the language and encourages learners to use their whole linguistic knowledge to enhance their comprehension (Amaniyazova, 2020). Which further proves that reflective practice, communication, and pedagogical flexibility are necessary for translanguaging to be implemented effectively, making it a soft-skill-dependent professional activity.

Translanguaging has been gaining a considerable amount of attention for its bilingual and multilingual quality, especially in pedagogy. In particular, it is connected to globalisation (Singh et al., 2012). Consequently, the majority of countries are growing awareness of that, as they experience an increase in the students coming from diverse linguistic backgrounds, thus expanding the possibilities of the number of languages used in a single classroom (Blommaert, 2010; Vertovec, 2007). This, in turn, has led teachers and educators to pay close attention to this matter, since they play one of the biggest roles in providing effective teaching (Duarte & GüntherVan der Meij, 2018; Amaniyazova, 2020).

Kazakhstan has always been a home to a variety of languages, and is gradually shifting from bilingual to a multilingual country (Yeskeldiyeva & Tazhibayeva, 2015). In accordance with the Law on Languages (Law of the Republic of Kazakhstan, 1997) of the Republic of Kazakhstan, Kazakh is the state language; Russian is an official language used on an equal basis with Kazakh in government. Alongside this, English,

though not official, has been seen as "a language of successful integration into global economics" (Karimsakova, 2022, p. 1) and is increasingly prioritized in education and professional contexts. Through programs like the "Trinity of Languages," which eventually evolved into the Trilingual Education Policy, the government has encouraged citizens to acquire proficiency in Kazakh, Russian, and English (Nazarbayev, 2007). Despite these initiatives, there are still issues, mainly because there are limited numbers English-proficient teachers and students, which causes a disconnect between classroom practice and policy (Kaiypova & Kim, 2024). Therefore, translanguaging attempts to fill this gap.

Majority of the previous studies on this topic in Kazakhstan were conducted either on elite or highly private schools, such as Nazarbayev Intellectual Schools and Bilim-Innovation Lyceums, frequently using very small samples and mostly from northern areas (Alzhanova, 2020; Amaniyazova, 2020; Klyshbekova, 2020; Kuandykov, 2021; Akhmetova, 2021; Tuskeyeva, 2022; Baigulova, 2025). State secondary schools in this area have not received much attention due to the lack of research from the south, which is mostly limited to one top school (Yakshi, 2022). The findings of these studies showcase a mixed viewpoint of the educators, who, in spite of their support to the use translanguaging, hold monolinguistic point of view and see student's home languages in English lessons as either a barrier or as a last resort. This, in turn, leads them to restrict translanguaging despite its potential advantages.

As said above, there is still little research on how EFL teachers understand and utilize multilingual practices in state schools, especially in southern Kazakhstan. Since southern and northern parts of Kazakhstan differ in terms of regional variations in sociolinguistic settings, community language practices, and educational contexts, teachers in the south may view multilingual classroom activities differently than their northern counterparts (Jumagaliyeva, 2021; Sadulova et al., 2025). Previous research may not fully reflect the broader national context because these schools may differ from elite institutions in terms of their educational environments, student language profiles, and instructor experiences. As a result, neither the national classroom situations nor the soft-skill-related professional issues experienced by teachers in ordinary educational settings are sufficiently illustrated by the research that is currently available.

In order to address a neglected context and link national policy with regular teaching practice, this study examines how EFL teachers in southern Kazakhstani state secondary schools view and employ translanguaging in their classrooms.

Thus, the current study attempts to address and answer following research questions:

1. What is the level of familiarity and understanding of the concept of translanguaging among English teachers in Kazakhstan?
2. What are English teachers' attitudes toward using students' first languages (Kazakh or Russian) alongside English in EFL classrooms?
3. How do English teachers implement translanguaging or multilingual practices in their classrooms, including strategies, tools, and student language use?
4. How do institutional policies and teachers' personal teaching philosophies influence the use of multiple languages in EFL classrooms, and what gaps exist between ideal and actual practices?

Literature review

The Concept of Translanguaging

Translanguaging is a relatively recently developing phenomenon (Lewis et al., 2012). First coined by Cen Williams in the 1980s, it has been created with an educational mind in Welsh. At first, it came from the Welsh term "trawsieithu," which was once understood to mean "translinguifying" before being changed to "translanguaging" (Lewis et al., 2012). Although it appeared in the 20th century, it was mostly popularised by books such as Baker's "Foundations of Bilingual Education and Bilingualism" (2001, 2006, 2011) and Ofelia García's (2009) "Bilingual Education in the 21st Century." At first, it mostly referred to a teaching strategy, where it alternated between input and output languages to enhance learners' language skills. It can be illustrated as such: students may, for instance, read in one language while writing in another or have a discussion in one language while reading in another (Baker, 2011). Translanguaging has transformed progressively to encompass a variety of discursive strategies used by multilingual speakers to create meaning across languages using their whole linguistic arsenal (Garcia, 2009; Wei, 2011).

Despite the various definitions, the term translanguaging remains somewhat ambiguous (Flores, 2014;

Poza, 2017). Poza (2017) argued that in some literature, translanguaging is reduced to code-switching, which misrepresents its full conceptual meaning. Kano (2013) differentiates translanguaging from code-switching by conceptualizing translanguaging as a meaning-making process that mediates between input in one language and output in another through cognitive processing. While code-switching involves formal alternation between languages, translanguaging entails shifts across both languages and communicative modes, including reading, writing, listening, speaking, or a mix of these. As Williams (1996, as cited in Lewis et al., 2012) notes: "translanguaging means that you receive information through the medium of one language and use it yourself through the medium of the other language. Before you can use that information successfully, you must have fully understood it" (p. 64). Moreover, he also points out that, "translanguaging entails using one language to reinforce the other in order to increase understanding and in order to augment the pupil's ability in both languages" (Williams, 2002, as cited in Lewis et al., 2012, p. 40).

Translanguaging essentially entails translating meaning between languages, which calls for complete comprehension. When translating a proverb or saying, for instance, it is necessary to understand the original meaning and choose an equivalent phrase in the target language. Williams (1996), alongside pedagogical implications, envisioned translanguaging as a cognitive process, which included the exchange of two languages that has an impact on educational consequences. He maintained that the process involves various abilities of listening and reading, such as choosing information to effectively deliver and communicate in speech and writing, as well as absorbing and adapting information. Therefore, because translanguaging progresses from identifying parallel terms to processing and communicating meaning, it necessitates a deeper comprehension than simple word-for-word translation.

Theoretical and Pedagogical Significance

Translanguaging was first introduced as a pedagogical theory (Williams, 1996). Even when not explicitly identified, it occurs naturally in classrooms, without teachers' influence or initiation. In fact, they happen behind the teachers' backs secretly, especially when students are not permitted to use a mix of languages (Canagarajah, 2011a). However, as in the research by Creese and Blackledge (2010), when given the opportunity, teachers and learners use translanguaging with proactive goals, thus enabling a comfortable space for students to learn a language.

In addition to allowing speakers to use their entire linguistic arsenal without strictly adhering to socially established boundaries of language (Otheguy et al., 2015) and encouraging integrated application of languages as an evolving framework (Canagarajah, 2011b), translanguaging challenges language hierarchies and promotes a holistic view of languages (Garcia & Wei, 2014).

Translanguaging is especially useful in the classroom settings, where students' languages are different from that of the subject. It provides a bridge between majority and minority languages, thus empowering both instructors and learners, enhancing learning experience, meaning-making, and identity development (Wei, 2018). Building on the Williams's conceptualization of translanguaging, Baker (2001, 2006, 2011) advocates for the significance of the idea as a pedagogical activity by discussing four possible educational benefits to translanguaging: 1) it may encourage deeper comprehension of the subject; 2) it might aid in the development of the weaker language (ex. target language); 3) it might enable cooperation and connections between the home and school; and 4) it might be useful for collaboration of fluent speakers with beginners.

Translanguaging in English as a Foreign Language (EFL) Teaching

English as a Foreign Language (EFL) refers to the teaching of the English language from a foreign country's perspective, where the native language is not English and where English has no usage outside of the classroom. Translanguaging is therefore more likely to occur in EFL contexts, and there is growing documentation of its use (Nambisan, 2014).

Traditional language teaching methods, such as "Direct," "Audiolingual," and "Task-Based Language Teaching" methods, emphasized the usage of the target language only (Krashen & Terrell, 1983; Larsen-Freeman, 1986; Howatt & Smith, 2014), thus "English-only policy" during lessons or "the monolingual principle" (Howatt, 1984, p. 173). The idea behind it is that by minimising the mother tongue, there will be maximum exposure to the target language, hence maximum learning results (Portoles & Marti, 2017). However, there have been debates on the efficiency of these practices, and they have been called for re-evaluation (Sridhar, 1994; Larsen-Freeman, 2018). Therefore, the usage of bilingualism or multilingualism should not be considered a "problem," but instead an asset to the teaching (García, 2009).

According to Escobar (2020), English policy rules in EFL courses may sometimes clash with learners' innate multilingualism. In their study, it was discovered that students use translanguaging to improve their comprehension of the subject, reduce stress, and express themselves more freely both in and outside of the classroom. Despite the English-only regulations, learners still use translanguaging to compare languages and participate in meaningful discussions. They concluded that the inclusion of translanguaging of EFL in classrooms enables students to feel safe, promoting self-assurance, metalinguistic awareness, and autonomy over their language acquisition.

Another study done by Littlewood and Yu (2011) analysed the strategic use of L1 in Hong Kong EFL classrooms, and found that the teachers, despite the feeling of guilt, use L1 to scaffold the clarification of the words' meanings, which accelerates the language process. Similarly, in China, Wang (2019) discovered that L1 contributes to the enhancement of communicative skills and teacher-student relationships.

The use of L1 in EFL classes in Turkey produced conflicting outcomes. According to interviews, students were generally in favour of using Turkish in class, but they frequently avoided it. On the other hand, observations indicated that a lot of L1 use did occur, despite students' reports that teachers should use L1 infrequently (Yuvayapan, 2019).

These findings demonstrate that translanguaging is a valuable tool in EFL, which makes it more relevant to Kazakhstan.

In the majority of the EFL studies, teachers and students usually use translanguaging in an unplanned, spontaneous way, because of insufficient knowledge of the term and training of the teachers (Nguyen, 2022).

Teachers' Attitudes Toward Translanguaging

Numerous studies have tried to explain how instructors view translanguaging in various circumstances thus far. For instance, Wang (2019) investigated the attitudes and behaviours of Chinese students and teachers and discovered the mixed reception of translanguaging: some teachers welcomed the idea of using L1 in classrooms as long as it achieves its goal; others objected to the idea, referring to the policy or to protect the "national language from contamination" (p. 6). Another Chinese study (Pinto, 2020) showed that teachers, conversely, felt positive about the idea and importance of translanguaging as long as it concerns the lesson. The research done in Russia (Chicherina & Strelkova, 2023) uncovered that teachers' translanguaging is useful in introducing difficult material, explaining complex concepts, and facilitating translation techniques. In addition, they agreed that ignoring or banning L1 is harmful, as it decelerates the learning of students, but they believe that its overuse causes interference with English acquisition. As such, these studies showcase a trend of teachers acknowledging the importance of translanguaging, yet fearing its overuse among students.

Translanguaging in the Kazakhstani Context

The use of translanguaging in English classes by Kazakhstani instructors has been the subject of a modest but expanding body of study. Similar to international research, the majority of the instructors endorse translanguaging practice, but rarely use it in the classroom due to "English policy," their monolingual ideologies, fear of appearing "unprofessional," assessment expectations, teaching training, or simply guilt (Amaniyazova, 2020; Akhmetova, 2021; Karabassova & San Isidro, 2023; Tastanbek et al., 2023). From her personal experience, Klyshbekova (2025) notes: "Before proceeding, it is important to note that I have had a fair share of self-doubt and feelings of guilt when it comes to using multiple languages in my teaching. Although I was an English language teacher at a Kazakhstani trilingual school, I was also educated in the idea of maximum exposure to the target language and viewed resorting to multilingual practices as some sort of problem or deficiency. Partially, my resistance derived from the fact that multilingual teaching practices are not part of the status quo in Kazakhstani schools (p. 124)".

Most of the research shows a pattern of teachers who show disparities between their beliefs and practice. Due to the usefulness of the translanguaging, especially in situations such as clarification, comprehension of complex tasks, or simply scaffolding, the majority of the educators used translanguaging even when they held monolingual views (Akhmetova, 2021; Tuskeyeva, 2022; Yakshi, 2022).

Nevertheless, there are still significant limitations with the presented works. Most of the studies were conducted with small samples and originated from either elite or selective schools, so the results may not represent the whole country. The literature mainly ignores public schools, particularly in the southern regions of Kazakhstan. Thus, there is a need to study to capture teachers' views from more typical

educational contexts in light of these limitations.

Methods and materials

Research Design

The current study utilised a qualitative approach to investigate English teachers' attitudes towards translanguaging in EFL classrooms. The reason for qualitative research, more specifically for the interview, lies in the fact that it allows a deeper understanding, knowledge, views, and experiences of the given topic (Hussein, 2022). The goal was to determine the teacher's ability to understand translanguaging and how they utilise or evade it in the real classroom settings.

Participants

A total of 16 English teachers from 5 various state secondary schools of South Kazakhstan were selected for this study. The participants were chosen based on convenience sampling. 6 participants were between 20–25 years old, 5 were 26–30, and 4 were over 30. Teaching experience varied as well: 7 teachers had 0–4 years of experience, 5 had 5–9 years, and 4 had been teaching for more than 10 years. Regarding educational background, 10 participants held a bachelor's degree, 5 held a master's degree, and 1 participant had completed a PhD in a related field. Participation was voluntary. Before the study, all teachers were informed of the study's goal, their right to withdraw at any time, and the fact that their responses would remain anonymous and confidential.

Procedure

The interview was distributed online through Google Forms to schools, which was then shared via teachers' official emails and official group chats. Before taking the interview, the participants were informed of the research's aim and, to make sure the participants agreed to be part of the study, a consent statement was placed inside the form. The study took place in the 2025-2026 academic year's autumn semester.

Instrument

The data were gathered via a structured written interview developed for this study, which was validated by 3 experts. The interview included 8 open-ended questions, which were divided into four main categories: teachers' understanding of translanguaging (conceptual knowledge), their attitudes and opinions toward using multiple languages, their classroom practices and pedagogical strategies, and the influence of institutional expectations or personal teaching beliefs.

Data Analysis

Qualitative content analysis was used in order to examine the interview data from 16 participants. To facilitate methodical coding and organisation, the responses were imported into MaxQDA 24. The analysis began featuring numerous readings of the transcripts to identify important units that are related to participants' understanding, perspectives and their teaching practices. Related codes have been grouped into broader groups and subcategories once these units were inductively coded. This procedure resulted in a structured set of topics that represented the perspectives and translanguaging experiences of instructors (Table 1).

Table 1.

Categories, Subcategories, and Codes from Qualitative Content Analysis of Teacher Interviews

№	Category	Subcategory	Code
1	Understanding of Translanguaging		Not familiar
			Basic understanding
			Intermediate understanding
			Advanced understanding
2	Attitudes on Multilingualism	Native Language Use	Balanced Approach
			Positive/Facilitative View
			Flexible Or Multilingual Approach
			Negative/Opposed View
		Perceived Benefits	Comprehension Support
			Learner Confidence

			Cultural Connection
			Inclusive Environment
			Policy Alignment
			Cognitive Growth
			Collaborative Learning
			Global Mindset
		Perceived Challenges	Language Balance
			Reduced English Practice
			Insufficient Training
			Curriculum Limitation
			Diverse L1s
			Teacher Proficiency
			Time Constraint
			L1 Attitudes
3	Teaching Practices	Language Use	L1 Explanation
			English Practice
			Translation Support
			Confidence Building
			Time Efficiency
			L1 Brainstorming
			Translanguaging
			Inclusive Approach
		Students' L1 Use	Controlled Use
			Concept Clarification
			Confidence Building
			English Emphasis
			Level-Based Allowance
			Balanced Approach
		Usage of Dictionaries	Bilingual & Online Dictionaries
			From Bilingual To Monolingual
			One Type Dictionary
4	Institutional Influences		English-Only Policy
			Multilingual Support Philosophy
			Policy-Philosophy Balance
			Ideal-Practice Gap
			Strategic L1 Use
			No Clear Influence
			Respectful Multilingualism

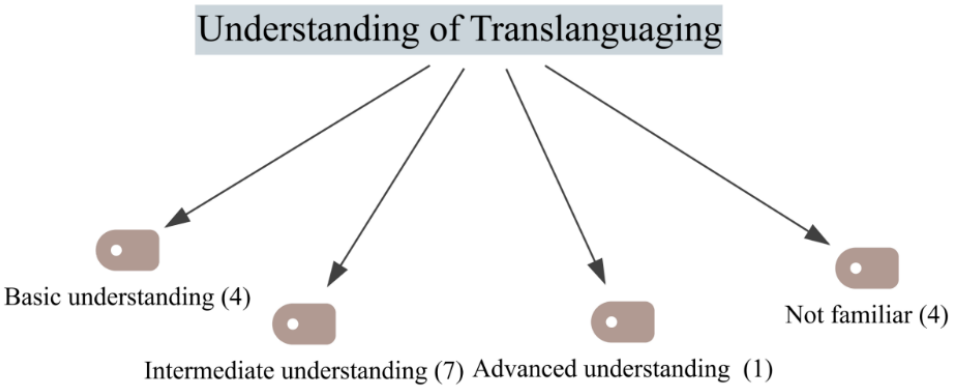
Results

The results of the qualitative content analysis of 16 English instructors' interview replies are shown in this section. The four criteria that shaped the interview are used to arrange the results: 1) teachers' understanding of translanguaging; 2) attitudes toward the use of multiple languages; 3) classroom practices; and 4) institutional and personal factors influencing multilingual pedagogy.

Teachers' Understanding of Translanguaging

Teachers' familiarity with the term varied across the sample. Out of 16 participants, 12 were familiar with the concept, while 4 were not and could not provide a description. The degree of comprehension was divided into 3 groups: basic understanding (4), intermediate understanding (7), and advanced understanding (1) (Figure 1).

Figure 1.
Participants' knowledge of translanguaging



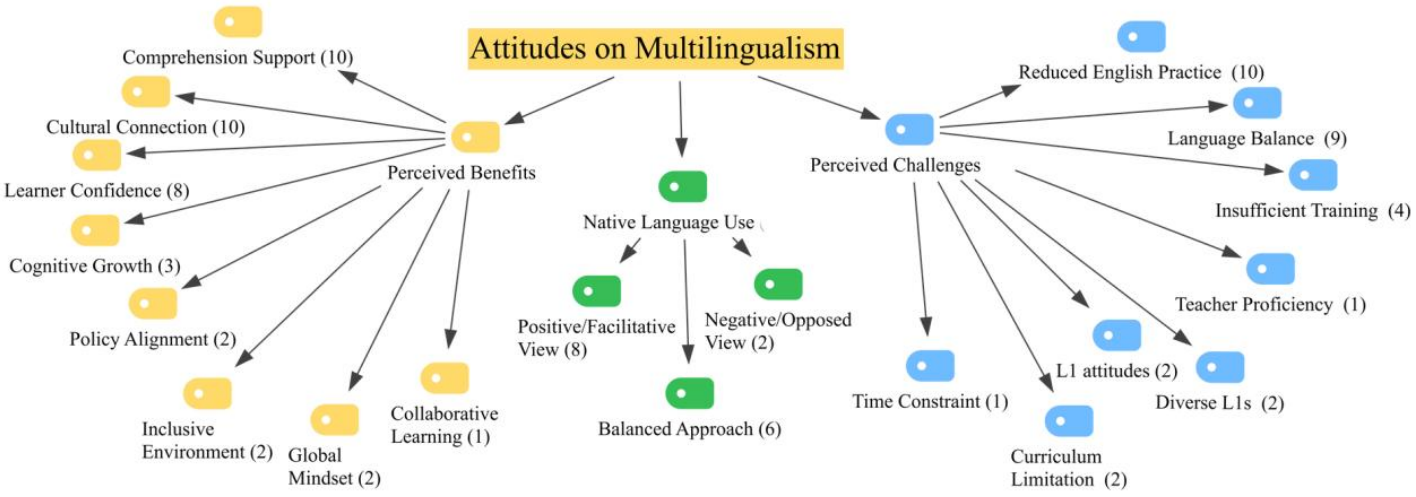
Teachers with basic comprehension referred to translanguaging mostly as *"mixing more than one languages at the same time," "being able to speak multiple languages at the same time,"* and *"using more than one language to help students understand and learn better."* Whereas teachers with intermediate knowledge pointed out the complexity of the term, as well as to mention its purpose of it in the educational field. The participant with advanced level, alongside with the explanation of the term, emphasised the differences of translanguaging and code-switching, and stressed pedagogical implications:

Translanguaging is the process in which multilingual speakers use all their language resources flexibly and dynamically to communicate, think, and learn rather than keeping their languages separate. In simple terms, it means using more than one language in a fluid way to make meaning. For example: A student might read a text in English, discuss it in Kazakh, and write reflections mixing Kazakh and English. A teacher might explain a concept in English but allow students to ask questions or give examples in their home language. It's not just "code-switching" (changing from one language to another); translanguaging sees all of a person's languages as one integrated linguistic system that supports learning and expression.

Teachers' Attitudes on Multilingualism

The interviewees generally showed positive attitudes towards using their native language in the classroom alongside the English language. As shown in Figure 2, out of 16 participants, 8 held a positive stance, 6 leaned towards a balanced approach, and 2 opposed the practice.

Figure 2.
Teachers' attitudes on multilingualism



Native Language Use by Students

Supporters highlighted the usefulness of this practice, as one participant noted that it helps students *"understand difficult ideas, feel more confident, and save time when something is too hard to explain in English."* Those who were inclined toward a mixed approach maintained a positive point of view, but stressed the need to use the target language more. Some participants indicated that L1 use is acceptable for beginner-level students, but should be limited as proficiency increases. For instance, one participant stated, *"I think it's appropriate to use students' native language while teaching lower levels like beginner, elementary. But in order to make them speak fluently, students should be surrounded by the target language."* Another participant added, *"If we're talking about young learners, I mean it's ok until they learn new words to use them in a classroom. However, if it's about high school students, then they have to try to talk in English while they are in a classroom."* The teachers with negative stance mostly referred to this practice as *"incorrect"* and *"not good."*

Perceived benefits of Translanguaging

Participants generally identified multiple benefits in using the first language (L1) in EFL classrooms. The majority of the answers (10) reported that multilingual practices enhance comprehension, commenting that "*Using multiple languages in EFL classrooms helps students understand better…," "It makes learning English easier to understand…,"* and *"…understand complex ideas more easily…."* Likewise, cultural relevance was equally brought up by most teachers (10), writing that "*It …builds cultural and linguistic awareness…"* or *"It…respects students' cultural and linguistic backgrounds."* Others (8) indicated that it boosts confidence, as one participant noted: *"Using multiple languages in EFL classes helps students feel more confident and comfortable."* In addition to the confidence, it *"…reduces anxiety, and keeps them engaged."*

Several teachers (3) mentioned the cognitive growth that students face when using L1 during class hours. They observed that it develops their critical thinking, adapting, and building knowledge to the existing one. One participant explained:

"Well, by using multiple languages in a classroom, we built new one on already existing knowledge. By that I mean they already know the rules and the structures of Kazakh and Russian, by connecting them with English, we help them learn it fast and easily."

2 participants linked multilingual practices to Kazakhstan's trilingual education policy, noting that it *"fits well with Kazakhstan's trilingual education policy."* Others (2) pointed to inclusivity, and by using multilingual use, *"teachers make learning more meaningful and inclusive."*

A few more individual remarks suggested broader possible results, such as promoting a more global perspective (2) or fostering more seamless student collaboration (1).

Perceived challenges of Translanguaging

As illustrated in Figure 2, Teachers noted many recurring difficulties associated with employing several languages in English classes. A common issue among respondents (10) was students' excessive reliance on their mother tongue, which teachers claimed may limit opportunities for English practice. This was illustrated by one participant: *"Students may rely too much on their first language and speak less English."* Additionally, many participants reported problems in achieving an appropriate balance (9) between English and students' native languages, especially in courses with limited time or challenging subjects. This was reflected in one respondent's comments: *"The main challenges are that students may depend too much on their first language, use less English in class, and it can be hard for teachers to balance both languages,"* and *"The main challenges…balancing when and how to switch languages effectively."*

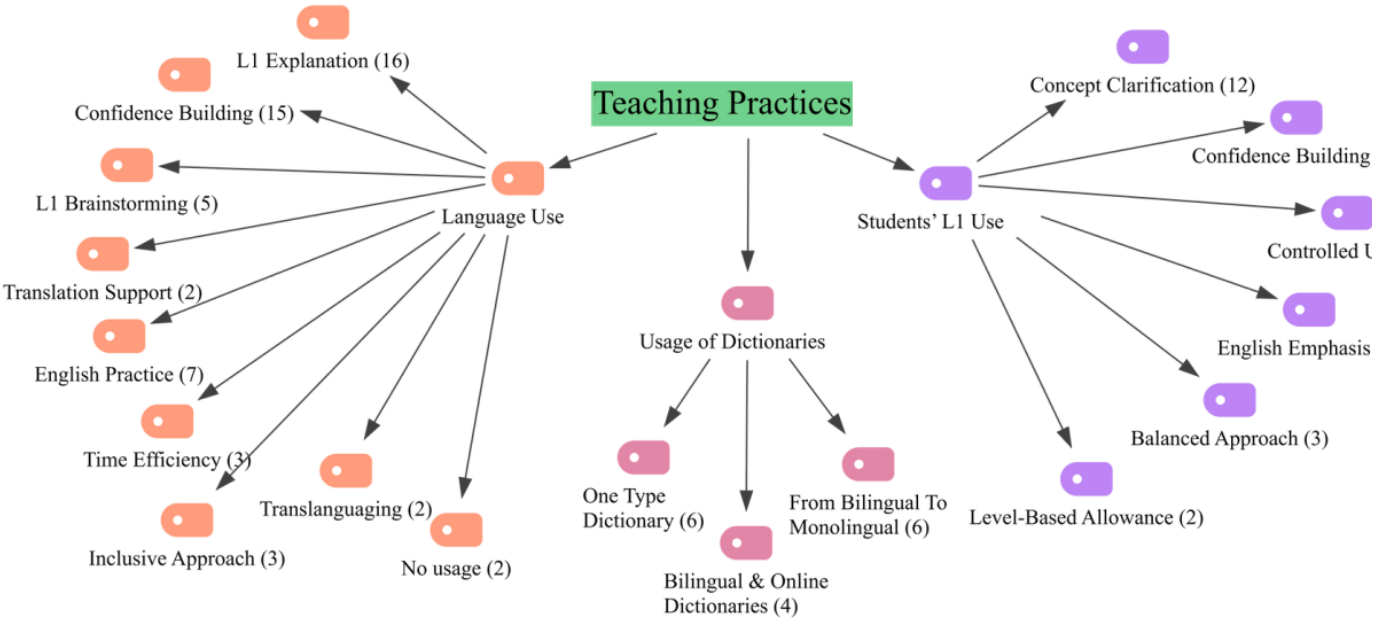
Some participants described the lack of guidelines for teachers in this particular field and limited teacher training (4) on how to integrate multiple languages strategically into lessons. Another point was that teachers may not be knowledgeable of the students' languages (1): *"Not all teachers are equally fluent in all local languages."* Moreover, the same L1 diversity was applied to the students as well (2), as a teacher described it, *"Learners may or may not know a certain language,"* while another wrote, *"not everyone shares the same first language."*

Furthermore, there were mixed opinions (2) on the usage of the mother tongue in EFL classrooms. As

one teacher expressed, *"…some teachers and students believe only English should be used…."* Others pointed to curriculum constraints (2), explaining that, *"Curricula often emphasise grammar, written tests, and exam-performance, and less focus on communicative competence, speaking, and real-world use of English."* Time management was highlighted as a minor challenge by 1 teacher.

Teachers' teaching practices

Figure 3.
Teachers' teaching practices



Language Use by Teachers

Teachers reported employing various languages in their English courses in strategic and diverse ways, as seen in Figure 3. All of them (16) said they utilized Kazakh and Russian in addition to English to help them understand, especially when introducing new language, grammatical rules, or difficult directions. One participant put it this way:

Personally, while teaching new vocabulary, I use flash cards and ask: "What is that?" in Kazakh or Uzbek, after their answer I explain the English translation, so by that I'm building a new knowledge on existing one, by connecting it.

Moreover, teachers stated that they do so to elevate learners' confidence (15) in language, accentuating that it will lead to natural English speaking. For instance, a respondent noted: *"I make these choices because it saves time, reduces confusion, and helps students feel more confident before they start using English independently."* Another participant added, *"This helps students understand better and feel more confident before fully switching to English."* It was also shown that it helps students use their cognitive skills and active involvement, as claimed by a teacher, *"This process makes their thinking richer and promotes participation, especially among lower-level learners."*

Many teachers reported using L1 for brainstorming (5) or translating (2) and used English afterwards (7) or mainly for communication purposes. For instance, several participants commented: *"I let students discuss ideas in their first language before sharing in English," "However when it's comes to discussion or sharing ideas, I encourage students to use English as much as possible," "I introduce new vocabulary in English, then briefly translate it into Kazakh or Russian,"* and *"In group work, I allow students to brainstorm ideas in their L1 first, then express them in English."*

Additionally, respondents indicated that using L1 saves time (3) and creates inclusive environment (3). As one participant noted, *"I make these choices because I believe that all languages are valuable learning tools."*

Several teachers (2) described using translanguaging strategically to support learning. For instance, one teacher stated, *"I use all three languages strategically depending on students' level and the lesson goal."* Another explained, *"During vocabulary lessons, I often encourage translanguaging activities: students might write English definitions but give examples in Kazakh or Russian, or discuss differences in meaning across the three languages."*

2 participants reported using English exclusively, without incorporating the students' first languages, stating that they *"speak in English in classes."*

Students' L1 Use

A majority of instructors said that they permit students to speak their home languages during English classes, but in a restricted or limited manner. Most of the teachers stated that they allow L1 usage, as long as it helps with comprehension of the topic (14): *"For example, they can use Kazakh or Russian to ask questions, discuss difficult topics, or help each other understand new material."* Teachers generally allowed native language use to help students understand difficult material, clarify ideas, or support peer explanations. Furthermore, some noted the benefits of reducing anxiety and increasing confidence (6) in students, as commented by one teacher, *"I allow this because it supports learning, reduces stress, and helps students feel more comfortable."* However, several respondents would mostly limit the usage of L1 and ask students to swiftly return to the English language (7). As one teacher stated: *"However, I remind them that the goal is to communicate as much as possible in English, so we always return to English after short explanations."*

Some were more lenient and mostly emphasised (6) the balanced approach of L1 and English (3). In the words of one respondent: *"I also remind them to use English as much as possible so they can improve their speaking skills. Using both languages in balance makes learning easier and more effective."* According to certain teachers, using L1 is especially helpful for younger students or lower-level learners who are still honing their vocabulary and comprehension abilities (2).

Usage of dictionaries

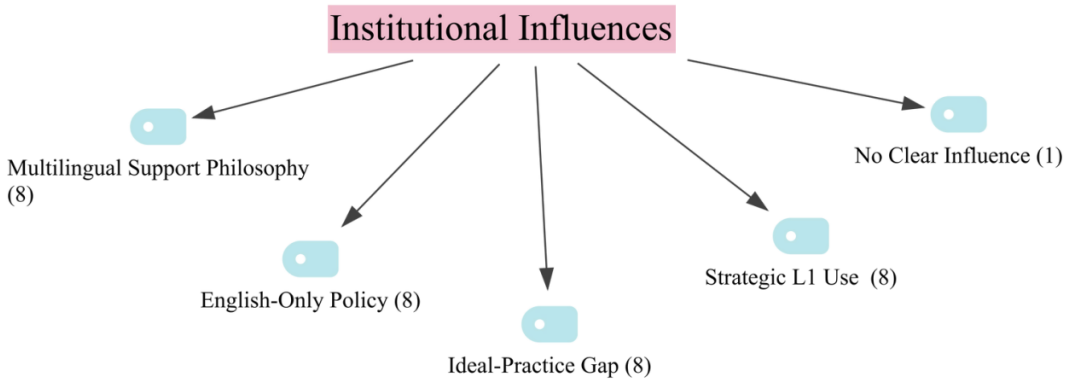
The use of dictionaries to assist in vocabulary development was usually recommended by teachers, but their choices varied depending on the students' level of ability. Out of 16 participants, 6 advocated for one type of dictionary, such as monolingual or bilingual; another 6 stated that they first use bilingual, then gradually move on to the monolingual; and 4 allowed all dictionaries, mostly emphasising bilingual and online dictionaries. Those who supported one type of dictionary mostly stated that bilingual is *"easy,"* or that students *"can't understand definitions,"* whereas online dictionaries were claimed to be more on a *"convenient"* side. The monolingual, in this case, was described by the respondent as *"it's better to focus on one language when remembering new words."*

Other instructors believed that learners should use bilingualism in their low-level state to later move on to monolingual, as they gradually become independent in English. For example, a teacher wrote: *"I encourage using bilingual and online dictionaries because they help students understand meanings quickly and learn correct usage. As they improve, I also suggest monolingual dictionaries to help them think more in English."*

Those who preferred to use both bilingual and online explain that it is easier and faster for the students to learn the language that way (Figure 3).

The Influence of Institutional Expectations or Personal Teaching Beliefs

Figure 4.
The Influence of Institutional Expectations or Personal Teaching Beliefs



Both institutional rules and individual teaching philosophies had an impact on teachers' usage of several languages in the classroom.

Most of the teachers (8) reported that their ideology encourages the flexibility between English, Kazakh, and Russian to improve comprehension and confidence among learners. However, the majority of interviewees (8) also noted that school regulations prioritise English-only learning, especially in official courses or upper grades. Thus, this clashes with their ideal and practical settings in classrooms (8). For example, one participant said:

My teaching philosophy supports using multiple languages to help students learn more effectively and feel confident. However, institutional policies often encourage using only English in class, so I try to balance both. Ideally, I'd like to use Kazakh and Russian more for clarification and discussion, but in practice, I limit it to short explanations or support when students really need it.

Some claimed to balance between policy and their own philosophy, therefore using L1 strategically (7) in their lessons: *"So, there's a bit of tension between institutional rules and my personal beliefs. I try to balance both by using L1 purposefully only when it clearly supports learning."*

1 teacher mentioned no influence from the institution: *"They don't have a significant influence."*

Discussion

The analysis of 16 teachers' interview answers presents us with interesting results regarding their perception of translanguaging. As seen from the results, the majority of the teachers demonstrated their acknowledgement and at least basic understanding of translanguaging, with a smaller portion being intermediate and advanced. It likely suggests that the popularity of the term is growing amongst educators, although not to a knowledgeable state. Tastanbek et al. (2023) pointed out that theoretical knowledge is needed to get the instructors to believe in translanguaging pedagogical benefits, although they emphasised that simply teaching them might not be enough. These results indicate that educators are becoming more proficient at teaching inclusively and are open to experimenting with methods that involve all type of students, which illustrates their professional abilities and willingness to grow.

In line with prior studies (Amaniyazova, 2020; Alzhanova, 2020; Tuskeyeva, 2022), the majority of the participants expressed positive attitudes toward multilingual practices. Respondents noted that such practices make it easier for students to understand topics, create a comfortable space, and boost confidence. It aligns with the general notion of benefits that can be acquired through translanguaging (Lewis et al. 2012). It was especially useful with tasks that required explaining complex ideas, particularly to lower-level students. Many argued that it makes all students included and builds their cognitive skills. It may be supported by the fact that students feel comfortable with teachers whom they can relate to and understand. Because they intentionally modify lessons to meet students' affective and cognitive requirements, these perceptions show instructors' emotional intelligence and communication sensitivity. In multilingual and digitally mediated learning contexts, pedagogical flexibility and reflective professional judgment are essential soft skills that are demonstrated by such behaviors.

However, the teachers would allow translanguaging in a controlled manner, indicating that students should use the target language only when they reach higher-level proficiency. Baker (2011) supports this

method by remarking that *"the teacher can allow a student to use both languages, but in a planned, developmental and strategic manner, to maximize a student's linguistic and cognitive capability, and to reflect that language is sociocultural both in content and process"* (Baker, 2011, p. 290). Teachers' professional autonomy and desire to use creative instructional approaches may be restricted by this constrained approach, which implies an unwavering commitment to monolingual beliefs and institutional expectations.

This major positive attitude contrasts with other Kazakh research, where a strong monolingual approach is often reported (Amaniyazova, 2020; Akhmetova, 2021; Yakshi, 2022). However, interestingly enough, in Tuskeyeva's (2022) research, the most positive viewpoint was from Kazakh-speaking teachers, whereas Russian teachers showed a negative approach to it. The participants' nationality was not recorded for this study, so it might be important to consider in future research.

Nevertheless, the participants list several challenges regarding the use of translanguaging. Most mentioned a limited time to balance all the languages, being unacquainted with some of the languages, and coordinating practices with institutional regulations or curricular requirements. A recurring concern was the conflict between individual teaching philosophies and institutional demands. A number of instructors noted that their ability to properly employ translanguaging is hampered by English-only mandates. Kuandykov (2021) writes that *"school language policy, which is based on monolingual rule, was found to have a substantial impact on teachers' beliefs and decision-making."* It is interesting to note, however, that EFL teachers are more likely to be expected to teach only in English and limit L1, whereas other fields, such as STEM, may be expected to practice multilingualism (Klyshbekova, 2025). Conversely, Shymkent teachers from the study of Yakshi (2022) would use translanguaging in their classrooms despite the institutional policy, which highlights variability in how teachers negotiate policy constraints and personal beliefs.

Teachers reported using L1 to scaffold, brainstorm, and support comprehension, and it illustrates a deliberate, conscious usage of translanguaging in the lessons. However, as this current study relied on self-report only, it has to be noted that the real practice might be quite different, as research from Yuvayapan (2019) revealed that, despite the teachers' claim of strategic use of translanguaging, most of the time it came unplanned and spontaneously.

Conclusion

In conclusion, despite current institutional limitations, this study shows that EFL instructors in southern Kazakhstani state secondary schools usually see translanguaging favorably and strategically use it to improve student comprehension and engagement. Though their limited application shows the need for more institutional support and focused professional development, teachers' attitudes and actions reveal rising professional soft skills including pedagogical flexibility, communicative sensitivity, and reflective judgment.

In spite of these findings, we must acknowledge the study's limitations. As the research sample contained only 16 instructors from various state schools, it may not represent the whole southern or Kazakhstani generalizability. Moreover, the study utilised self-reported data, which might not fully reflect real classroom practices. It is recommended to do observations of classroom practices to validate the findings.

The results highlight the significance of integrating multilingual teaching and translanguaging into ongoing professional development programs, especially in light of Kazakhstan's wider digitization of education. In order to help educators better adapt to the challenges of multilingual classrooms, CPD programs should focus on improving teachers' soft skills, such as professional self-efficacy, reflective autonomy, and digital pedagogical competence.

It should be noted that research has practical implications for policy creation and teacher preparation. Programs for professional development should place a strong emphasis on translanguaging programs for teachers to make them informed of the matter, as there have been numerous benefits to language learning. Institutions, on the other hand, attempt to balance the English-only and multilingual expectations, especially in light of Kazakhstan's trilingual educational system.

Conflict of Interest Statement

The authors declare no potential conflicts of interests regarding the research, authorship, or publication

of this article

Author Contributions

Meruyert Seitova: Conceptualization, Methodology, Supervision, Validation, Writing – Review & Editing, Project Administration.

Aruzhan Kurban: Investigation, Data Collection, Data Curation, Formal Analysis, Visualization, Writing – Original Draft, Literature Review, Writing – Review & Editing.

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PEDAGOGICAL COMMUNICATION AS A FACTOR IN THE EMOTIONAL WELL-BEING OF STUDENTS

Abstract. This article explores the impact of various pedagogical communication styles on the emotional well-being of primary school students within the context of contemporary education. The relevance of the study is linked to the need to create a favorable psycho-emotional climate in the classroom, which enhances students' academic motivation and reduces anxiety. The main objective of the empirical research was to identify correlations between communication styles (authoritarian, democratic, and laissez-faire) and students' emotional responses. The study involved students from the specialty "5B010200 - Pedagogy and Methods of Primary Education" at Aktobe Regional University named after K. Zhubanov during their teaching practice. The research methods included questionnaires, classroom observation, the Luscher color test, and statistical analysis using SPSS 26.0. Results indicated that a democratic communication style contributes to the development of emotional stability and intrinsic motivation, while authoritarian and liberal styles are associated with increased anxiety and reduced engagement. The study underscores the importance of developing flexible communication strategies and emotional intelligence among future teachers.

Keywords: communication style, emotional state of students, primary education, anxiety, teaching practice/

Introduction

In the Republic of Kazakhstan, in the context of modernization of education and the introduction of updated educational content, the requirements for the quality of pedagogical interaction are increasing. One of the key factors determining the success of the educational process is the teacher's communication style, which creates an emotional atmosphere in the classroom. The education system of the Republic of Kazakhstan is aimed at developing the student's personality, social activity, creativity and internal motivation, which is impossible without the emotional well-being of students.

The emotional well-being of students is recognized as a priority not only in national but also in international educational policy. In particular, the UN Convention on the Rights of the Child (1989), ratified by Kazakhstan, emphasizes the right of every child to respect for human dignity, protection from any form of violence and the creation of conditions conducive to his or her comprehensive development (World Health Organization, Article 29, 2020). Effective pedagogical interaction and the creation of a positive emotional climate in the classroom are directly related to these international commitments.

The UNESCO Social and Emotional Learning (UNESCO, 2021) guidelines emphasize that an emotionally supportive school environment promotes better learning, the development of stable interpersonal relationships, and reduced anxiety among students. The World Health Organization (WHO), through its Health Promoting Schools initiative, emphasizes the importance of a psychologically safe environment as a key condition for maintaining and strengthening children's mental health (OON, 1959).

Issues of pedagogical interaction acquire particular importance in the context of training future primary school teachers. In this context, the activities of the Aktobe Regional University named after K. Zhubanov are of particular interest. Here, we train qualified specialists in the field of primary education who are capable of establishing effective communication with their future students, including developing empathy, the ability to listen, observe and support children. This study is also based on data collected from students of this university studying in the specialty "Pedagogy and Methodology of Primary Education", which allows us to consider the problem from the position of a practice-oriented approach and professional readiness for emotionally sensitive pedagogical interaction.

Methods and organization of the study

The study was conducted at the Faculty of Education of the Aktobe Regional University named after K. Zhubanov and included a mixed (qualitative-quantitative) approach. The empirical base consisted of data collected from students in the specialty "5B010200 - Pedagogy and Methodology of Primary Education", as well as primary school students as part of their teaching practice. The study involved 68 third- and fourth-year students and 112 primary school students from four schools in the city of Aktobe: 21, 27, 35, 56. We also involved class teachers from the elementary classes where students completed their internships and where the experiment itself took place.

To diagnose the communication style of teachers, the questionnaire of I.A. Zimnyaya was used, adapted to the conditions of primary school education. The students' emotional state was assessed using the Luscher Color Test method, as well as questionnaires with closed and open questions aimed at self-assessment of emotional comfort, anxiety level, and mood in the learning environment.

In addition to the questionnaire, observation and pedagogical interview methods were used, which allowed for a deeper understanding of the nature of pedagogical interaction. To increase the reliability of the results, data triangulation was used: comparison of information obtained from students, pupils and mentors (practicing teachers).

Quantitative data were processed using SPSS 26.0 software: methods of descriptive statistics, correlation analysis (Pearson) and one-way analysis of variance (ANOVA) were applied, which made it possible to identify significant relationships between the teacher's communication style and the emotional reactions of students. Qualitative data were analyzed using content analysis followed by categorization of participants' statements.

This integrated approach provided a comprehensive examination of the influence of pedagogical communication on the emotional state of primary school students in the context of both the educational environment and the personal characteristics of the teacher.

Research results and discussion

As part of the theoretical analysis of the chosen research topic, we relied on the works of foreign and domestic scientists. Thus, Zimnyaya I.A., Selevko G.K. identified the concept of "communication style" as a stable set of techniques, forms and methods of interaction between a teacher and students. It is determined by the personal characteristics, pedagogical attitudes and professional position of the mentor (Putilovskaja, 2021; Selevko, 2006). In turn, Levin K. emphasizes that communication style has a long-term impact on self-esteem, motivation and adaptation of students in the educational environment (Novikova, 2023). Davydov V.V., Lazarus R., Myers D. interpret "emotional state" as a person's internal psychological state, reflecting the level of his emotional well-being, experiences, moods and attitudes towards what is happening. In the context of education, this condition manifests itself in the level of anxiety, motivation, emotional involvement and resilience of students to stress factors (Kuzakina, 2024; Esetova, 2020; Majers, 2018).

An analysis of the works of Kazakhstani scientists Karaev Zh.A., Kabdykalikova S.K., Kobdikova G.Zh., testifies to the importance of teachers' orientation towards a personality-oriented model of interaction. Researchers emphasize that effective pedagogical communication must be flexible, sensitive to changes in the emotional background of students, and contribute to the creation of a trusting and supportive educational environment (Karaev, 2023; Kobdikova, 2019).

Communication styles (authoritarian, democratic, liberal) are considered in the context of their influence on the personal development and psycho-emotional background of the child. According to research by A.A. Rean and I.A. Zimnyaya, a democratic style helps reduce anxiety and build trust and confidence in students (Rean, 2006; Putilovskaja, 2021).

In the context of digitalization of education, pedagogical communication is acquiring new features, transforming into multimodal interaction, where digital communication channels are used along with verbal and non-verbal forms. We view the style of pedagogical communication as a dynamic system that includes digital behavioral patterns that manifest themselves in the online environment: through feedback in electronic diaries, participation in instant messengers, online learning, and digital platforms. In the modern educational paradigm, pedagogical communication should not only be personally oriented, but also

technologically adapted, open to constant reflection and change in response to students' emotional signals in the digital environment. In this regard, the teacher's choice of communication style, as well as his ability to build trusting interactions with students in both traditional and hybrid or online forms of education, are of particular importance.

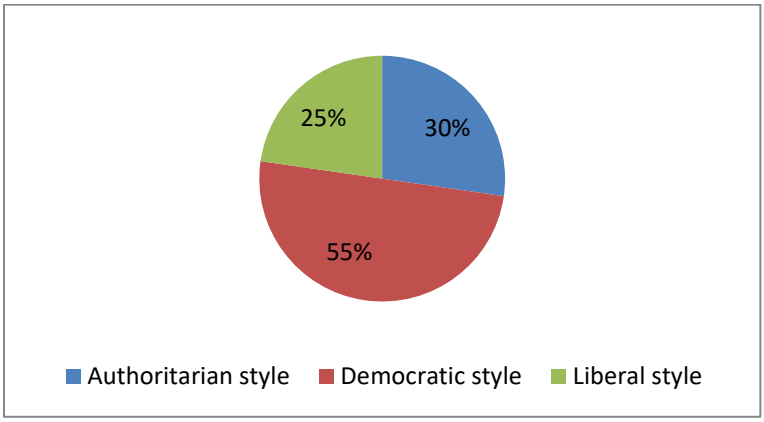
Given the growing importance of the emotional aspect in educational practice, special attention should be paid to the psychological state of the students themselves, especially those studying in elementary grades. The emotional state of primary school students during the primary school period is a key indicator of adaptation to the educational environment, influencing the success of learning and the psychological development of the child. According to L.D. Stolyarenko, emotional well-being is formed in close connection with interpersonal relationships and the style of interaction between adults and the child, and its disruption can cause both short-term and long-term difficulties in learning and socialization (Stolyarenko, 2010). We interpret the emotional state of primary school students as an integrative characteristic reflecting the level of internal stability, adaptability and satisfaction with the learning environment, and we believe that a teacher who is aware of their communication strategies is able to consciously influence the formation of this state.

Based on the obtained theoretical data, an empirical study was developed aimed at identifying specific relationships between the teacher's communication strategies and the emotional reactions of students. The psychological study was conducted with the aim of empirically testing theoretical conclusions and included both quantitative and qualitative diagnostic methods. Particular attention was paid to identifying the degree of comfort of the educational environment, the level of motivation, anxiety and the general emotional state of students with different styles of interaction between teachers.

The first study was conducted among 68 third - and fourth-year students in the specialty "5B010200-Pedagogy and Methodology of Primary Education," using questionnaires to assess the teacher's communication style (according to Levin's classification) and an emotional state scale. Comparison of the results made it possible to identify the relationship between communication style and the emotional state of students.

Figure 1

Results of diagnostics of communication styles of teachers according to the questionnaire of I.A. Zimnyaya



Source: Stolyarenko, L. D., (2010)

The diagram shows the results of the diagnostics of communication styles of future primary school teachers using the questionnaire of I.A. Zimnyaya. The democratic style prevails (55%). An authoritarian style was recorded in 30% of pedagogues. A liberal style was noted by 25% of respondents. The interpretation of the results allows us to state that the focus on a democratic communication style contributes to maintaining a positive emotional climate in primary school and should be a priority in the system of teacher training.

The following diagnostics were carried out with primary school students during their educational and pedagogical practice. 112 primary school students from comprehensive schools in the city of Aktobe served

as referees. This assessment revealed the emotional state of primary school students at the beginning and end of the pedagogical study. The Luscher color test was used as a basis.

Table 1

Results of the diagnostics of emotional state according to Luscher (at the beginning and end of the experiment)

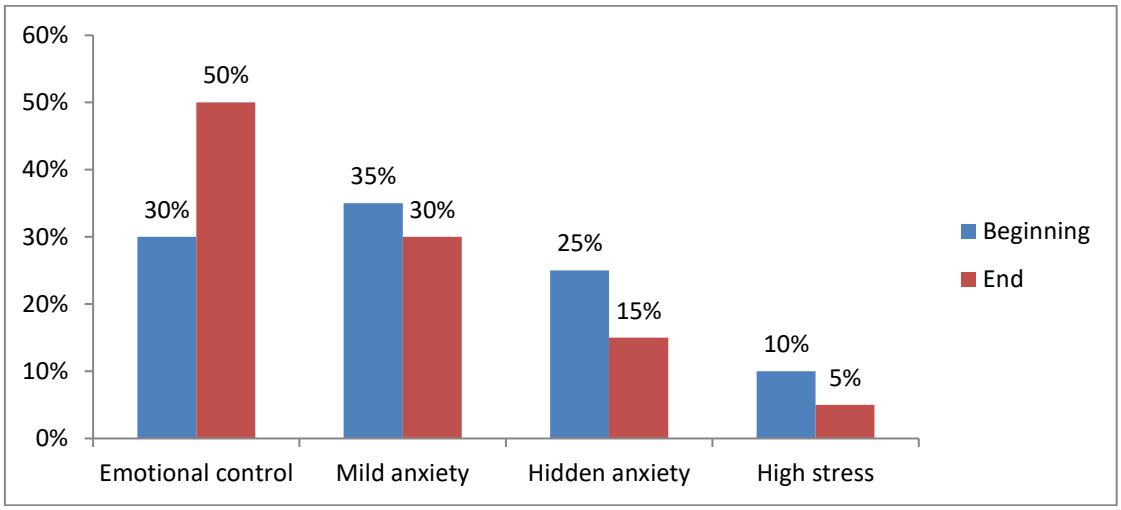
Class	Number of students	Comfortable state		High anxiety	
		beginning	end	beginning	end
1	18	4	10	8	3
2	26	9	18	9	4
3	34	15	28	10	3
4	34	16	29	11	3

Source: Stolyarenko, L. D., (2010)

The results of the table show positive dynamics in the emotional state of primary school students at the end of the pedagogical experiment. The greatest improvements are observed among students in grades 3-4, which is explained not only by a more stable adaptation to the school environment, but also by the active use of modern behavioral strategies by teachers.

Figure 2

Results of the Luscher Color Test



Source: Stolyarenko, L. D., (2010)

A comparative analysis of the emotional state of schoolchildren before and after the experiment shows positive dynamics. The proportion of students with emotional comfort increased from 40% to 58%, indicating an improvement in the psychological climate in the classroom. The number of children with mild anxiety decreased from 30% to 24%, and latent anxiety decreased from 20% to 12%. Particularly significant is the reduction in high stress levels - from 10% to 6%. This indicates the effectiveness of introducing a teaching style focused on support and emotional involvement.

The improvement in the emotional state of schoolchildren at the post-diagnostic stage is explained by the introduction of well-thought-out behavioral strategies of the teacher, aimed at creating a trusting and supportive educational environment.

The following strategies have proven to be the most effective:

- *empathic listening* (the teacher listened attentively to students' opinions and feelings without criticism; actively monitored children's emotional cues and adapted their communication style to the current mood of the class);

- *gamification of the educational process* (the introduction of game elements (points, badges, mini-quests) to increase motivation and reduce anxiety in stressful situations);

- *digital feedback technologies* (using online tools (e.g. Padlet, Mentimeter) to anonymously express

emotions, suggestions, questions);

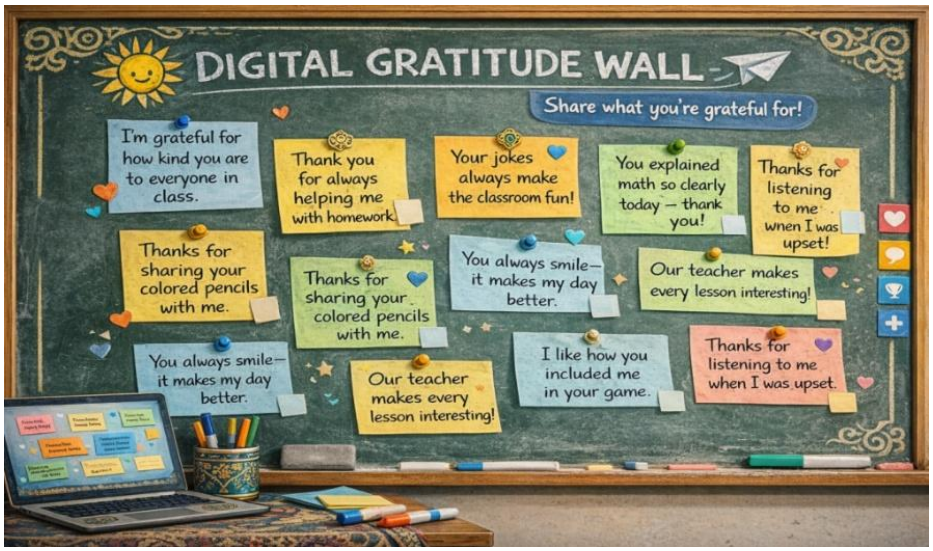
- *creating an "emotional vocabulary" in the classroom* (developing children's ability to recognize and name their emotions through working with pictograms, colors, or simple digital applications);

- *micro-practices of mindfulness* (short breathing exercises, "minutes of silence," and visualization techniques to reduce stress and restore concentration).

As an example, consider the "Digital Gratitude Wall" technique: using an online board, children write down what they are grateful for in each other and in the teacher. This enhances a positive classroom climate. As part of this technique, students are encouraged to regularly record in the digital space words of gratitude to classmates and the teacher for help, support, goodwill, or successful collaboration in the lesson. This form of interaction helps children develop skills of emotional reflection, the ability to notice positive manifestations in the behavior of others and to express gratitude in a socially acceptable form. In addition, the Digital Gratitude Wall enhances a sense of community, reduces anxiety, and creates a sustainable, positive emotional climate in the classroom, which is especially important in hybrid and distance learning settings.

Figure 3

Digital Gratitude Wall



Source: Vasic B.K., Kubieva V.A., Kapina E.A. (2025)

In order to identify the relationship between the style of pedagogical communication and the emotional state of students, a questionnaire was developed, including both closed and open questions aimed at self-assessment by schoolchildren and future teachers of such parameters as the level of emotional comfort in the learning environment, the degree of anxiety in the process of interaction with the teacher, the general mood and emotional background in the classroom, and the perception of the teacher's behavioral strategies.

The purpose of the questionnaire: to determine which components of pedagogical communication influence the emotional state of students, and to compare the perception of these factors by the children themselves, students of pedagogical fields and practicing teachers.

Table 2

Structure of the questionnaire "How I feel in lessons/classes"

Block 1. Emotional comfort	**Do you enjoy coming to school? (yes/no)** **Do you feel confident in class? (always/sometimes/never)** **What helps you feel comfortable in class? (open-ended question)**
Block 2. Anxiety and its causes	Are you afraid to answer questions at the board? (Yes/Sometimes/No) What makes you nervous in class? (Options: a strict teacher, fear of making mistakes, unclear assignments, etc.) Tell me about moments in class that make you especially nervous. (Open-ended question)
Block 3. Perception of teacher behavior	Does your teacher praise you more often than criticize you? (yes/no) Does your teacher speak to you in a friendly manner? (always/sometimes/never) Does your teacher notice when you're sad or tired? (always/sometimes/never) What words from your teacher stand out to you? (open-ended question)
Block 4. General mood and climate in the class/group/team	What's your typical mood like in class? (open-ended question) How do you rate the classroom atmosphere? (1-10, please explain your answer) Would you like your teacher to change anything about how they interact with you? (open-ended question)

Source: Vasic B.K., Kubieva V.A., Kapina E.A. (2025)

The questionnaire aims to obtain a comprehensive picture of the students' emotional state and to reveal which aspects of communication (support, demandingness, participation, feedback, etc.) are observed or contribute to emotional well-being. Comparing the opinions of pupils, students and teachers will allow for data triangulation and increase the reliability of the interpretation of the results.

The survey was conducted among three groups of respondents: 112 primary school students (grades 1–4); 68 students in the specialty "5B010200 - Pedagogy and Methodology of Primary Education" and 12 primary school teachers. The results were distributed as follows:

1) Emotional comfort in the learning environment

Among school students, 62% of respondents reported feeling comfortable in the classroom and enjoying attending school. At the same time, 24% indicated that they occasionally experience anxiety, particularly when answering questions at the board or taking tests. Another 14% admitted to feeling insecure or fearful, especially in situations where teachers adopt a strict or authoritarian communication style.

Among university students, 58% believed that the democratic communication style demonstrated by their mentors contributes to a positive and supportive learning environment. However, 31% noted that increased anxiety among students is most commonly associated with unconstructive criticism or a lack of attention from teachers. An additional 11% reported observing emotional stress among learners resulting from insufficient feedback and limited pedagogical support.

Among pedagogues, 69% identified support and active listening as the most important factors in creating a psychologically comfortable educational environment. Nevertheless, 23% acknowledged that heavy workloads sometimes prevent them from adequately considering students' emotional well-being during the educational process. Furthermore, 8% reported experiencing difficulties in establishing effective communication with withdrawn, anxious, or emotionally vulnerable students.

2) Level of anxiety and the reason for its occurrence

Based on the results of closed questions: the main sources of anxiety for schoolchildren are: fear of being called upon without preparation (37%); criticism from the teacher in the presence of the class (32%); comparison with other students (21%); unclear assignments or instructions (10%).

Based on the results of open questions: children most often use the words: "I'm afraid of making a mistake," "I'm always worried," "I sometimes don't understand what they want from me." Students cited the following as reasons for anxiety: "suppression of initiative" and "lack of positive reinforcement". Teachers highlighted: "emotional instability of children," "family problems," "weak academic motivation."

3) Classroom mood and the influence of teacher communication style:

The findings indicate that 74% of elementary school students believe that the overall classroom atmosphere largely depends on the teacher's behavior and communication style. This highlights the significant role of teachers in shaping a positive emotional climate and fostering students' engagement in the learning process. Students exposed to a democratic communication style reported the most positive learning

experiences. In particular, 84% indicated that they felt more confident, motivated, and actively involved in classroom activities when teachers encouraged open communication, respect, and collaboration.

In contrast, an authoritarian communication style was associated with less favorable emotional outcomes. Sixty-three percent of respondents reported experiencing feelings of tension, discomfort, or anxiety in classrooms where teachers adopted a strict and controlling approach to communication.

A liberal communication style also presented certain challenges. Forty-one percent of students reported confusion regarding learning tasks and a decline in motivation, suggesting that insufficient guidance and limited teacher involvement may negatively affect students' understanding of instructional expectations and their engagement in the educational process.Quantitative data were processed using SPSS 26.0 software: methods of descriptive statistics, correlation analysis (Pearson) and one-way analysis of variance (ANOVA) were applied, which made it possible to identify significant relationships between the teacher's communication style and the emotional reactions of students. In particular, statistically significant correlations were established between a democratic communication style and such indicators as high academic motivation ($r = 0.62$, $p < 0.01$) and emotional comfort ($r = 0.58$, $p < 0.01$). The authoritarian style showed inverse relationships, particularly with regard to anxiety ($r = -0.49$, $p < 0.01$) (Rogov E.I., 2006).

The results of a survey conducted among primary school students, students of pedagogical specialties and practicing teachers showed that the majority of respondents noted a significant influence of the style of pedagogical communication on their emotional state: a democratic style is associated with a feeling of security, motivation and a positive attitude towards learning, while an authoritarian style is associated with anxiety, fear of making mistakes and a decrease in activity. Students participating in the internship emphasized the importance of feedback and empathy in creating a comfortable learning environment, while teachers emphasized the need for an individual approach and the ability to regulate the emotional background of the class. The combined data from the questionnaire confirmed the importance of developing flexible communication strategies and emotional competence in future teachers.

Conclusion

The results of the study confirmed that the teacher's communication style has a significant impact on the emotional state of students. The democratic style turned out to be the most effective in terms of emotional comfort, academic motivation and student trust. It promotes the formation of a favorable psycho-emotional climate, the development of confidence and a reduction in anxiety levels. An authoritarian style, on the contrary, correlates with a high level of tension and fear of mistakes, and a liberal style – with uncertainty and emotional instability.

The data obtained indicate the need for increased attention to the issues of training future teachers in the field of pedagogical communication and emotional intelligence. Including modules on developing empathy, reflection, and emotionally sensitive interaction skills in educational programs will be an important step towards improving the quality of primary education.

Thus, the results of the study have both scientific and applied significance: they allow for the development of recommendations for improving the effectiveness of pedagogical communication, contribute to the justification of educational policies focused on the emotional well-being of students, and emphasize the need for continuous psychological support of the educational process in the context of updated educational content in the Republic of Kazakhstan.

Conflicts of Interest Statement.

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Author Contributions.

Vasic Bibigul: Conceptualization, Methodology, Data curation, Writing-Original draft preparation. Kubiyeva Venera: Reviewing and Editing. Kapina Elmira: Data curation, Writing-Reviewing and Editing

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STUDENTS' LEARNING APPROACHES AND TEACHING QUALITY IN CHEMISTRY TEACHER TRAINING PROGRAM: A COMPARATIVE PERSPECTIVE OF STUDENTS AND TEACHERS

Abstract. This study comprehensively analyzed the learning approaches of future chemistry teachers and the quality of chemistry teaching, and identified their relationship. The data for the study were collected through an online survey. 179 students from 8 higher education institutions and 29 teachers from 6 higher education institutions in Kazakhstan participated in the research. The data were collected on the basis of a Likert scale and processed using t-test for independent samples, correlation and multiple regression analysis. The results showed that strategic and deep learning approaches are relatively dominant among students, while the surface learning approach is weakly observed. It was also found that teachers rate the quality of lectures and laboratory classes higher than students, which is due to the fact that teachers prioritize the scientific validity and structure of the content, and students pay more attention to learning activity, the ability to participate in classes and the availability of feedback. Correlation and regression analyses showed that the quality of lectures, seminars and especially laboratory classes is positively related to students' deep and strategic learning approaches. The quality of laboratory classes was the strongest predictor of the deep learning approach. The results of the study indicate the need to strengthen the content connection between lectures, seminars, and laboratory classes, and to systematically introduce interactive teaching methods and feedback in the chemistry teacher training program.

Keywords: chemistry teacher training, student learning approaches, quality of education, correlation-regression analysis.

Introduction

The relationship between learning outcomes and effective teaching has been widely studied in higher education. Parpala and Lindblom-Ylänne (2007) and Zakaria et al. (2025) show that learning outcomes depend on both teachers' teaching approaches and students' learning approaches. Trigwell et al. (1999) also found that there is a strong relationship between teaching approaches and students' learning approaches. In particular, while in traditional teacher-centered teaching, students tend to use surface learning approaches, student-centered teaching promotes the development of deep learning approaches.

The ways in which students learn are called learning strategies or learning approaches. Biggs (1978) proposed the presage–process–product (3P) model, suggesting that students' learning approaches are shaped by the interplay between their previous learning experiences, their learning environment, and their learning outcomes. Subsequent research has shown that how students perceive their learning environment influences their learning approaches (Keenan, 2025; Trigwell et al., 1999).

Entwistle et al. (1997) proposed the ASSIST (Approaches and Study Skills Inventory for Students) tool for identifying students' learning approaches, dividing learning approaches into three main categories: deep, surface, and strategic:

The surface learning approach is often based on mechanical memorization of material, and is characterized by a lack of attention to the connections between topics (Duff, 2004).

The strategic learning approach is focused on achieving high results and includes features such as effective time management, systematic organization of learning activities, and adaptation to assessment requirements (Duff, 2007).

The deep learning approach is characterized by students' efforts to understand the meaning of the learning material, connect new knowledge with previous knowledge, and critically analyze it (Duff, 2004).

Studies in the natural sciences have found that students who use deep learning approaches are more likely to develop scientific explanations, ask questions about cause-and-effect relationships, and engage in metacognitive thinking, while students who use surface learning approaches are more likely to describe facts

and perform procedural actions (Chin & Brown, 2000).

In science subjects, especially chemistry, students' learning approaches are often shaped by laboratory work, experimental tasks, and problem-solving. Such learning environments allow students to develop scientific explanations and analyze cause-and-effect relationships rather than simply memorizing information (Chin & Brown, 2000; Hofstein & Lunetta, 2004). Thus, laboratory classes help students to critically examine the material and create a conducive environment for the development of deep learning approaches. However, despite the potential of laboratory learning environments, research shows that chemistry students often use both deep and surface learning approaches, demonstrating their difficulty consistently engaging in deep learning (Keenan, 2025). These difficulties are primarily due to students' insufficient systematic acquisition of learning strategies, their reliance on personal perceptions rather than effectiveness, and a lack of skills in effectively using deep learning approaches. Furthermore, students' tendency to choose simpler and less demanding approaches leads them to use surface or strategic learning approaches even when deep understanding is required.

Students' learning approaches do not automatically change during their studies. Their formation and change largely depend on teaching methods, assessment systems, characteristics of the learning environment, and students' learning load. Therefore, if the learning process is not focused on students' deep understanding, analysis, and connection of knowledge, students may continue to use surface learning approaches (Asikainen & Gijbels, 2017). It has also been found that students who use deep learning strategies often achieve high academic results, while relying on surface learning approaches is often associated with low academic achievement. However, students with average academic performance may use both deep and surface learning approaches (Gabut et al., 2026). Therefore, students learn in different ways (Clark & Mayer, 2003).

Students' learning approaches are not static and can vary depending on the learning environment, teaching methods used, and assessment requirements (Struyven et al., 2005). For example, student-centered interactive teaching methods promote the development of deep learning approaches by increasing students' active participation and developing critical thinking and analysis (Trigwell et al., 1999; Shukla, 2024). However, some studies suggest that problem-based learning promotes the development of deep learning approaches in students, but has little effect on surface learning approaches (Dolmans et al., 2016).

The study of teaching quality, which influences the formation of students' learning approaches, was comprehensively considered in the 20th and 21st centuries. In the 1900s, students were given tests in the subjects they studied and the results showed the quality of education, in the 1930s, the teaching method and the quality of education were linked, in the 1950s-60s, the influence of the teacher on the quality of education was studied, and in the 1980s-90s, the influence of teachers, students and their interactions on the quality of education was studied. However, modern studies focus on factors such as student perception of learning and teacher teaching (Al Kharusi, 2023; Blömeke, 2022; Money, 1992). Students are important stakeholders in the process of evaluating the quality of education, because "who eats the food, their opinion must be taken into account in order to know the taste" (Seldin, 1993). Marsh (1984) concluded that students' evaluation of teaching quality is characterized as follows: (1) multifaceted; (2) reliable and stable; (3) aimed at assessing the performance of the teacher; (4) relatively valid for various indicators of effective teaching; (5) relatively unaffected by variables that are often considered biases; and (6) useful as feedback on teaching for teachers, in course selection for students, and in personnel decisions for administrators.

In assessing the effectiveness of student learning, Stringer and Irwing (1998) used questionnaires to assess the quality of teaching, feedback, workload, course integration, learning motivation, and overall assessment. Wilson et al. (1997) used questionnaires to assess teaching: good teaching, clear goals, workload, assessment, independence, and general skills. The studies of Stringer and Irwing (1998) and Wilson et al. (1997) mainly rely on questionnaires to assess the quality of teaching in social studies and do not take into account laboratory work specific to natural sciences. Laboratory classes are an important component in teaching natural sciences (Agustian, 2024). Studies have shown that the effectiveness of laboratory teaching should be assessed by indicators such as the connection between theory and practice, the development of experimental skills, data analysis, scientific thinking, and the formation of investigative actions (Hofstein & Lunetta, 2004; Abrahams & Millar, 2008). Ogunkola and Archer-Bradshaw (2013) provide a questionnaire for science teachers to assess their teaching practices. The questions in this paper

focus on the teacher's student assessment process.

As chemistry teaching is characterized by laboratory work, research on evaluating teaching quality among students in chemistry teacher training program, as well as the development of questionnaire instruments for this purpose, remains limited. Only the study by Dalgety et al., (2013) investigated students' attitudes towards chemistry, students' knowledge of chemistry, and thoughts about teaching chemistry using a questionnaire. However, the questionnaire questions were mainly aimed at assessing the teacher's influence on the student, his ability to increase interest in knowledge, and build confidence in learning. That is, the questionnaire questions were not intended to assess the actual quality of teaching, the effectiveness of teaching materials, or the level of lesson content.

The Approaches to Studying Inventory (ASI) questionnaire proposed by Entwistle and Ramsden (1983) has been widely used in the study of students' learning approaches. Later, the ASSIST questionnaire was proposed as an improved version of this tool (Entwistle et al., 1997). Another popular tool for determining students' learning approaches is the Study Process Questionnaire (SPQ) proposed by Biggs (1987). Later, this questionnaire was improved and the Revised Study Process Questionnaire (R-SPQ-2F) was proposed to measure students' deep and surface learning approaches (Biggs et al., 2001).

Thus, the results of the literature review indicate that the relationship between students' learning approaches and teaching quality in higher education has been widely studied. However, given the specifics of chemistry teaching, the issue of parallel assessment of the quality of education based on the opinions of students and teachers in lectures, seminars and laboratory classes has not been sufficiently addressed. In addition, the learning approaches of students in chemistry teacher training programs have not been studied in the context of Kazakhstan.

Research questions:

1. What learning approaches do students in the chemistry teacher training program use most?
2. Are there differences between students' and teachers' perceptions of teaching quality?
3. How do students' learning approaches relate to different teaching formats?

Methodology

Based on the methodology proposed in Miskeljin and Arsenijevic (2014), a parallel study was chosen to conduct on the same topics from the perspective of teachers and students. A Likert scale (1–5) was used to collect data (1 – strongly disagree, 5 – strongly agree). The survey consisted of two main parts. The first part was aimed at identifying students' learning approaches and was based on the concept of the ASSIST (Entwistle et al., 1997). The internal reliability of the survey was Cronbach's alpha coefficient ($\alpha = 0.84$). In this part, students' surface, deep and strategic learning approaches were assessed. In the second part, participants were asked about the quality of chemistry teaching: lectures, seminars and laboratory classes.

Questions related to lectures covered aspects such as the content of teaching materials, clarity of information, use of digital technologies and visuals, teacher interaction with students, providing feedback, and increasing student interest in the subject.

The questions for the seminar sessions were aimed at assessing indicators such as the seminar's connection to the lecture content, the use of interactive teaching methods, active student participation, opportunities for discussion and group work, deepening theoretical knowledge, and the development of students' critical and creative thinking skills.

Questions for laboratory classes covered aspects such as the relationship between theory and practice, organization of experimental work, teacher guidance and feedback, compliance with safety requirements, analysis of experimental results, and increasing students' interest in chemistry.

To verify the content validity of the questionnaire, three experts (specialists in the field of chemistry education) evaluated the content of the questions and checked their subject-specific relevance. In addition, formal approval was obtained from the university ethics committee before conducting the study. The internal consistency of the questionnaire was determined by Cronbach's alpha coefficient, which showed a high level of reliability ($\alpha = 0.96$).

The survey was distributed online via the Google Forms platform. In the survey for students, they assessed their own learning approaches and also expressed their opinions on the quality of lectures, seminars, and laboratory classes conducted by teachers.

In the questionnaire for teachers, they assessed students' learning approaches and also assessed the quality of lessons in relation to the teaching format they conduct. Since not all teachers may conduct lectures, seminars, and laboratory classes in the same way, three separate questionnaire links were prepared for teachers: assessment of students' learning approaches + assessment of the quality of lectures; assessment of students' learning approaches + assessment of the quality of seminars; assessment of students' learning approaches + assessment of the quality of laboratory classes. Each teacher received a questionnaire link corresponding to the teaching format which they conduct. Thus, the study provided the opportunity to assess learning approaches and lesson quality in parallel based on the opinions of students and teachers.

Descriptive statistics (mean, standard deviation) were calculated during the analysis of the collected data. Independent samples t-test was used to compare the ratings of students and teachers. Correlation analysis was used to identify relationships between variables, and multiple regression analysis was used to identify factors affecting learning approaches. All statistical analyses were performed using Jamovi version 2.6.44.

Participants. A total of 179 1st-4th year students of the specialty "Chemistry Teacher Training" from 8 higher educational institutions of the Republic of Kazakhstan participated in the study, with a 100% response rate. In addition, teachers conducting lectures, seminars and laboratory classes of the specialty "Chemistry Teacher Training" from 6 higher educational institutions of the Republic of Kazakhstan were also involved in the study. A total of 29 teachers (14 lecturers, 12 teachers conducting laboratory classes and 3 teachers conducting seminars) participated in the survey, providing their answers with a 100% response rate.

The wide range of study participants ensured comparability of the results across higher education institutions and allowed for a comprehensive analysis of the quality of chemistry teacher training.

Results and discussion

Comparative Evaluation of Students' Learning Approaches by Students and Teachers

Using survey data collected from students and teachers, a comparative analysis of the learning approaches of students in the chemistry teacher training program was conducted. The analysis focused on three types of learning approaches: surface, strategic, and deep (Tables 1–3). The means of the two groups were compared, and the statistical significance of differences was determined using a t-test for independent samples.

Table 1.

Surface Learning Approach

Variable	Group	Total number of responses	Mean	SD	T (t-test)	df	p
Surface learning approach	Students	179	2.69	0.71	1.42	206	.156
	Teachers	29	2.47	0.41			

Table 1 presents the comparative results of students' and teachers' assessments of students' use of the surface learning approach. Although there was a difference in the mean values of the surface learning approach between students (M = 2.69, SD = 0.71) and teachers (M = 2.47, SD = 0.41), the result of the t-test for independent samples showed that this difference was not statistically significant ($t(206) = 1.42$, $p = .156$). The results indicate that students use the surface learning approach in some situations, but this approach is not the dominant one in their learning activity.

A number of factors may influence the use of the surface learning approach. For example, the large volume of learning materials (students – 3.25, teachers – 3.14) and a lack of complete understanding of the connections between topics (students – 3.07, teachers – 3.07).

In addition, some students noted a lack of useful and interesting information in lessons (students – 2.19, teachers – 1.72) and indicated that they had difficulty determining what information to remember (students – 2.50, teachers – 2.31).

Entwistle et al. (1997) wrote that the characteristics of the learning environment and excessive learning load can affect students' choice of surface learning approach, and our study results also support this view. According to Biggs (1982) theory, if learning tasks are focused more on memorization than on understanding, students are more likely to memorize mechanically. However, the relatively low indicators indicate that the majority of students do not just memorize the learning material, but also try to understand and master it in a meaningful way. However, an important issue here is that the surface learning approach has not been completely eliminated. This situation indicates the need to structure the learning content, clarify important concepts, strengthen the logical connection between topics, and systematically introduce elements of reflection. Asikainen and Gijbels (2017) argued that learning approaches do not change by themselves, and that a purposefully organized learning environment is needed to develop them. Therefore, the persistence of the surface learning approach, even if weak, indicates that some structural or methodological factors in the learning process still need to be improved.

Table 2.
Strategic Learning Approach

Variable	Group	Total number of responses	Mean	SD	T (t-test)	df	p
Strategic learning approach	Students	179	3.75	0.61	1.15	206	.251
	Teachers	29	3.60	0.75			

According to the survey results, students' use of strategic learning approaches in learning chemistry was rated relatively highly by both groups (students – 3.75, teachers – 3.60). The results of the t-test for independent samples showed that there was no statistically significant difference between the assessments of students and teachers ($t(206) = 1.15$, $p = .251$).

Individual indicators showed that not all components of the strategic learning approach were developed to the same level in students. Although students rated themselves as being able to manage their time effectively (students – 3.80), teachers' ratings were relatively low (3.45). This difference reflects the gap between students' self-assessment and external monitoring. Nicol and Macfarlane-Dick (2006) showed that students' self-assessment does not always fully correspond to actual learning activity, and that systematic feedback and reflection are necessary for students to develop self-regulation skills.

It was observed that the steady work throughout the semester (students – 3.46; teachers – 3.34) and systematic preparation for the exam (students – 3.96; teachers – 3.62) were not always maintained consistently. In addition, the relatively high assessment of teachers on the indicators of completing the task when necessary (students – 3.90; teachers – 3.69) and motivation (teachers – 3.79; students – 3.65) indicate that students use strategic elements, but there is a certain instability in steady work throughout the semester, systematic preparation for the exam and the stable realization of their learning potential. Pintrich (2000) explained this situation with the incomplete formation of self-regulation skills in students and instability of motivation. That is, a strategic learning approach requires not only the ability to plan, but also the ability to maintain motivation and continuous support for the learning process. However, Keenan (2025) showed that students' choice of strategic learning approaches is largely driven by the need to adapt to exam requirements and optimize time use.

Table 3.

Deep Learning Approach

Variable	Group	Total number of responses	Mean	SD	T (t-test)	df	p
Deep learning approach	Students	179	3.68	0.57	0.66	206	.507
	Teachers	29	3.66	0.74			

As shown in Table 3, the level of students' use of deep learning approaches in chemistry learning was estimated approximately equally by students and teachers (students – 3.68, SD = 0.57), (teachers – 3.66, SD = 0.74). And the results of the t-test for independent samples ($t(206) = 0.66$, $p = .507$) showed that there was no difference in the assessments of students and teachers regarding the use of deep learning approaches by students.

The results showed that students' use of a deep learning approach to mastering chemistry was lower than that of a strategic approach, but higher than that of a surface approach. However, individual indicators indicated that deep processing is not always possible. For example, students rated the desire to understand the connections between ideas highly (3.88), while teachers rated it highly (3.66), which indicates that students highly value themselves from an analytical perspective, while teachers do not always notice this ability in them. Similarly, students rated the desire to understand the meaning of a task before completing it (3.93; teachers - 3.88), but the rate of asking questions about lectures and literature was low (students - 3.42; teachers - 3.55), which is evidence of the incomplete formation of skills for connecting new knowledge with previous knowledge and reflection. In addition, the motivation to think deeply about the information received was rated lower in both groups (students - 3.17; teachers - 3.31), which suggests that students do not always find enough time and opportunity to process the material in depth. In general, these results indicate that although elements of deep learning are formed in students, it is not implemented consistently and systematically.

Chin and Brown (2000) showed that students who use the deep learning approach in science subjects tend to make scientific explanations, compare evidence, and find meaningful connections. Our results are similar: students strive to understand the connections between ideas and grasp the meaning of the task. However, the fact that the deep learning approach is lower than the strategic approach and that some indicators remain at an average level indicates that this approach is not fully established. In particular, the decrease in asking questions about lectures and literature and encouraging students to think about the information received for a long time indicates that students' cognitive activity does not always reach a reflective and critical level. An important issue here is the extent to which the learning environment encourages students to process the material in depth. If the learning process is dominated by a lack of time, a large amount of information, or a share of reproductive tasks (Entwistle et al., 1997), students are more inclined to master the learning material functionally than to analyze it meaningfully. Therefore, our results indicate that although elements of deep learning have been formed, further improvement of the learning environment is necessary for them to become a permanent practice.

Comparative Evaluation of Teaching Quality by Students and Teachers

Further, based on the opinions of students and teachers, responses regarding the quality of lectures, seminars, and laboratory classes in the chemistry teacher training program were analyzed (Tables 4–6). The average scores of students and teachers for each training format were compared, and the statistical significance of the difference between them was determined using the t-test for independent samples.

Table 4.
Quality of Lectures

Variable		Group	Total number of responses	Mean	SD	T (t-test)	df	p
Quality of lectures		Students	179	3.81	0.64	-3.27	191	.001
		Teachers	14	4.38	0.44			

As shown in Table 4, the results of the evaluation of the quality of chemistry lectures showed that there was a difference between the opinions of students and teachers. The average student rating was M = 3.81 (SD = 0.64), while the teachers' rating was M = 4.38 (SD = 0.44). The results of the t-test for independent samples showed that this difference was statistically significant ($t(191) = -3.27$, $p = .001$).

When comparing individual indicators, significant differences were also observed. In terms of content quality, students rated the quality of lecture materials as 3.80, while teachers rated it as 4.43. Similarly, in terms of content freshness, students rated it as 3.87, while teachers rated it as 4.50.

There were also differences in the methods of delivering the material. For example, students rated the clarity of the materials as 3.84, while teachers rated it as 4.36. In addition, students rated the use of visuals as 3.58, while teachers rated it as 4.00. These indicators indicate that students largely rely on teaching methods to rate the quality of lectures as high.

The student-teacher ratio for audience interaction and feedback was 3.89, while the faculty member's was 4.29. This suggests that students may not be able to participate actively in lectures in all situations. There was also a difference in the indicators of student support and motivation. For example, the indicator of increasing student interest was 3.85 for students, and 4.43 for teachers. In addition, the indicator of providing professional guidance was rated by students as 3.97, and by teachers as 4.43. And the indicator of encouraging independent research in terms of the cognitive impact of the lecture was 3.87 for students, and 4.50 for teachers.

The statistically significant difference between students and teachers in terms of lecture quality is particularly striking. While teachers rated lecture quality highly, students rated it relatively low. While teachers often focus on the accuracy, relevance, and structure of the content, students are more likely to focus on how clear, interesting, and accessible the material is. Ramsden (1992), Biggs (1999) and Deslauriers (2019) showed that the quality of teaching in higher education is determined not only by the quality of the content, but also by how students interact with it. Our study also shows this gap: while teachers rated quality highly in terms of content and professionalism, students rated components such as clarity of concepts, use of visuals, and interaction with the audience lower.

This result suggests that in subjects such as chemistry, which are rich in abstract concepts, it is important to explain the lecture not only by simply conveying information, but also by visualizing concepts, clarifying them with examples, and explaining them through interactive communication with the student. If the lecture is mainly aimed at systematically conveying the content, but also by not using methods that enhance the cognitive participation of the student, it may not be perceived as fully qualitative by the student. Therefore, the identified gap in lecture quality is not only a perception difference, but also an indication of the need to make the traditional form of teaching more student-centered.

Table 5.
Quality of Seminar Sessions

Variable	Group	Total number of responses	Mean	SD	T (t-test)	df	p
Quality of seminar sessions	Students	179	3.83	0.65	0.38	180	.704
	Teachers	3	3.69	0.13			

The results of the evaluation of the quality of the seminar classes showed that students and teachers generally rated this form of training positively. The average student rating was 3.83 (SD = 0.65), and the teacher rating was 3.69 (SD = 0.13). Although there was a slight difference in the mean values, the results of the t-test for independent samples showed that this difference was not statistically significant (t(180) = 0.38, p = .704).

In the evaluation of the seminar classes, certain differences were observed in the two groups on individual indicators. For example, students highly rated the coverage of the lecture content of the seminar topics (student – 3.93), while teachers rated it relatively low (teacher – 3.33). This indicates that students perceive the seminars as a practical form of learning that consolidates the theory in the lecture.

In terms of organization and teaching methods, the ratings for the interestingness of the seminars (student – 3.82; teacher – 3.67) and the level of stimulation of student activity (student – 3.88; teacher – 4.00) were close to each other. This indicates that the seminars were held in a generally active format, but the relatively low student ratings indicate the need for further improvement of the teaching methods used.

Indicators related to learning outcomes and skills development also showed that seminars contribute to deepening knowledge. For example, the indicators of deepening theoretical knowledge (student – 3.94; teacher – 4.00), increasing scientific interest (student – 3.82; teacher – 4.00), and developing explanatory skills (student – 3.77; teacher – 3.67) indicate the importance of seminars in developing cognitive and academic skills.

Differences were also observed regarding interactivity and lesson format. For example, students rated the use of the discussion format highly (student – 3.77), while teachers rated it low (teacher – 2.67). At the same time, students rated the use of the traditional format relatively highly (student – 3.77; teacher – 2.33), which indicates that interactive and traditional elements are used in the seminars.

In terms of support and professional development, the seminars' indicators of providing personal feedback (student – 3.76; teacher – 4.00), building professional confidence (student – 3.80; teacher – 4.00), and developing creative thinking (student – 3.75; teacher – 4.00) indicate that the seminars contribute to students' academic and professional development.

Although no statistically significant differences in the quality of the seminars were found, the small number of participating teachers (n = 3) limited the generalizability of the results. However, the higher student ratings of the discussion format suggest that they perceived the seminar as a space for reflection and exchange of ideas, rather than simply rehearsing content. This is consistent with findings from Prince (2004) and Freeman et al. (2014) that active learning formats enhance student engagement and learning experiences.

At the same time, teachers' perception of seminars in terms of content consistency and structure is explained by the concept of constructive alignment (Biggs, 1999; Kember, 2011). That is, while for students the quality of a seminar is often felt through participation and activity in the lesson, for teachers it is measured by how well it is organized in accordance with the learning objectives. These two different logics help to explain the subtle differences in the perception of the quality of seminar lessons. Therefore, in improving seminars, it is important not only to increase the number of active methods, but also to clearly demonstrate their connection to specific learning outcomes.

Table 6.

Quality of Laboratory Lessons

Variable	Group	Total number of responses	Mean	SD	T (t-test)	df	p
Quality of laboratory lessons	Students	179	3.88	0.64	-2.40	189	.017
	Teachers	12	4.34	0.48			

The results of the evaluation of the quality of laboratory classes showed that there was a difference between the evaluations of students and teachers. The average score of students was 3.88 (SD = 0.64), while the teachers' score was 4.34 (SD = 0.48). The results of the t-test conducted on independent samples showed that this difference was statistically significant (t(189) = −2.40, p = .017). This indicates that teachers

perceive the quality of laboratory classes more highly than students.

While teachers rated the monitoring of students' consolidation of theoretical knowledge through practical work during laboratory classes highly (4.33), students rated it relatively low (3.94). This suggests that although consolidation of theoretical knowledge through practice is one of the learning goals, its achievement is not always felt equally in students' learning experiences.

In terms of the connection between theory and practice, there was a difference in the indicators of the connection of laboratory work with lecture and seminar topics (teacher - 4.42; student - 3.88) and the clarity of the instructions for preparing for laboratory work (teacher - 4.33; student - 3.87). This indicates that students have a relatively low assessment of the connection between laboratory lessons and lectures and may perceive the level of practical consolidation of theory as insufficient. It also indicates the need to further improve the quality of theoretical material prepared for laboratory work.

In terms of feedback, the indicators of students' ability to ask questions (teacher – 4.42; student – 3.89) and receiving answers to questions (teacher – 4.42; student – 3.91) indicate that teachers believe that there is open communication during the lesson. However, the relatively low scores of students indicate that these opportunities are not equally available to all students and that the level of interaction in laboratory lessons needs to be further strengthened.

In terms of learning outcomes, the indicators of finding answers to theoretical questions (teacher – 4.50; student – 3.80), learning to analyze results and draw conclusions (teacher – 4.50; student – 3.95), checking the correctness of results (teacher – 4.50; student – 3.90), and understanding the relationship between data and results (teacher – 4.50; student – 3.91) indicate that laboratory classes are aimed at developing analytical skills. However, the relatively low scores of students indicate the need for additional methodological support and strengthening the elements of explanation and supervision in this process.

Compliance with safety rules during laboratory classes was highly rated (teacher – 4.50; student – 3.99). In addition, the indicators of increasing interest in chemistry (teacher – 4.50; student – 3.88) and developing professional confidence (teacher – 4.42; student – 3.88) indicate that teachers highly value their influence, while students perceive this influence relatively less.

The study showed that teachers rated the quality of laboratory classes higher than students. This gap suggests that although the structure and purpose of laboratory work are clear to the teacher, students do not always perceive it to the same extent. In particular, lower student ratings on indicators such as the connection between theory and practice, the ability to ask questions, analyze results, draw conclusions, and understand the relationship between data indicate that it is important not only to do the activity in laboratory classes, but also to explain the meaning of that activity.

This finding is consistent with Hofstein and Lunetta (2004) and Abrahams and Millar (2008) who found that the effectiveness of laboratory work is determined not by its mere execution, but by the extent to which it promotes conceptual understanding, analysis, and reflection. If laboratory lessons are focused solely on performing procedures, students may perceive them as technical activities without fully understanding the logic of the work. Our results also showed that students' deep learning approaches are also strengthened when the quality of laboratory lessons is high. This suggests that the laboratory environment in chemistry has not only practical, but also cognitive and metacognitive potential.

Thus, parallel evaluations of lectures, seminars and laboratory classes showed that teachers generally tend to rate the quality of all forms of learning higher than students. This difference suggests that teachers and students perceive the learning process through different lenses: teachers tend to focus on content accuracy, structure, and disciplinary logic, whereas students emphasize clarity of understanding, opportunities for active participation, feedback, and workload. Similar to this result, Ümit Avcı and Fatma Kalelioğlu (2019) showed in their study that students associate the quality of learning with the practical relevance of the content, the activity of teaching methods and the use of student-centered approaches. Therefore, the difference between the assessments of the two parties should be viewed not only as subjectivity, but as an indicator that the quality of learning is a multifaceted and complex phenomenon.

Relationship Between Teaching Quality and Students' Learning Approaches: Correlation and Regression Analysis

Table 7.

Correlation Between Students' Learning Approaches and the Quality of Teaching Formats

Learning approach	Lecture quality	Seminar quality	Laboratory quality
Deep learning approach	0.573***	0.551***	0.595***
Strategic learning approach	0.615*	0.605*	0.618****
Surface learning approach	-0.021	-0.023	-0.073

*The asterisks in the table indicate the statistical significance of the correlation coefficients (*p < 0.05, **p < 0.01, ***p < 0.001).*

Correlation analysis showed that deep and strategic learning approaches were positively and statistically significantly related to the quality of all teaching formats (Table 7). The highest relationship was observed between the strategic learning approach and the quality of laboratory lessons. On the other hand, the surface learning approach was not significantly related to the quality of teaching formats. This result indicates that learning approaches are a phenomenon that is formed not only by the intrinsic characteristics of the individual student, but also by the quality of the learning environment. Theobald (2020) showed that teaching approaches and learning approaches are interconnected, and that a student-centered and comprehension-oriented learning environment encourages deep learning approaches. Our study confirms this finding in the context of chemistry teacher training. If lectures, seminars and laboratory lessons are organized in a quality manner, students are also more likely to use meaningful and goal-oriented learning strategies.

Table 8.

Results of Multiple Regression Analysis to Predict Students' Learning Approaches

Predictors	Surface learning approach B	p	Strategic learning approach B	p	Deep learning approach B	p
Lecture quality	0.062	.716	0.301	.009	0.271	.014
Seminar quality	0.340	.168	0.027	.872	-0.184	.244
Laboratory quality	-0.458	.052	0.311	.049	0.477	.002

Table - 8.1.

Multiple Regression Model Fit Indices (R and R^2)

Model indicators	Surface learning approach	Strategic learning approach	Deep learning approach
R	0.148	0.642	0.613
R^2	0.022	0.412	0.376

Multiple regression analysis allowed us to predict the formation of students' learning approaches through the quality of different teaching formats. The results showed that the quality of lectures, seminars, and laboratory classes affects students' learning approaches to varying degrees.

For the deep learning approach, the model explained 37.6% of the variation in students' learning behavior ($R^2 = 0.376$). In this case, the strongest predictor was the quality of laboratory classes (B = 0.477, p = .002). In addition, the quality of lectures also had a statistically significant effect on the deep learning approach (B = 0.271, p = .014), while the effect of seminar classes was not significant (p = 0.244).

For the strategic learning approach, the model explained 41.2% of the variation in students' learning behavior ($R^2 = 0.412$). The results showed that lecture quality (B = 0.301, p = .009) and laboratory quality (B = 0.311, p = .049) were significant factors influencing the formation of a strategic learning approach. However, the effect of seminar classes was not statistically significant (p = .872).

The regression model for the surface learning approach was very weak ($R^2 = 0.022$). This indicates that the surface learning approach of students is not significantly related to the quality of lectures, seminars, and laboratory classes.

The results of the study showed that students' deep and strategic learning approaches are closely related to the quality of teaching formats. Multiple regression analysis allowed us to further explain this relationship. The fact that the quality of laboratory classes is the strongest predictor of deep learning approaches is fully consistent with the nature of the chemistry subject. During laboratory work, the students do not just accept ready-made knowledge; students make observations, interpret results, compare errors, and draw conclusions. Such actions directly correspond to the main characteristics of the deep learning approach - semantic processing, analysis, and linking new knowledge to previous knowledge. Therefore, it is natural that the quality of laboratory classes is seen as a decisive factor in the development of the deep learning approach.

The importance of the quality of lectures and laboratory classes in predicting strategic learning is also a significant result. This means that students' planning, effective use of time, task completion, and striving for high results are closely related to the organization of the learning environment. If the learning forms are meaningful, structured, and understandable, students will also be able to organize their learning activities more systematically. In other words, strategic learning can be viewed as not only a student's personal discipline skills, but also an adaptive response to a well-organized learning environment.

The weak regression model for the surface learning approach showed that this strategy is not directly explained by the quality of lectures, seminars and laboratory classes. This suggests that other factors – for example, low personal motivation, a focus on assessment, lack of time or already established learning skills – may be more important in the emergence of the surface learning approach. Therefore, reducing the surface learning approach should not be limited to improving the quality of classes; it requires a complex set of measures, such as revising assessment requirements, optimizing the learning load and developing students' metacognitive skills.

Overall, the results of the study showed that there is a systematic relationship between the quality of teaching methods and teaching formats in chemistry teacher training programs. In particular, the quality of laboratory classes was found to have a strong influence on the development of students' deep and strategic learning approaches. This finding is consistent with research showing that the outcomes of laboratory training encompass multiple learning domains. In particular, laboratory training contributes to the development of higher-level cognitive skills, including metacognitive and argumentative skills, especially in the context of problem-based learning and research-based experiments (Agustian, 2025). This result suggests that in improving chemistry teacher training programs, laboratory classes should be considered not only as a place for building technical skills, but also as a key pedagogical environment for developing semantic understanding, data analysis, reasoning, and professional thinking. In addition, strengthening the content consistency, interactivity, feedback, and reflection in lectures and seminars will allow students to develop deep and strategic learning approaches more sustainably.

Limitations of the study. This study has several limitations. First, the data are based on self-reported questionnaires from students and teachers, and therefore responses may be biased by the subjective perceptions of the participants. Second, the number of teachers participating in the study was relatively small, especially for seminar classes (n = 3), which requires some caution in interpreting the results. Third, the study was conducted in the context of higher education institutions in Kazakhstan, and therefore direct generalizability of the results to other countries may be limited. Future studies, including larger sample sizes and the use of qualitative methods (observation or interviews), could provide a more in-depth understanding of the relationship between teaching methods and teaching quality.

Conclusion

The results of the study revealed that strategic and deep learning approaches are relatively dominant among students studying in the "Chemistry Teacher Training" educational program at the participating higher education institutions, while the surface learning approach is used to a lesser extent.

It was found that students and teachers have different evaluation criteria for assessing the quality of education. Students assessed the quality of education mainly through the clarity of the material, the possibility of active participation, the availability of feedback, and the convenience of the learning load. For them, interesting, interactive lessons and the connection of theory with practice were important. Teachers, on the other hand, assessed the quality of education in terms of the scientific validity of the content, the

consistency of its structure, its compliance with educational objectives, and its subject logic. This difference indicates that the quality of education is not limited only to the content, but is also a multifaceted phenomenon directly related to the student's learning experience.

Correlation and regression analyses demonstrated a clear relationship between students' learning approaches and the quality of teaching formats. Deep and strategic learning approaches showed a statistically significant positive relationship with the quality of lectures, seminars, and especially laboratory classes. The quality of laboratory classes was found to be the strongest predictor of deep learning approaches, while the quality of lectures and laboratory classes played an important role in predicting strategic learning approaches. In contrast, the surface learning approaches were not significantly associated with the quality of teaching formats. This result suggests that laboratory and active learning formats in chemistry teaching are more conducive to students' meaningful understanding of the material, analysis, and purposeful organization of learning activities.

In this regard, in order to improve the quality of teaching in the chemistry teacher training program, it is necessary to pay attention to several areas. First, it is important to strengthen the content connection between lectures, seminars and laboratory classes. Second, it is necessary to expand interactive methods based on discussion, explanation, reasoning and active participation in seminar classes. Third, it is necessary to systematically develop students' skills in analyzing results, interpreting data and drawing reasonable conclusions in laboratory classes. Also, strengthening feedback and reflection in the teaching process, providing structured and understandable material will allow students to consistently develop deep and strategic learning approaches.

Conflicts of Interest Statement.

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Author Contributions

All authors contributed equally to the conception, development, analysis, and preparation of the manuscript. All authors have read and approved the final version of the article.

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FEATURES OF USE OF INTERACTIVE METHODS AND CAPABILITIES OF ARTIFICIAL INTELLIGENCE IN TEACHING THE HISTORY OF MATHEMATICS (ON THE EXAMPLE OF HIGHER EDUCATION)

Annotation: This article presents an interactive module focused on autonomous work for teaching historical elements within the university course «History and Methodology of Mathematics». The results indicate that well-structured autonomous interaction can improve both cognitive and emotional outcomes when studying historical topics related to new trends in teaching. The article describes the implementation of Artificial Intelligence (AI) - based tools for teaching fourth-year students. The learning model combines adaptive visualization, an intelligent training system (ITS), and sketch analysis using computer vision. The article presents a methodology for applying artificial intelligence to historical data. The use of interactive teaching methods increased the average student score from 5.2 to 6.4 $(p < 0.01)$. This is especially important in the training of progressive mathematics specialists.

Keywords: history of mathematics, interactive learning, artificial intelligence in education, pedagogical experiment, higher education

Introduction

The History of Mathematics in the system of training future mathematics teachers occupies a dual position. On the one hand, it is regarded as a cultural and methodological foundation of mathematical knowledge; on the other hand, in real educational practice it is often reduced to illustrative material that does not influence the formation of professional thinking. This situation is associated with the predominance of lecture-reproductive forms of instruction and the insufficient development of interactive methodologies for working with historical-mathematical sources.

The current stage of higher education development is characterized by increasing demands for research-oriented teacher preparation, the development of critical thinking, and digital literacy. Under these conditions, it becomes necessary to reconsider the role of the History of Mathematics as a discipline that forms methodological culture and the ability to analytically comprehend mathematical ideas.

The issue of pedagogically grounded use of artificial intelligence technologies becomes particularly relevant. Although their potential is actively discussed in academic circles, there are still no well-developed models integrating interactive methods and AI support in teaching the History of Mathematics without replacing students' independent intellectual activity.

Therefore, the purpose of this study is to develop and experimentally test an interactive model of teaching the History of Mathematics with elements of AI support in the context of higher education.

Research methods and organization

The modernization of higher education is closely related to the digital transformation of pedagogical practices and the integration of interdisciplinary knowledge. In this context, the history of mathematics plays a significant role in the professional training of future mathematics teachers and researchers.

Historical-mathematical education is considered as a means of forming a holistic understanding of mathematics as a developing system of knowledge. The inclusion of historical material contributes to understanding the genesis of mathematical concepts, development of proof-based thinking, formation of scientific reflection, strengthening interdisciplinary connections (Jankvist, 2009).

However, traditional lecture-centered approaches often reduce historical material to descriptive narration. Such presentation does not ensure students' engagement in analytical activity. In contrast,

interactive methods allow students to reconstruct the logic of scientific inquiry and actively interpret historical sources.

At the same time, artificial intelligence technologies create new opportunities for structuring educational content, modeling historical processes, and supporting students' cognitive activity. Nevertheless, most existing studies focus on automated assessment or content generation, while the use of AI as an analytical support tool in humanities-mathematical disciplines remains insufficiently explored.

The proposed model is based on the principle of the auxiliary role of AI. Artificial intelligence is viewed not as a source of ready-made solutions but as an instrument for structuring material, modeling discussion, and visualizing conceptual development. Modern theory regarding the use of the history of mathematics in the educational process is undergoing qualitative changes under the influence of new pedagogical paradigms and digital technologies. In recent years, international mathematics education research has identified several key directions of theoretical reflection:

The historical - mathematical context is no longer viewed merely as an illustration of «great figures and discoveries», but as a tool for understanding what mathematical knowledge is and how it develops. This corresponds to contemporary approaches to epistemological learning, in which students learn to perceive mathematics as a dynamic, conceptually evolving system rather than a fixed set of axioms and procedures.

When teaching basic mathematical laws, elements of the history of mathematics are used as a tool for developing the competence of proof and argumentation. Our research shows that incorporating historical evidence, alternative reasoning, and discussions from the history of mathematics can greatly enhance students understanding of the logical structure of mathematical terminology.

Through these approaches, students develop the ability to critically evaluate different arguments, compare different methods, and construct their own mathematical justifications. Modern scientists especially emphasize that studying the history of mathematics increases students cultural awareness by connecting mathematical ideas with philosophy, the development of science and cultural traditions of different historical periods and civilizations. Such connections increase students motivation and help them perceive mathematical knowledge within a broader intellectual and cultural framework.

From a poststructuralist and cognitive perspective, the history of mathematics can be interpreted as a series of conceptual contradictions and their subsequent resolutions, reflecting the gradual development of mathematical thought. This perspective identifies the cognitive challenges that students often face when working with abstract mathematical concepts.

Latest theories emphasize that working with historical sources and reconstructing discoveries promotes model-based reasoning. Students do not just absorb ready-made knowledge; instead, they reconstruct historical models, compare them, and test alternative interpretations – activities directly related to research-oriented learning.

With the appearance of digital learning environments, the theory of using the history of mathematics has expanded into the field of digital epistemology. Interactive simulations, digital reconstructions of proofs, online archives, and repositories of primary sources are becoming central rather than auxiliary components of the educational process.

In this context, AI support is viewed not as a replacement for students' competencies, but as a mediator that helps model historical thinking and structure knowledge.

Research suggests that integrating historical demonstrations, alternative forms of reasoning, and notable debates from the development of mathematics can strengthen students' comprehension of the logical foundations underlying mathematical arguments. This approach encourages learners to evaluate reasoning critically, examine different problem-solving strategies, and develop their own well - grounded explanations.

Many modern researchers also argue that the study of the historical development of mathematics broadens students' cultural understanding. By connecting mathematical concepts with philosophical ideas, the evolution of scientific thought, and the cultural contexts of various civilizations and time periods, students become more engaged and are better able to recognize mathematics as part of a wider intellectual tradition.

From the perspectives of poststructuralist and cognitive theories, the evolution of mathematics may be viewed as a chain of conceptual disagreements followed by their resolution, illustrating how mathematical

thinking has progressed over time. Such an interpretation helps reveal the mental difficulties learners may encounter when trying to grasp complex and abstract mathematical ideas.

Literature Review

Research in the methodology of teaching the history of mathematics highlights its importance for developing conceptual understanding and professional culture. Historical knowledge contributes to the formation of mathematical worldview and epistemological awareness (Jankvist, 2009; Strohmaier et al., 2025).

Interactive approaches such as problem-based learning, dialogical teaching, case analysis, and project-based tasks are recognized as effective tools for fostering deep learning. In historical-mathematical education, these methods allow students to reconstruct mathematical discoveries and understand the evolution of ideas.

Recent studies on artificial intelligence in education demonstrate its potential in adaptive learning, feedback systems, and data analysis (Zawacki-Richter et al., 2019). However, its application in humanitarian and mathematical education, including the History of Mathematics, requires further methodological development.

Researchers also emphasize the risks of uncritical AI use in academic contexts. Therefore, pedagogically grounded models ensuring academic integrity and independent thinking are especially important.

Modern research on the methodology of teaching the history of mathematics underscores its role in developing conceptual understanding, epistemological awareness, and professional culture in mathematics education. Historical perspectives enable students to perceive mathematics as an evolving, culturally embedded system of knowledge rather than a static collection of axioms and procedures - a view supported by contemporary epistemological learning frameworks. Such perspectives align with the goals of mathematical literacy, reflective thinking, and methodological reasoning (e.g., problem framing and model-based reasoning) as central competencies for future teachers and researchers.

Interactive pedagogical approaches - including problem-based learning, dialogical seminars, case analysis, and project-based tasks are recognized as effective strategies for promoting deep learning and analytical engagement. In the context of historical-mathematical education, these methods allow students to reconstruct seminal mathematical discoveries and understand the evolution of core mathematical ideas through inquiry-oriented activities.

Recent developments in educational research highlight the integration of Artificial Intelligence (AI) and digital technologies as an emergent dimension in mathematics and history of mathematics pedagogy. AI tools hold potential for adaptive learning, feedback systems, learning analytics, and structured conceptual visualization (Hwang et al., 2020). For example, research on teacher adoption of AI in mathematics education integrates theoretical models such as the Technology Acceptance Model (TAM) with technological pedagogical content knowledge (TPACK), demonstrating factors that influence effective integration of AI tools in teaching practice.

However, the methodological application of AI in humanities-mathematical domains, including the history of mathematics, remains underdeveloped. Contemporary studies emphasize the necessity of pedagogically grounded models that ensure academic integrity, promote independent student reasoning, and avoid uncritical dependence on automated outputs. Recent bibliometric research highlights emerging themes in AI and educational assessment, including the risks of bias, transparency, and ethical concerns associated with AI-assisted evaluation.

Moreover, international research on AI in mathematics education points out both opportunities and challenges in adopting AI technologies including ethical issues, the need for professional development, and infrastructure readiness underscoring that effective AI integration depends on teacher preparedness and contextual adaptation.

In this theoretical landscape, the history of mathematics plays a dual role: it informs epistemological frameworks for understanding mathematics and provides a context for critical reflection on the nature of mathematical knowledge. Philosophical foundations of mathematical pedagogy increasingly emphasize inquiry, reflexivity, and interdisciplinary integration -approaches that are supported by interactive and AI-

enhanced teaching models (Chalaune & Subedi, 2020; Honey et al., 2014; Kossybaeva et al., 2022; Sharafeeva, 2022; Shurygin et al., 2024). Additionally, research on model-based reasoning and problem framing in AI-augmented educational settings suggests that technology can facilitate students' engagement with complex conceptual structures while preserving space for human interpretation and scholarly dialogue.

Methodology

Interactive approaches to teaching the history of mathematics involve students directly in the reconstruction of mathematical concepts and historical discoveries, shifting the learning process from passive absorption of information to active analysis and reflection. Through guided workshops, project-based research, and reconstructions of historical reasoning, students strengthen their critical thinking, argumentative abilities, and methodological awareness by working with primary historical sources and exploring the logical organization of mathematical proofs.

This approach also promotes interdisciplinary connections and creative mathematical thinking by inviting students to consider and model alternative historical interpretations and hypotheses. The incorporation of digital technologies and artificial intelligence tools further supports the learning process by improving visualization, structuring historical information, and simulating intellectual discussions. At the same time, these tools function as cognitive aids rather than substitutes for students' independent analytical work.

As a result, this methodology enhances students' motivation, autonomy in learning, and deeper understanding of historical and mathematical concepts. It also contributes to the preparation of future teachers capable of engaging in research-oriented, reflective, and methodologically informed professional practice. The research design of the study relied on pedagogical modeling in combination with a formative experimental approach. The choice of the undergraduate level is justified by the fact that this stage is crucial for the formation of professional conceptions of mathematical knowledge and its historical development.

The research included three interconnected stages:

Analytical stage. Examination of existing teaching practices, identification of methodological challenges, and review of international approaches integrating interactive methods and AI in mathematical education.

Modeling stage. Development of an interactive AI-supported pedagogical model, grounded in epistemological principles and reflective learning frameworks, incorporating historical-mathematical content, interactive methods, and AI-assisted cognitive tools.

Experimental stage. Implementation of the model in the educational process and assessment of its effectiveness over one academic semester.

Two groups of undergraduate students were formed. Control group included traditional lecture-seminar instruction, and experimental group comprised interactive learning with AI support.

Both groups studied identical thematic modules Mathematics of antiquity, classical period, formation of analysis and analytic geometry, development of modern mathematical concepts.

The total number of participants ensured representativeness for pedagogical research, and students were selected to maintain comparable academic backgrounds.

The model integrates three main components:

1) Historical-mathematical content is structured around key conceptual developments, primary sources, and historical debates. This aligns with epistemological learning, helping students understand mathematics as a dynamic, evolving system.
2) Interactive teaching methods – including problem-based learning, dialogical seminars, case analysis, and project-based tasks to foster analytical thinking and methodological reflection.
3) AI-assisted tools – used as cognitive and organizational support, not as a replacement for independent reasoning.

AI functions included Generation of historical problem situations; Simulation of dialogues between mathematicians from different epochs; Visualization of the evolution of mathematical concepts; Support for analysis and interpretation of historical texts; Modeling alternative hypotheses and reasoning pathways.

This design is grounded in model-based reasoning theory and digital epistemology, which support research-oriented and reflective learning. Within this framework, students are encouraged to analyze

historical mathematical developments not only as a sequence of facts, but as a process of conceptual formation, interpretation, and argumentation.

Historical case analysis is used as one of the key instructional methods. It involves the structured examination of important episodes in the history of mathematics through primary sources and guided discussion questions. This allows students to understand the historical context of mathematical discoveries and the intellectual logic behind their development.

Dialogical seminars are also integrated into the model. During these seminars, students reconstruct historical mathematical arguments, evaluate alternative interpretations, and participate in peer discussion. This format helps develop critical thinking, argumentation skills, and the ability to compare different perspectives on the evolution of mathematical ideas.

Another important method is the reconstruction of discoveries. Students simulate original reasoning processes using historical sources and modern symbolic tools. In this process, AI can be used to generate intermediate steps, suggest alternative solutions, and support the visualization of reasoning pathways, while students remain responsible for independent interpretation and critical evaluation.

Project-based tasks further strengthen students' analytical and research skills. Students prepare mini-projects on specific historical figures, mathematical concepts, or stages in the development of mathematical thought. AI tools are used to organize materials and visualize conceptual connections, while students independently formulate analytical conclusions.

The effectiveness of the model was assessed across several dimensions. These included students' conceptual understanding of historical and modern mathematical ideas, methodological reflection on epistemological and cognitive processes, analytical competence in interpreting historical sources and reconstructing mathematical reasoning, academic independence in self-directed learning and argumentation, and learning motivation expressed through engagement and interest in historical-mathematical research.Data were collected through a mixed-methods research design that combined both quantitative and qualitative techniques. These included pre- and post- assessments to evaluate improvements in conceptual understanding and methodological competence, observation of seminar participation and AI-supported learning activities, analysis of students' written work and reflective essays, and expert evaluation of the quality of methodological reasoning and argumentation.

Recent studies emphasize the importance of using artificial intelligence as a tool that supports cognitive development rather than as a system that automatically generates solutions. AI-based technologies can enhance visualization, facilitate analytical support, and assist model-based reasoning, while still maintaining students' independent intellectual engagement (Hwang et al., 2020; Li & Yin, 2025; Zawacki-Richter et al., 2019).

This methodological framework also corresponds withepistemological andconstructivist perspectives on learning, which emphasize the social and reflective nature of acquiring mathematical knowledge in its historical context.

Results and Discussion

The findings of the experimental research indicate that the incorporation of interactive instructional strategies together with AI-supported tools considerably enhances the effectiveness of teaching the history of mathematics to prospective mathematics teachers. The comparison of some data the control and experimental groups revealed noticeable differences in a number of educational indicators, including the depth of conceptual understanding, analytical abilities of students, and level of methodological reflection, academic autonomy and motivational involvement of students. The results of the study are described in Table 1.

Table 1

The result of statistics

Principle	**Pre-test** $(M \pm SD)$	**Pre-test** $(M \pm SD)$	$\Delta\%$
Understanding concepts $(\max = 10)$	5.2 ± 1.3	6.4 ± 1.1	$+22\%$
Procedural skills $(\max = 10)$	4.8 ± 1.5	5.9 ± 1.2	$+23\%$
Overall satisfaction $(1-5)$	–	4.4 ± 0.6	–
$* \; p < 0.01$ **(paired t-test)**			

Compiled by the authors on the basis of a survey and testing.

According to the survey results, 86% of students stated that AI-generated visualizations helped them better conceptualize the history of mathematical terms. These visualizations improved their understanding of how mathematical concepts evolved from ancient Greek geometry to modern methods, including the use of integral calculus for calculating volume.

In addition, 71% of students reported that the prompts provided by the intelligent tutoring system were consistent with modern pedagogical approaches. In particular, students noted that the system supported learning through minimal intervention while encouraging learner autonomy and independent reasoning.

Furthermore, 79% of respondents expressed their willingness to recommend the AI-assisted learning club to their peers. This indicates that the integration of AI into the study of classical mathematical concepts and historical theoretical statements was perceived by students as both useful and engaging.Students who participated in the experimental group displayed a more comprehensive and integrated understanding of the historical evolution of mathematical ideas than those in the control group. The post-test assessment showed that these students were more capable of explaining the emergence of fundamental mathematical concepts, such as calculus and analytic geometry, and relating them to contemporary mathematical theories. This result corresponds with recent studies suggesting that interactive approaches to teaching mathematical history promote deeper conceptual learning and systemic reasoning. In particular, the experimental group demonstrated a statistically significant improvement $(p < 0.01)$in the combined indicators of conceptual understanding, indicating that interactive activities supported by AI tools help students construct coherent and interconnected knowledge frameworks.

Analysis of reflective essays and seminar discussions also revealed a higher degree of epistemological awareness among students in the experimental group. Rather than simply reproducing chronological information, these students described the processes through which mathematical knowledge developed, examined the historical circumstances surrounding discoveries, and reflected on the cultural and philosophical factors influencing mathematical thought. These observations align with theoretical perspectives that regard the history of mathematics as a powerful instrument for developing reflective thinking and shaping students' understanding of the nature of mathematical knowledge.

The results also present that active historical learning encourages students to perceive mathematics as a dynamic and evolving intellectual discipline.

Moreover, students in the experimental group showed stronger abilities in interpreting and analyzing historical mathematical documents. By studying primary sources, including translated Greek and medieval Arabic manuscripts, they were able to place mathematical arguments in historical context and provide reasoned explanations of their underlying logic. The integration of AI-generated modeling and visualization has facilitated the reconstruction of historical arguments, promoting model-based reasoning and analytical interpretation. These results suggest that artificial intelligence tools, used as cognitive supports rather than answer generators, can affectively help students overcome barriers to interpreting complex mathematical narratives.

AI support appeared to promote academic independence without undermining analytical activity. Students in the experimental group engaged in independent exploration of historical problematic situations,

developed alternative hypotheses about historical events, and critically evaluated AI-generated visualizations. These behavioral patterns reflect contemporary definitions of independent intellectual activity in AI-enriched environments (Alkhasawneh, 2025; Hwang et al., 2020) and suggest that appropriate pedagogical presentation of AI can enhance autonomy rather than reduce engagement.

Qualitative data obtained from student observations and self-reports revealed increased interest and motivation in the experimental group. Students frequently noted that AI-assisted visualizations made abstract historical sequences more accessible and engaging - a finding consistent with research on the motivational capabilities of interactive and digital learning tools. Furthermore, this visualization connected students' historical mathematical elaborations to a broader cultural, philosophical, and scientific context, enriching interdisciplinary learning and supporting broader educational goals.

The results of this study confirm that interactive teaching methods combined with AI-enabled tools create a dynamic learning environment that improves both cognitive and affective educational outcomes. These results are consistent with theoretical expectations emerging from several contemporary research streams:

Epistemological Frameworks for Learning: Students' ability to articulate how mathematical knowledge develops reflects contemporary views that positioning historical material as an epistemic resource deepens conceptual understanding.

Based-of-Model Thinking and Digital Epistemology: Using artificial intelligence tools helped students visualize conceptual transitions and explore alternative reasoning pathways, consistent with the new idea of digital epistemology, where technology mediates complex conceptual understanding.

Conclusion

Nonetheless, the study underscores the necessity for clear methodological guidelines when integrating AI into the educational process. There have been cases of uncritical acceptance of AI results with minimal teacher involvement. This supports broader evidence that AI tools are most effective when they are embedded in structured pedagogical activities that foster critical assessment and reflective thinking.

Despite the promising results, several limitations should be consideration:

Institutional context: The research was conducted at a single university, which may restrict the generalizability of the results. Future research should utilize multi-center studies in different educational contexts.

Duration of intervention: The experiment spanned one academic semester. Longer-term studies could better assess the sustained impact on professional competencies.

Qualitative depth of interaction with AI: Although quantitative improvements were evident, in-depth analysis of discourse and reasoning patterns during interaction with AI (e.g., dialogue transcripts or decision logs) remains an area for future research.

Future research should explore adaptive AI systems tailored to individual learner profiles, explore the ethical framework for using AI in history and the humanities, and further explore how AI can support higher-order thinking without reducing learner autonomy.

Conflicts of Interest Statement.

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

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Akhmanova D.M. - Conceptualization, Methodology, Supervision, Proofreading.
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Kossybaeva U.A. - Literature Review, Data Analysis, Final Editing.
Kervenev K.Ye. - Visualization, Writing –Original Draft
Orazbekova R.A. – Validation, Writing–Reviewand Editing

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INTEGRATION OF THE INFORMATION SYSTEM "QUALITY MANAGEMENT OF HIGHER AND POSTGRADUATE EDUCATION" WITH RELATED SYSTEMS

Abstract. This article focuses on developing and testing a model to integrate the information system "Quality Management of Higher and Postgraduate Education" with related university and government digital systems. The purpose of the study is to develop an architectural and functional model for intersystem interaction to ensure automated data exchange between internal university subsystems and the Unified Higher Education Platform. Pilot implementation confirmed the integration solution's ability to transmit data on academic staff, students, educational programs, international activities, and research publications. Common errors in authentication, request formation, and data validation were identified, along with areas for improvement in interface design, navigation, and processing speed for large data sets. The findings show that integrating the quality management information system with interconnected digital platforms enhances the reliability, coherence, and managerial value of educational data. The practical significance of the study lies in the potential application of the proposed model as a foundation for developing a unified digital system for quality management in higher and postgraduate education.

Keywords: information system; education quality management; higher and postgraduate education; data integration; API; digital ecosystem

Introduction

With the rise of computer technologies, specifically automated systems in education, the effort required for data collection, preparation, and results processing has greatly decreased, enabling the creation of reliable data in a structured, timely manner.

Data reliability is significantly improved through integration with university learning management systems (LMS) and related government information systems for higher education administration.

University LMS platforms support data entry and management regarding students, staff, educational program content, teaching and research infrastructure, and overall institutional resources. Particularly, student information systems store student data, organize learners by educational programs, and align them with relevant curricula. Academic performance management systems automate monitoring and evaluating student achievement based on rating-based assessment frameworks. Additionally, testing systems help assess students enrolled in universities across various disciplines included in the curriculum.

Recent studies see the integration of information systems in education not just as a technical task of data exchange between separate platforms, but as a vital part of the broader digital transformation of educational institutions. Within this perspective, integration includes connecting learning management systems (LMS), student information systems (SIS), analytical modules, learning assessment services, and administrative platforms. The literature shows that the digital transformation of universities progresses by a gradual merging of previously separate solutions; however, the sustainability of such transformation relies not only on technological infrastructure but also on process maturity, organizational coordination, and data quality (Fernández et al., 2023; Mijač et al., 2024). At the same time, a major limitation in existing research is that, while digitalization is discussed broadly, less attention is paid to the architectural mechanisms of integration, including APIs, interoperability, reference data synchronization, and master data management.

This article will attempt to address this gap by focusing on the integration of the information system "Quality Management of Higher and Postgraduate Education" with internal university and external governmental platforms. The main research question guiding the study is: How can API-based integration of

quality management information systems enhance data reliability and support managerial decision-making in higher education?

The contribution of this study is threefold. First, it proposes an architectural and functional model for intersystem interaction based on API-based data exchange. Second, the findings present a pilot implementation in real institutional contexts, specifically at two universities. Third, it identifies key challenges in authentication, data validation, and interface design, emphasizing the importance of data management and coordination.

Literature review

A significant body of research has examined the integration of student information systems (SIS) with related university services. Many studies consider SIS the foundational infrastructure of digital university governance, supporting the management of student groups, academic performance, faculty workload, and administrative tasks. Empirical studies (Çelik & Ayaz, 2022; Daim et al., 2024; Mazadu et al., 2022) show that the success of SIS implementation depends not only on system functionality but also on information quality, usability, service quality, and levels of organizational support. An important counterpoint is that even a well-designed system does not automatically generate integration impacts: without process alignment and high-quality input data, informational interconnectedness remains superficial rather than meaningfully useful.

A specific area of research examines learning management systems (LMS) as a vital part of the digital educational infrastructure. Recent studies show that LMS are increasingly seen not just as standalone e-learning platforms but as inseparable components of a larger integrated system that includes analytics, assessment, feedback tools, and administrative services. Research on the main factors influencing LMS adoption in universities highlights the significance of institutional support, technological infrastructure, and user preparedness (Alduraywish et al., 2022). Bibliometric analyses of LMS-related publications in developing countries indicate a growing interest in scalability and integrating LMS into the overall framework of digital education; however, the architectural aspects of integration remain less developed than questions of implementation and usage (Pham et al., 2022). In addition, Sayaf (2023) demonstrates that the adoption of e-learning systems in higher education relies on a combination of success factors in information systems and constructivist learning conditions, effectively linking platform integration with the quality of pedagogical design.

Contemporary literature mainly examines the integration of information systems through the lens of learning analytics. In this perspective, integration is understood as the consolidation of students' digital traces, LMS data, assessment results, course activity, and feedback into a unified analytical environment. Systematic reviews show that learning analytics is increasingly shifting from simple reporting toward decision-support ecosystems aimed at managing student engagement, self-regulation, and academic success (Bergdahl et al., 2024; Palanci et al., 2024). At the same time, studies emphasize that analytical tools yield meaningful impact only when embedded within pedagogical and organizational contexts, rather than functioning as standalone dashboards disconnected from the learning process (Drugova et al., 2024; Kleimola & Leppisaari, 2022). Thus, learning analytics can be regarded as one of the most developed mechanisms for integrating educational data, but not as a comprehensive substitute for integration itself.

Within this strand, research on learning analytics dashboards has been developing actively. A systematic review by Paulsen and Lindsay (2024) shows that contemporary dashboards are mainly focused not only on data visualization but also on supporting learning as a process. This is further supported by studies on gamified, collaborative, and AI-powered dashboards, in which the focus shifts from merely displaying indicators to interpretation, reflection, and decision support (Alam et al., 2023; Echeverria et al., 2025; Cabral et al., 2025).

At the same time, an important limitation can be identified: a substantial share of the literature focuses on the effects of already implemented solutions, while providing less detailed analysis of how these dashboards are integrated with SIS, LMS, and institutional data repositories. In other words, dashboards are often examined as pedagogical interfaces rather than as components of the university's broader enterprise information system architecture.

The findings of several studies indicate that analytical integration plays an essential role in tracking

student engagement and predicting academic success. For example, Fan et al. (2021) identify key factors influencing student engagement in the context of learning analytics in online and blended learning settings. Flanagan et al. (2022) demonstrate how behavioral data analysis can provide early warnings of risks related to declining academic performance. Kleimola et al. (2025) highlight the link between learning analytics and the development of self-regulated learning, while Candra and Jeselin (2022) expand on this research by showing that students' perceptions of digital platforms depend not just on the technical quality of the applications but also on how well they are integrated into the actual learning process. These findings are important for the study of information system integration, as they suggest that the value of data exchange between different systems lies not solely in technical connectivity but in the system's ability to support pedagogically and managerially meaningful decision-making.

Finally, broader reviews of educational technologies confirm that integrating digital tools can positively impact learning outcomes; however, the mere technological intensification of the educational environment does not, in itself, guarantee improvement. Valverde-Berrocoso et al. (2022) conclude that the effects of educational technology on student outcomes are heterogeneous and strongly context-dependent. This has important implications for research on information system integration: the central issue is not the number of platforms deployed, but the degree to which they align, interoperate, and integrate into the university's managerial cycle. The literature in this area remains unevenly developed. While topics such as adoption, user satisfaction, dashboards, and specific learning analytics interventions are relatively well explored, considerably less attention has been paid to architectural and functional models of integration that bring together LMS, SIS, quality assurance systems, and external governmental platforms into a unified digital ecosystem of education. It is precisely this gap that underscores the need for further research in this field (Mohamed et al., 2023; Fernández et al., 2023; Mijač et al., 2024).

Methods

Research Design

The study was conducted as part of applied, project-based research, including elements of design science, architectural modeling, and pilot empirical testing. This approach was chosen because the study's goal was not to describe individual digital practices but to develop, implement, and evaluate a model for integrating the information system "Quality Management of Higher and Postgraduate Education" with related university and government information systems.

The methodological framework of the study consisted of four interconnected stages. In the first stage, the problem domain was outlined, including key objects of integration and the structure of information flows. The second stage involved developing an architectural and functional model of how systems interact, focused on consolidating data from university subsystems and facilitating their transfer to the external digital platform. At the third stage, an API-based data exchange system was set up, including authentication procedures, request handling, data validation, and data updating protocols. The fourth stage involved piloting the system in real institutional settings, followed by a technical and functional assessment.

Therefore, regarding the research design, the study can be described as a pilot project centered on creating and testing an integration prototype, in which the theoretical problem was advanced to a working solution and evaluated in real institutional conditions. This increases the study's practical significance but also introduces certain limitations: the results primarily demonstrate the model's functionality and institutional relevance, rather than statistically generalizable effects for a large user base.

A key feature of the study was that the developed system was designed not as a standalone university solution but as part of a larger digital ecosystem. In this context, the pilot implementation focused on ensuring compatibility with the Unified Higher Education Platform, which serves as an external layer for national data integration. This suggests that the architectural choices in the study were intentionally made with cross-level data sharing in mind – between internal university systems and the external national higher education platform.

The focus of the study was the information system "Quality Management of Higher and Postgraduate Education," designed as an integrated core to unify fragmented data on students, academic staff, educational programs, learning outcomes, and institutional infrastructure. The system's architecture was designed to support a unified digital educational ecosystem, ensuring organized interaction between internal and external

data sources.

The technological foundation of inter-system exchange was built on an API-driven approach, allowing the automated transfer of structured data among the quality management information system, university subsystems, and the Unified Higher Education Platform. The integration process involved several consecutive steps: authenticating with access keys; creating requests with predefined parameters; sending requests to the server; server-side processing involving database interactions; generating responses; and handling results on the client side.

The pilot implementation was carried out in real operational conditions within the information systems of two universities: Astana IT University and the University of International Business. During the testing phase, both the system's technical functionality and its practical effectiveness in managing educational quality were assessed. The participating institutions used the API to send data on academic staff, students, international activities, educational programs, and research publication output. This allowed the system to be tested across various data categories that differ in structure, completeness, and update schedules.

To analyze the research results, methods such as qualitative functional analysis, descriptive technical assessment, and thematic grouping of user feedback were used. Integration errors were categorized by type, source, and API interaction phase. System activity logs were reviewed for compliance with specified performance and reliability standards. User evaluations were grouped into recurring thematic categories that highlighted both the system's strengths and areas for future improvement.

Results

II Development of the architecture of the subsystem for organizing WEB access to information resources of the software package

With the advent of computer technologies and especially with the advent of automated systems in education, the labor intensity of collecting, preparing information and processing results, obtaining reasoned data in the established manner has sharply decreased.

Increased data reliability is achieved through integration with university learning management systems (LMS) and related government higher education management systems.

The university education management system allows entering data on the students, personnel, content of educational programs, and educational, scientific, and laboratory facilities, as well as the infrastructure as a whole. Information on students is entered into the student body management system, where students are grouped by educational programs and compared with the curriculum. The academic performance system allows automating the academic performance monitoring processes based on a rating system for assessing students' knowledge. The testing system allows testing students registered at universities in the disciplines included in the curriculum.

Information about staff is available in their personal profiles, where their academic and scientific portfolio, personal achievements are entered, with a connection established with their workload and schedule.

Data on educational programs implemented in universities on a national scale are concentrated in the Register of EPs of Higher and Postgraduate Education (goal, objectives, learning outcomes and a list of disciplines with a description). More detailed information on EPs with a detailed curriculum is in the HEIs training management system with a link to individual curricula of students, the Catalog of disciplines.

Detailed information on the university infrastructure is available in the HEI management system (educational areas, laboratory facilities, computer equipment and its administration systems, technical characteristics and capacities, residential areas, etc.).

All data must be connected in the digital ecosystem of the HEI and transferred to the Unified Platform of Higher Education (UPHE). The digital ecosystem of universities is managed through different levels of data administration, where the roles and level of access of each participant in the educational process are determined.

When transferring data, their correctness is checked for each direction and their affiliation. Then the data is automatically exported to the system.

Thus, the data transfer procedure can reveal quite a lot of incorrect data that is not directly related to

its purpose. The data updating procedure involves automatic correction of some data when changes are detected in other data. To perform the data updating procedure, the IS uses a generalized repository that describes the relationships between different DBMS, programs, components and ensures the efficiency of IS management.

Transferring data via API

To ensure the integration of the information system "Quality Management of Higher and Postgraduate Education" with other systems, such as accounting systems for teachers, students and university infrastructure, an API was developed and used (https://hedu.kz/api/swagger/#/).

API allows you to automate data exchange processes, ensuring fast and efficient transfer of information between systems.

The process of transferring data via API includes the following steps:

1) Authentication: Data transfer begins with authentication in the system using API keys to ensure security and limit access to authorized users only;

2) request formation: the user or application creates a request to the API, specifying the necessary parameters and data to be transferred;

3) sending a request: the generated request is sent to the server where the API is running, using standard communication protocols;

4) Request processing: the API server receives the request, analyzes it and performs the necessary actions, including accessing the database or other data sources;

5) generating and sending a response: after processing the request, the server generates a response containing the requested data or the results of the operation and sends it back to the client;

6) receiving and processing the response: the user receives a response from the server and processes the received data in accordance with the application logic.

Errors and their identification

During testing of the information system using the API, the following errors were identified:

1) Authentication error: Incorrect transmission or use of authentication data resulted in API access being denied or incorrect data being received;

2) Query generation error: An incorrect query generation caused the API server to misinterpret the request and return incorrect results;

3) Data validation error: Incorrect or incomplete data passed through the API resulted in errors during server-side processing.

To eliminate these errors and ensure more stable and reliable operation of the information system, thorough API testing was carried out at all stages of development, and its operation was regularly monitored during operation.

Data transmitted

During the testing of the information system "Quality Management of Higher and Postgraduate Education" on experimental sites of universities in Kazakhstan, it was revealed that universities actively use API to transfer various information. Volumes of data transferred via API:

- information about teachers:

1) personal data of teachers (full name, contact information, qualifications and work experience);

2) information on the admission of teachers to advanced training courses and academic programs;

3) information about foreign teachers;

4) information on the mobility of teachers;

- information about the university's international projects:

1) information on current international agreements with foreign educational organizations;

2) information on participation in international scientific projects with foreign organizations;

3) information about branches/representative offices abroad and foreign universities;

4) information on participation in international educational projects with foreign organizations;

5) the number of publications in Scopus and Web Of Science by field of activity;

- information about students:

1) personal data of students (full name, contact information, date of birth);

2) information on admission, education and graduation of students;

3) information on the current academic performance of students, including grades and attendance;

4) participation of students in international exchanges and academic mobility projects.

Identified problems and suggestions

During testing, the following problems and suggestions for their elimination were identified:

- problems with data display:

1) in some reports the data was displayed incorrectly, which required additional checks and corrections;

2) the ability to manually enter and correct data in reports was added;

- delays in loading data:

1) there were periodic delays when loading large amounts of data;

2) it was recommended to optimize data processing algorithms and improve server performance;

- interface improvements:

1) users suggested adding additional filters and settings to the information display interface;

2) It was suggested to improve navigation through the system and make it more intuitive.

System activity logs

Analysis of system activity logs during the testing period showed stable operation of the IS. The average system response time was 200-300 ms, which corresponds to the stated requirements. Minor system failures were identified and promptly eliminated.

User Reviews

Users who participated in the testing provided the following feedback and suggestions:

- positive reviews:

1) convenient and intuitive interface;

2) broad opportunities for managing educational programs and monitoring the quality of education;

3) high performance and stability of the system;

- suggestions for improvement:

1) adding additional settings and filters;

2) optimization of data loading speed;

3) improved navigation through the system and simplification of some functions.

The use of advanced software technologies in the development of the Smart University system and the modern level of communications development allow for prompt access to system data via the Internet or the corporate network of universities.

When providing WEB access to an existing DB, a number of ways are possible – complexes of technological and organizational solutions. The practice of using WEB technology to access an existing DB provides a wide range of technological solutions, interconnected in different ways – overlapping, interacting, etc. The choice of specific solutions when providing access depends on the specifics of a particular DBMS and on a number of other factors, such as: the availability of specialists capable of mastering a certain branch of technological solutions with minimal costs, the existence of other DBs, WEB access to which should be carried out with minimal additional costs, etc.

The implementation of corporate information systems based on the Internet/Intranet architecture is based on the principle of "open architecture", which allows for a corporate system implementation that is quite independent of a specific manufacturer. All software for such systems is implemented in the form of applets or servlets (programs written in the JAVA language), or in the form of CGi modules (programs written, as a rule, in Perl or C, C++).

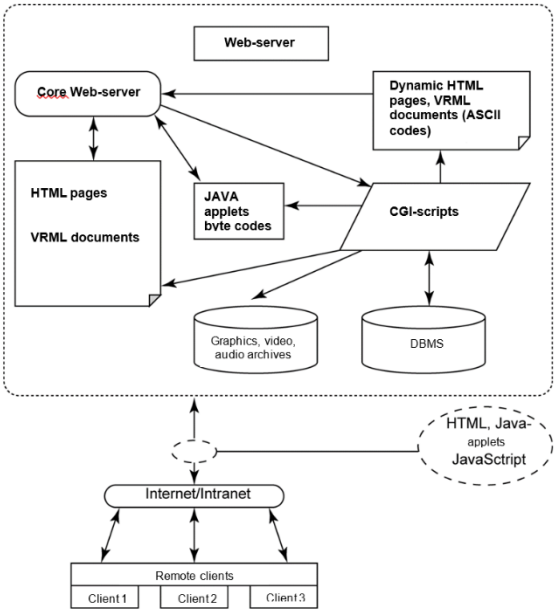
The main economic advantages of such architecture include: relatively low costs of implementation and operation; high ability to integrate existing information resources of corporations; increased level of efficiency of equipment use; availability of application software from any workstation with appropriate access rights; minimum composition of software and hardware at the workstation; minimum costs of setting up and maintaining client workstations, which allows implementing systems with a very large number of users.

The traditional client-server scheme is simple: the client sends requests, and the server responds. Because the client and server are different computers, they are able to split (or divide) the computing load, allowing work to be done more quickly. Figure 1 shows a functional diagram of user interaction in an

Internet/Intranet architecture.

Figure 1

Functional diagram of interactive user interaction in the Internet/Intranet architecture



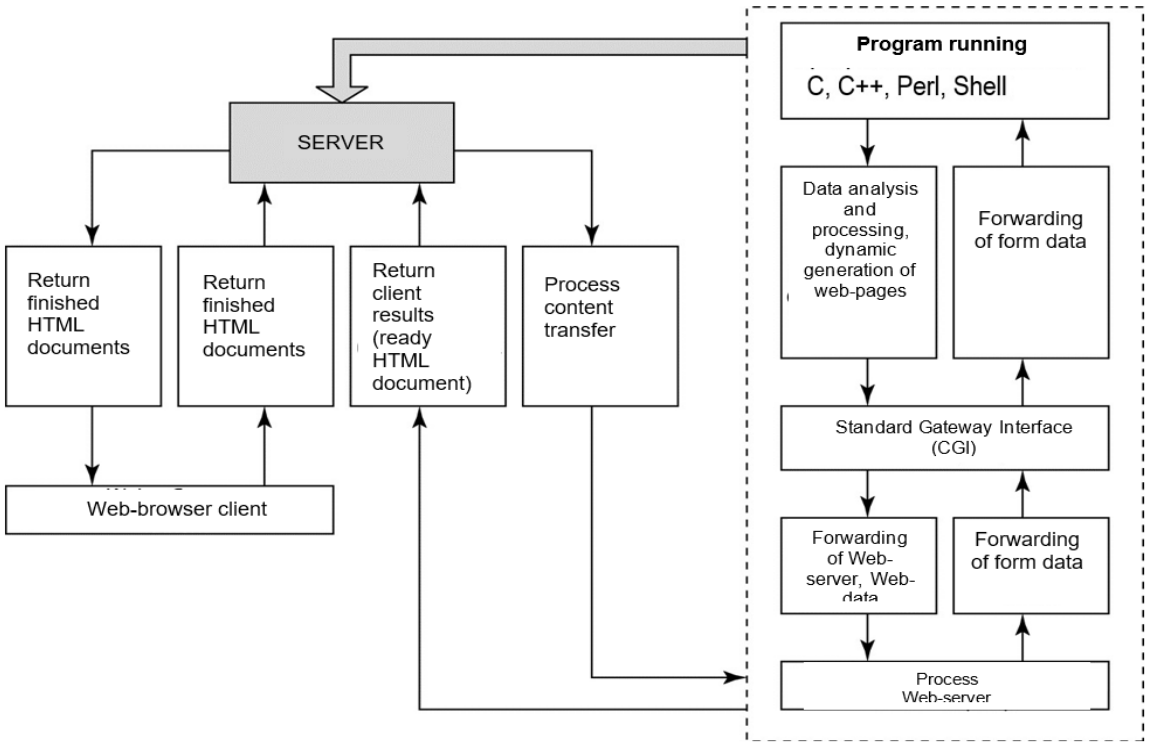
At the client's

- sends ASCII codes of HTML pages (or VRML documents), JavaScript elements;
- sends images, audio, video archive files, etc.;
- sends byte codes of JAVA applets;
- receives information from the user (the result of filling out an active form or statistical information requested by a CGI script);
- fills the database;
- receives notifications from the user and regulates access to the WEB site resources;
- depending on the user's information, dynamically generates HTML pages or VRML documents, accessing, if necessary, databases and existing HTML pages and VRML documents on the WEB site. Figure 2 shows the interaction diagram between the browser, server, and CGI script.

The client, after receiving a response from the WEB server, does the following:

- visualizes an HTML page or VRML document in the browser window;
- interprets Javascript commands, modifies the image of an HTML page, etc.;
- by interpreting byte codes of Java applets, it allows loading and executing active applications;
- maintains a dialogue with the user filling out forms and creates new requests to the WEB server;
- with the help of utilities, reproduces codes of audio and video files, supports multimedia tools;
- provides virtual reality simulation by viewing VRML documents.

Figure 2
Simplified diagram of interaction between browser, server and CGI script



When a client interacts with a program running on a WEB server, the sequence of steps shown in Figure 3 is performed.

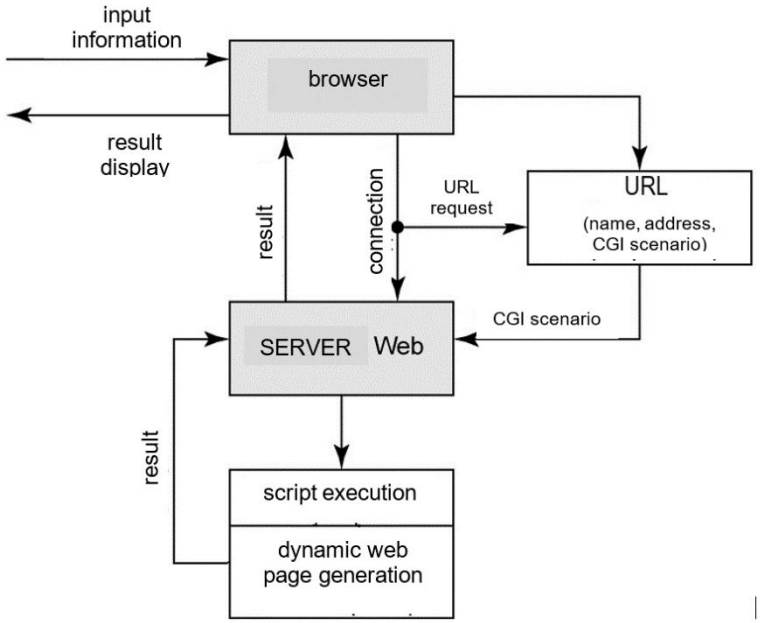
The listed tasks of the WEB client are provided by the capabilities of the browser and specialized software (utilities) located on the client's workstation.

In the implementation of client software, “applets” have great potential – programs written in Java, an object-oriented language, or more precisely, programming technology, originally designed for integration with a WEB service and use in a network environment.

In addition to integration with the WEB-navigator, a virtual Java-machine (JVM) was specified, on which Java-programs, certain architectures, data element representations and the Java-machine command system should be executed (interpreted). The initial Java-texts are translated into the codes of this machine. Consequently, with the advent of a new hardware-software platform, only the Java-machine will be "impressed" in import; all applications written in Java will go without changes. In addition, it was determined that when editing external links of a Java-program and when working with the WEB-navigator, a search for necessary objects can be performed transparently for the user not only on the local machine, but also on other computers accessible via the network (in particular, on the WWW-server). The discovered objects are loaded, and their methods are then executed on the user's machine.

Figure 3

Sequence of actions during interaction between a client and a program running on a WEB server.

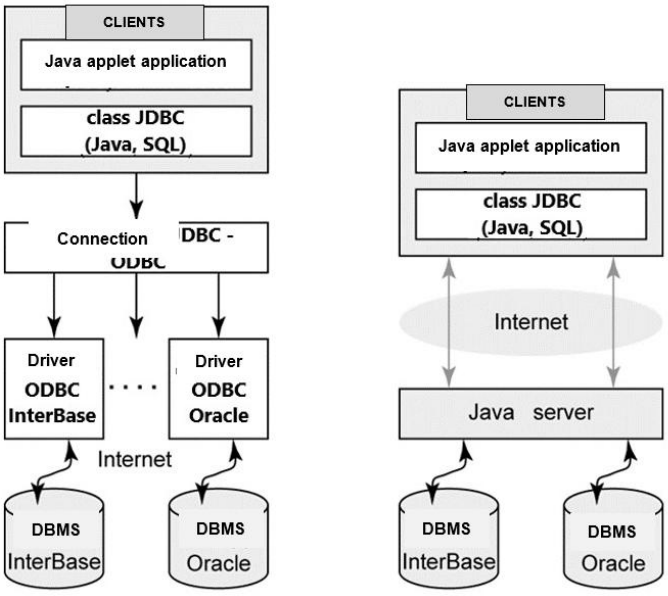


This makes clear the most important advantage - zero cost of administering client systems written in Java. It is enough to update the version of the object on the server, after which the client will automatically receive the new version, not the old one.

Being modular, applets must receive information from data storage devices, process it, and write it back for further processing by other applets. Monolithic programs can afford to have their own data processing schemes, but Java applets, which cross the boundaries of operating systems and computer networks, need to publish open data access schemes. Therefore, standard relational data access is important for Java programs, the first option of which is the JDBC (Java Database Connectivity) interface. Figure 4 shows the options for implementing JDBC communication with a database.

Figure 4

Options for implementing JDBC communication with a database



According to Internet conventions, JDBC identifies a database using a URL of the form:

jdbc:<subprotocol>:<name associated with DBMS or Protocol>

In an Internet/intranet database, "name" may contain a network URL

//<hostname>:<port>/..

<subprotocol> can be any name that implies a database. The subprotocol name "odbc" is reserved for ODBC format data sources. A typical JDBC URL for an ODBC database looks like this:

jdbc:odbc:<DNS - ODBC name>;User=<user name>;PW=<password>

II Organization of the user interface for accessing databases

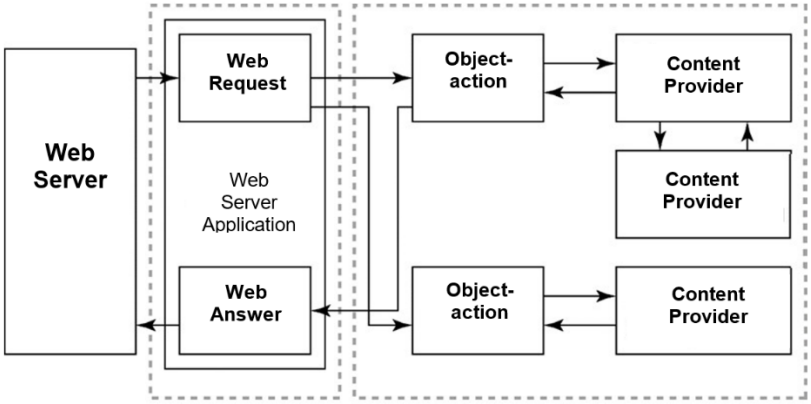
When providing WWW access to an existing DB, a number of ways are possible – complexes of technological and organizational solutions. The practice of using WWW technology to access an existing DB provides a wide range of technological solutions, interconnected in different ways. The choice of specific solutions when providing access depends on the specifics of a particular DBMS and a number of other factors, such as: the availability of specialists capable of mastering a certain branch of technological solutions with minimal costs, the existence of other DBs, WWW access to which should be carried out with minimal additional costs, etc.

In order to reduce the cost of the developed automated system of access to information in databases for Internet users, a proprietary WEB server for external access has been developed. In the Smart University system, the InterBase (Firebird) server is used to work with remote databases, where the concept of an active server core was first implemented. The functions of the InterBase active core include a patented mechanism of event signalers, stored procedures, triggers, user-defined functions (UDF - User-defined function) and BLOB filters. The joint work of these functions ensures the transfer of data processing to the server, where they are executed faster and more reliably. InterBase ensures high availability and data integrity using declarative initial integrity mechanisms, including cascade operations. Many applications (multimedia, scientific, Internet applications) require the ability to process unstructured data. InterBase is the first relational database to satisfy this requirement using BLOB. Using BLOB allows storing audio, video, graphic and binary information in the database. In modern applications, BLOB filters are used to compress and transform data. The compactness of the InterBase core saves disk space for later use by business-critical applications. InterBase also provides performance comparable to competing databases with lower memory requirements for additional savings on memory costs.

The C# programming environment adopted for the implementation of the developed system has great potential for creating your own WEB server by using, for example, WebBridge C# technology, without worrying about the choice of API (NSAPI or ISAPI). The general structure of the WEB server application is shown graphically in Figure 5.

Figure 5

General structure of WEB server application.



The task of the WEB server is to prepare the received data for the type of server application and send the user a response prepared by the application. The transmitted hypertext documents are formatted in the HTML standard – the language for describing hypertext documents. These documents are stored in static form (a set of files on a disk) and are dynamically compiled depending on the parameters of the request by

special software. For dynamic compilation of HTML documents, the WWW server uses specially designed CGi programs.

This solution is effective for large databases with a complex structure and when it is necessary to support search operations. The disadvantages of this method include a long time for query processing, the need for constant access to the main database, and additional loading of database support tools associated with processing queries from the WWW server.

To solve the problem of reducing the time of request processing, it is necessary to minimize the data transfer via the Internet and the Internet connection time between the client and the server. For example, for the network version of test control, minimization of requests to the server is solved by "downloading" the test selected for testing to a remote computer (client). After the test transfer is complete, the client no longer needs to contact the server, and it is disconnected until the moment when it needs to transfer the test results to the server.

The functioning of the server, which serves remote test subjects, consists of:

- launching the server and preliminary preparation of tests for their transmission to remote clients. The server analyzes the registered profiles of the test subjects and selects the tests necessary for testing. The selected tests are then compressed for transmission and placed in a special "transport" folder on the disk;
- saving the results of the tests carried out in the main results database and terminating the server.

For a client wishing to undergo testing at a great distance, the following is performed:

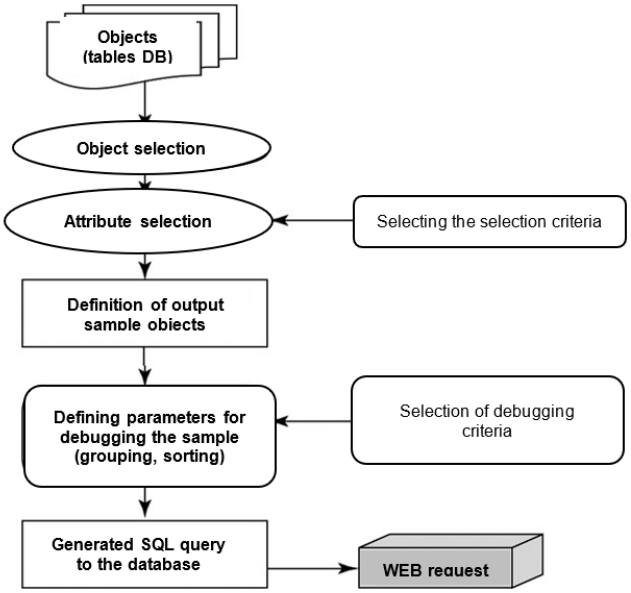
- user identification by the server and receiving the file with the test. If the client with the entered password is registered, the server will transfer the file with the test to him;
- unpacking the test and testing, disconnecting from the server, the testing process;
- connection to the server, transfer of the results of the testing to the server and completion of work by disconnecting from the server.

For working with databases in the application of WEB servers, the C# programming environment adopted for the development of the system under consideration provides a number of components: TQueryTableProducer (for providing the result of an SQL query to the database in the form of an HTML table), TDataSetTableProducer (similarly forms a table in the HTML language, into which it places all the records of the TDataSet object), TDataSetPageProducer (replaces templates in the HTML document template with the value of the corresponding database fields from the current record).

When receiving a request to execute, it creates TWebRequest and TWebResponse objects to place the HTTP request and response of the server in them. These objects are transferred to the WEB dispatcher (the dispatcher built into the WEB module or TWebDispatcher component), which controls the operation of the server application, supporting a set of action objects, TWebActionitem class objects that process various types of requests. If after completing the request processing, the dispatcher has not found a suitable action object, then the server message for sending to the client is not sent and the server breaks the connection with the client. This technology is also used when executing remote client requests for reference information about data in the database of the system in question.

For this purpose, the work proposes a "query constructor" that allows constructing various queries to the database, selecting the database objects needed for analysis from the available ones and setting the selection parameters based on their inherent attributes. The scheme of the "query constructor" operation is shown in Figure 6.

Figure 6
Scheme of the "Query Designer" operation



The results of generated SQL queries to the database can be presented to the user as HTML pages or as tables in the browser window.

Testing of the test version of the Information System "Quality Management of Higher and Postgraduate Education" in pilot mode showed that the system is generally operational, data exchange is carried out in accordance with the technical specifications. The technical parameters of the information system are met.

Bugs (errors) discovered during testing were subsequently corrected, and appropriate changes were made to the nodes.

Thus, it should be noted that the version of the Information System “Quality Management of Higher and Postgraduate Education” has passed testing and is ready for integration with other modules of the Unified Platform for Higher Education.

Discussion

The findings confirm that the integration of the information system “Quality Management of Higher and Postgraduate Education” with university-level and external national systems should not be viewed merely as a localized technical task of data exchange. Rather, it should be considered as a foundation for building a unified digital framework for managing the quality of higher and postgraduate education.

The pilot implementation at Astana IT University and the University of International Business demonstrated that API-based integration makes it possible to consolidate diverse categories of institutional data, including information on students, academic staff, educational programs, international activities, and research publications, within a single management system. The subsequent transmission of these data to the Unified Higher Education Platform shows the potential of such integration to reduce fragmentation, improve data consistency, and support more systematic quality assurance processes.

These results are consistent with contemporary research (Çelik & Ayaz, 2022; Daim et al., 2024; Mazadu et al., 2022), which emphasizes that the value of digital transformation is determined not by the number of implemented digital platforms, but by their interoperability, alignment with institutional processes, and integration into the university management cycle.

At the same time, the present study offers a more practice-oriented perspective compared to much of the reviewed literature. While many studies focus primarily on LMS adoption, user satisfaction, learning analytics dashboards, or the effectiveness of individual digital tools, this research proposes an architectural and functional model of intersystem interaction. This is one of the key strengths of the study, since the literature still provides limited examples of models that integrate LMS, SIS, quality assurance subsystems,

and external governmental platforms into a unified digital ecosystem.

In this regard, the proposed solution partially addresses the identified research gap by demonstrating how system integration can be implemented through specific procedures, including authentication, request formation, data validation, data updating, and transmission to external platforms. The study therefore contributes not only to the theoretical discussion of digital transformation in higher education, but also to the practical development of institutional quality management mechanisms.

Importantly, the pilot implementation revealed both the advantages and the limitations of the integration approach. The errors identified in authentication, request formation, and data validation indicate that the main risks of such systems are related not only to software implementation, but also to the quality of source data, the accuracy of exchange rules, and the reliability of intersystem interaction protocols. In other words, the existence of a functioning API does not automatically guarantee reliable, complete, or managerially meaningful integration.

Therefore, the further development of such systems requires special attention to master data management, unified reference data, formalized validation protocols, and continuous monitoring of data exchange quality. Without these elements, digital integration may remain a technical procedure rather than becoming a meaningful instrument for quality assurance and evidence-based decision-making.

Positive user evaluations of the interface, system performance, and quality-monitoring capabilities indicate the functional suitability of the proposed solution in real institutional contexts. However, these results should be interpreted with caution. First, the study was conducted as a pilot and was limited to two universities, which does not allow for broad generalization to the entire higher education system. Second, the evaluation focused mainly on the technical and organizational functionality of the model, rather than on its long-term effects on the quality of managerial decision-making, institutional performance, or educational outcomes.

Conclusion

The study demonstrated that the integration of quality management information systems with university and external national systems has significant potential for improving the management of higher and postgraduate education. The proposed API-based model enables the consolidation, validation, updating, and transmission of institutional data, thereby creating the basis for a more coherent and transparent digital quality assurance ecosystem.

The pilot implementation confirmed that such integration can improve the availability and consistency of data related to students, academic staff, educational programs, international activities, and research outputs. It also showed that intersystem interaction can support institutional monitoring and reporting processes, while reducing duplication and fragmentation of information flows.

At the same time, the study revealed that successful digital integration depends not only on technical connectivity, but also on the quality of data governance. The reliability of such systems requires standardized data structures, unified reference directories, clear validation rules, and continuous monitoring of data exchange. These factors are essential for transforming integration from a simple data transmission mechanism into a practical tool for supporting quality management.

The results suggest three main directions for further development. First, pilot implementation should be expanded to include a larger number of universities with different organizational and digital maturity levels. Second, data quality standards and validation procedures should be strengthened at both institutional and national levels. Third, analytical decision-support modules should be added to allow universities and authorized bodies to use the collected data not only for reporting, but also for strategic planning, risk identification, and evidence-based quality improvement.

Thus, the integration of quality management information systems can become an important element of the digital transformation of higher education. However, its full value will be achieved only when technological interoperability is combined with organizational regulation, reliable data governance, and analytical maturity. This combination can transform the system from a technical platform for data exchange into a full-fledged mechanism for managing the quality of higher and postgraduate education.

Conflicts of Interest Statement.

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Author Contributions

Aidos Mukhatayev: Conceptualization, Methodology, Supervision, Project Administration, Writing – Review and Editing. Serik Omirbayev: Conceptualization, Strategic Guidance, Validation, Supervision, Writing – Review and Editing. Andrii Biloshchytskyi: Methodology, Formal Analysis, Technical Expertise, Validation, Writing – Review and Editing. Aidar Ispussinov: Resources, Digital Infrastructure Analysis, Data Collection, Visualization, Writing – Review and Editing. Yurii Andrashko: Methodology, Statistical Analysis, Validation, Visualization, Writing – Review and Editing. Yuliya Idiyatova: Literature Review, Data Collection and Curation, Formal Analysis, Writing – Original Draft, Final Editing. Indira Abilmazhinova: Investigation, Data Analysis, Regulatory and Institutional Review, Writing – Original Draft, Writing – Review and Editing.

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PATTERNS OF CHATGPT UTILIZATION BY DUAL-DEGREE STUDENTS IN ETHICAL CONTEXTS

Abstract. In the context of the rapidly changing educational landscape due to the development and implementation of AI in almost all areas of life, ChatGPT has become an important topic for discussion. The use of ChatGPT in the educational process gives rise to a number of ethical issues related to academic honesty and independence in learning. This issue is most relevant among students of dual-degree programs at Kozybayev University and the University of Arizona. As part of the study, a literature review and a survey of 86 first- and second-year students in the areas of biotechnology, information systems and pedagogy of dual-degree programs were conducted. The results showed that most students use ChatGPT to complete educational tasks in the academic process. Some respondents note their dependence on AI and the need to verify the reliability of the information received. To increase students' ethical awareness, an activity using the AI Incident Database (AIID) was proposed within the English language classes. As a result, students noted the importance of critical thinking when working with AI and the need for the constant implementation of such educational practices in the educational process.

Keywords: ChatGPT, academic integrity, dual degree programs, language development, AI Incident Database.

Introduction

Modern educational technologies inevitably transform the academic environment, influencing the educational process such as with the Internet or online learning. One of the most significant tools of digital education has become ChatGPT – artificial intelligence capable of generating text based on entered data, simplifying access to information and providing support in educational activities. Since ChatGPT was launched in November 2022, this tool has become an integral part of many students' learning, particularly for dual degree students whose course load and academic demands are significantly higher than usual. The dual degree programs, implemented in partnership between M. Kozybayev North Kazakhstan University and the University of Arizona, offer students a unique opportunity to receive an international education without leaving Kazakhstan. The program begins with intensive study of English, which allows students to master the necessary language skills for further study. After mastering English, all specialized disciplines are taught exclusively in English, which meets international educational standards and the requirements of the University of Arizona. This structure of study allows students not only to deepen their knowledge in the chosen field, but also to develop academic and professional competencies in English. It should be noted that the academic workload within this program is extremely high, requiring maximum concentration, self-organization, reflection, and resistance to academic, and sometimes personal, challenges from students. Thus, the integration of AI solutions into students' educational practice seems to be a logical and predictable phenomenon. However, their use gives rise to several ethical questions related to the acceptable and unacceptable use of AI tools in the educational environment.

The rise of large language models (LLMs), particularly ChatGPT by OpenAI, has sparked a global debate among educators, ethicists, and policymakers. Since its public release in late 2022, ChatGPT has rapidly transitioned from a novel experiment to a mainstream tool in academic environments. It is now employed in a variety of contexts – from writing assistance and coding help to more controversial uses such as automatic essay generation. This sudden integration has challenged long-standing educational norms, especially those concerning originality, academic integrity, and assessment design. The educational system was unprepared for such a disruptive force, emphasizing the need for both institutional policies and

pedagogical frameworks that guide ethical AI usage. While some universities have embraced AI tools with structured guidance, others have banned them outright due to concerns over plagiarism and authenticity. In this context, exploring students' ethical reasoning becomes critical – not only to adapt educational practices but also to prepare future professionals for responsible AI engagement in society at large.

The integration of AI, and particularly ChatGPT, into educational processes has been the subject of intense research in recent years. Current research highlights both the benefits and challenges associated with the use of AI in higher education, especially in the context of ethical aspects and academic integrity. E. Kasneci with co-authors describe ChatGPT as a powerful tool to support the educational process, promoting the development of critical thinking and improving students' writing skills (Kasneci et al., 2023). They note that students actively use ChatGPT for essay writing and exam preparation. Similar ideas are found in the studies of J. Dempere, which emphasize the transformative potential of AI in teaching and research (Dempere et al., 2023). X. Song investigated the impact of ChatGPT on medical students and concluded that AI contributes to improved access to information and increased interactivity in the learning process (Song et al., 2024). However, the authors also note the need for clear instructions and restrictions to prevent abuse and overreliance on the use of AI in educational activities. M. Seitova, Z. Halmatova, L. Kazykhankyzy and P. Bhullar highlight that the use of ChatGPT raises serious concerns about academic integrity, especially in the context of plagiarism and substitution of students' independent work, and also note that ChatGPT may reduce students' ability to create original and creative works and threaten the development of independent thinking (Seitova et al., 2024). Similar concerns are shared by G. Makimova and S. Baisultanova, who note that without proper control, AI tools can lead to a decrease in the quality of education and superficial assimilation of the material. The most valuable conclusion of the researchers is that the ethical side of using AI in educational activities needs to be taught, not only through the creation of norms or policies for regulation (Mbwambo & Kaaya, 2024).

This study aims to analyze the patterns of ChatGPT use among dual-degree students, identify the associated ethical risks, and propose an example activity to address inappropriate patterns of AI use in learning English. The paper addresses the following questions:

– What are the main patterns for using ChatGPT among dual-degree students?

– How do the results obtained compare with the global experience of using AI in educational processes?

– What role can the activity of working with the AI Incident Database (AIID) play in English lessons in increasing ethical awareness and developing students' language competencies?

Thus, analyzing the patterns of ChatGPT use in the context of dual degree programs is an important research task that will not only identify key trends, but also offer strategic solutions to minimize ethical risks.

Literature review

The release of ChatGPT in late 2022 transformed the educational landscape, becoming the fastest-growing consumer application in history. Generative Artificial Intelligence (GenAI), which uses large language models (LLMs) to create human-like text and media, has introduced both revolutionary opportunities and significant challenges for higher education institutions. The following literature review examines current research on publications associated with GenAI and ideas of its ethical integration into academic settings. According to RSR Online (2024), "more than 40% of students use AI technologies in their studies," which indicates that AI is no longer a marginal tool but a mainstream educational resource.

Several researchers have explored what students actually do with these tools, for instance, Bhullar et al. (2024) identify common patterns: drafting texts, generating ideas, getting help with assessments, and improving communication. Chan and Hu (2023) describe something very similar, noting that students turn to AI mostly for brainstorming, language support, and organizing their thoughts. What neither group of authors finds surprising is that these patterns repeat across very different educational contexts. The consistency itself is worth paying attention to, because it suggests that ChatGPT use is not random or experimental but has already settled into recognizable habits.

Kasneci et al. (2023) warn that relying on LLMs too heavily can weaken critical thinking over time and create problems with academic integrity. Dempere et al. (2023) raise a similar concern, pointing out that

while ChatGPT offers personalized feedback and saves time, it also makes plagiarism easier than it has ever been. Mbwambo and Kaaya (2024) go further and list misinformation, dishonesty, and lack of transparency as ongoing issues that institutions have been slow to address. Reading these studies together, one pattern becomes hard to ignore: the very features that make ChatGPT useful (speed, fluency, accessibility) are the same features that make it dangerous when students use it without reflection. Song et al. (2024) report that learners describe their AI experiences as helpful but also somewhat troubling, because efficiency sometimes comes at the expense of actually understanding the material. Chan and Hu (2023) found that students worry about accuracy and fairness even while they continue using these tools daily. This kind of ambivalence is not unique to AI of course (students have always had complicated relationships with shortcuts), but the scale here is different.

Seitova et al. (2024) show that English teachers in Kazakhstan recognize AI as a valuable classroom resource, though they insist on methodological control and clear guidelines. Makimova and Baisultanova (2024) make a point that resonates well beyond Kazakhstan: having access to digital technology does not automatically improve teaching, what matters is how instructors design their lessons around it.

One direction that deserves more attention is teaching students to think critically about AI itself. Feffer et al. (2023) propose using the AI Incident Database (AIID) in the classroom, which exposes learners to documented cases where AI systems caused harm. This is not about scaring students away from technology but about building the kind of awareness that lets them use it responsibly. For the present study, this approach is particularly relevant because it connects language learning with ethical reasoning in a way that feels natural rather than forced.

To conclude, students do use ChatGPT in broadly the same ways, and these ways are already well established (Bhullar et al., 2024; Chan & Hu, 2023). The ethical risks that accompany this usage are also well documented, even if solutions remain scarce (Kasneci et al., 2023; Mbwambo & Kaaya, 2024). Students recognize both the benefits and the dangers, which means they are not naive about what they are doing (Song et al., 2024). And perhaps most importantly, there is a growing agreement that what is needed now is not more warnings about AI but concrete pedagogical strategies that help students engage with it thoughtfully (Feffer et al., 2023).

Materials and Methods

The study was conducted in several stages. At the first stage, a comprehensive literature review on the use of AI in educational practice was conducted, with an emphasis on the use of AI by students in the learning process. The theoretical basis of the study was formed by the works of such scientists as E. Kasneci, J. Dempere, X. Song, M. Seitova, Z. Halmatova, L. Kazykhankyzy, P. Bhullar, G. Makimova and S. Baisultanova and others.

The second stage was a survey of students studying in dual-degree programs. The survey was aimed at identifying the frequency and purposes of using ChatGPT, as well as students' attitudes towards the ethical aspects of its use. The survey results helped determine the level of students' awareness of the risks of academic dishonesty associated with excessive dependence on AI. The questionnaire was designed following principles of clarity, neutrality, and relevance to the study's objectives. It was pre-tested with a small focus group of five students from the same academic tracks to identify ambiguous formulations and ensure alignment with local academic contexts. Feedback from this pilot group led to the refinement of language and the addition of open-ended questions to capture more nuanced perspectives. Questions were structured to minimize bias and provide both quantitative and qualitative insights into student behaviors and ethical reasoning.

Our survey was based on previous studies, in particular M. Feffer, N. Martelaro, H. Heidari (RSR Online, 2024), C. Chan, W. Hu. Through the lens of this research, we were able to identify key trends and patterns in the use of AI-based chatbots by international students. The questions in the survey were also adapted to the realities of our educational process. The study employed a mixed-methods approach. Quantitative data from closed-ended questions provided measurable patterns of behavior and perception, while open-ended responses offered qualitative insights into individual motivations, ethical reasoning, and cognitive challenges. This methodological triangulation enhanced the reliability of findings by allowing for cross-validation of data and a more holistic understanding of students' interactions with ChatGPT.

The survey consisted of closed and open questions and was structured as follows:

1. General information: questions about age, specialty, year of study, and level of English proficiency.

2. Frequency and purposes of using ChatGPT: how often students use AI and for what tasks (options were suggested by students with the opportunity to supplement the answer with their own ideas).

3. Impact on the educational process: questions were aimed at assessing how the use of AI affects the completion of educational tasks and the development of independent skills.

4. Ethical aspects and critical perception of information: students assessed the admissibility of using ChatGPT for educational purposes and awareness of the risks of academic dishonesty and questions about checking the accuracy of information received from AI and their degree of trust in it.

Qualitative data from open-ended questions were analyzed using thematic coding. Recurrent themes – such as autonomy, trust, ethical boundaries, and dependency – were identified through inductive analysis. Responses were reviewed by two researchers (authors of the given article) independently to ensure inter-rater reliability. Discrepancies in coding were resolved through discussion and consensus. This allowed the researchers to identify underlying concerns not captured by the quantitative results alone.

The questionnaire was anonymous and filled out by 86 first- and second-year students of the following specialties: Information Systems in Management (2024 admission year), Special Pedagogy and Inclusive Practice (2023 admission year), Psychology in Education (2023 admission year), Biotechnology (2024 admission year) via Google Forms. The sample size of 86 students represents approximately 60% of the total population enrolled in dual-degree programs during the 2023–2024 academic year, ensuring high representativeness. Stratified sampling was implicitly achieved due to the inclusion of students from three different specializations and two academic years. English proficiency levels were also considered to account for differences in access to and interpretation of English-language AI tools.

Results

We considered several case studies that served as the basis for our study. According to a study conducted in Hong Kong (Chan & Hu, 2023), university students have a positive attitude towards the use of generative AI tools in the learning process. The students actively use AI for writing essays, preparing for exams, completing written homework, and other complex tasks for which a certain amount of time is allocated. However, despite the recognized benefits, there are concerns: the information that AI provides is not always reliable, due to such a problem as “hallucination,” the information is fictitious or shuffled by AI in order to solve the problem faster. Moreover, questions related to privacy and ethical aspects of using technology are acute (Chan & Hu, 2023). The next study was conducted among medical students and revealed mixed reactions to the use of ChatGPT. Students noted easier access to information and increased interactivity in learning but expressed concerns about the reliability of the data provided as well as the lack of clear ethical standards for the use of AI in education (Song et al., 2024). A Russian study conducted by the online campus of the Higher School of Economics found that 43% of students are already actively using AI for educational purposes. Mostly they use it for solving various educational tasks, writing term papers, lab work, reports, abstracts, essays, etc. More than half of students note the need to double-check the information received from AI, while 22% rely entirely on AI when performing various educational tasks. Researchers note the possible development of technology dependence (RSR Online, 2024). These studies and international experience served as the basis for developing our survey, which was adapted to the specifics of dual degree programs and the local context. Our findings highlight both similarities and differences in students’ approaches to using AI, and deepen our understanding of the ethical implications of this practice, allowing us to identify potential solutions to these issues based on the most common patterns. Consider the data we obtained in our empirical study.

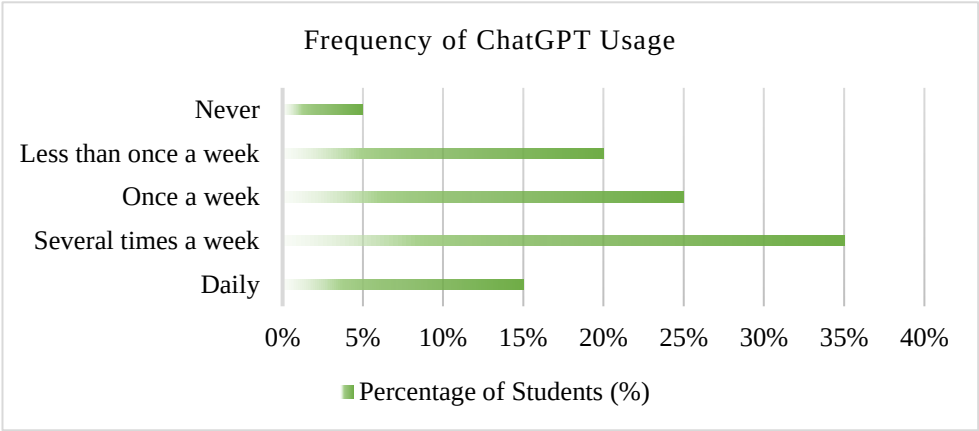
As noted earlier, the survey involved first- and second-year students of dual-degree educational programs aged 18 to 22. The first question of the questionnaire was devoted to collecting demographic data of the participants. Among the respondents, 34% are studying in the biotechnology program, 38% in information systems, and 28% in pedagogy. The distribution by courses is as follows: 47% of first-year students and 53% in the second year. The level of English proficiency varies from beginner (20%) to intermediate (50%) and advanced (30%) (Table 1).

Table 1.
Demographic Profile of the Participants

Category	Parameters	Percentage of Participants (%)
Age	18–22 years	-
Field of Study	Biotechnology	34%
	Information Systems	38%
	Pedagogy	28%
Year of Study	1st Year	47%
	2nd Year	53%
English Proficiency Level	Beginner	20%
	Intermediate	50%
	Advanced	30%

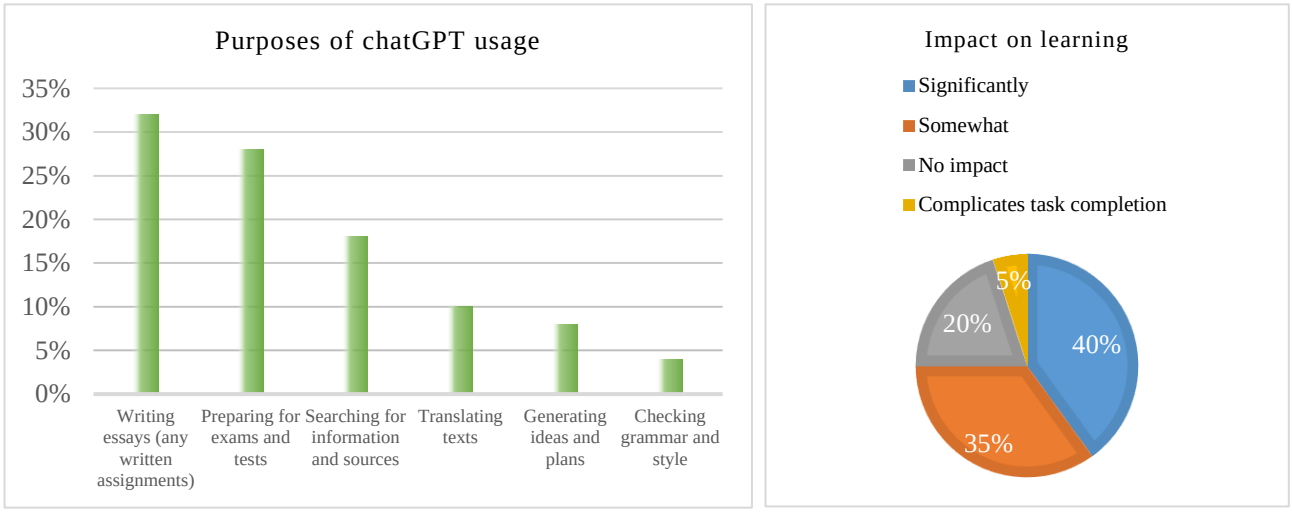
The second question of the survey is related to how often students use AI for personal and non-academic purposes. The results revealed that the frequency of ChatGPT use varies among students: 15% use it daily, 35% use it several times a week, 25% use it once a week, and 20% use ChatGPT less than once a week. Only 5% of students have never used this tool for academic purposes. 15% of students use ChatGPT daily, 35% use it several times a week, 25% use it once a week, 20% use it less than once a week, and only 5% have never used ChatGPT for academic purposes. More detailed data are presented in Diagram 1.

Diagram 1.
Frequency of ChatGPT Usage



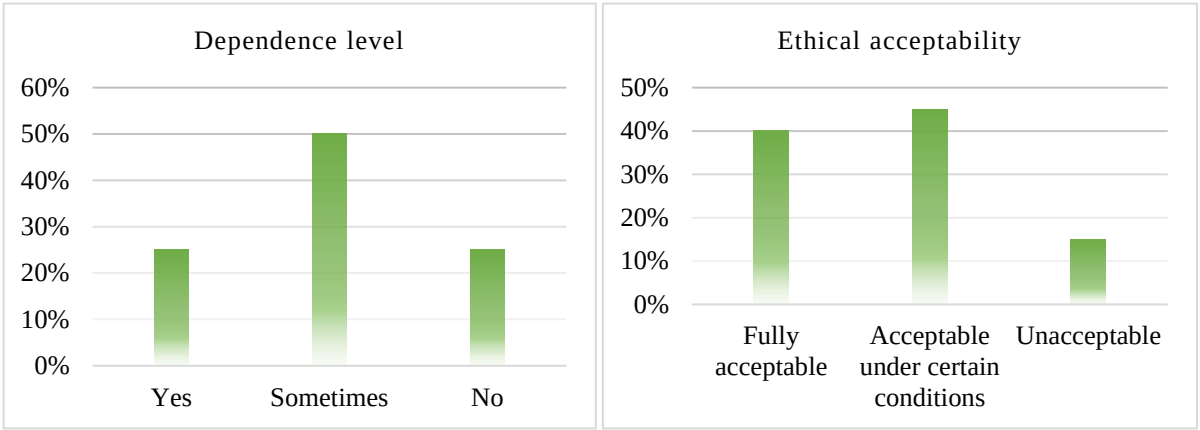
The third and fourth questions were aimed at identifying the specific purposes of using the chatbot in the educational process and getting students' opinions on how it affects their learning in general. Regarding the third question, students note that they use ChatGPT for various academic tasks: 32% use it to write essays and term papers, 28% to prepare for exams and tests, 18% use AI to search for information and sources, 10% to translate texts, 8% to generate ideas and plans, and 4% to check grammar and style. As one student noted in the "other" column: "I use ChatGPT to structure essays and find arguments. It helps me cope with assignments faster." In the fourth question, the impact of ChatGPT on the learning process is assessed differently: 40% of students believe that AI makes it much easier to complete learning tasks, 35% note that it simplifies the work to some extent, 20% do not see any impact on the learning process, and 5% believe that using ChatGPT complicates the completion of tasks, creating a false sense of confidence in the reliability of the information. The data are presented in more detail in Diagram 2.

Diagram 2.
Purposes and impacts of ChatGPT usage



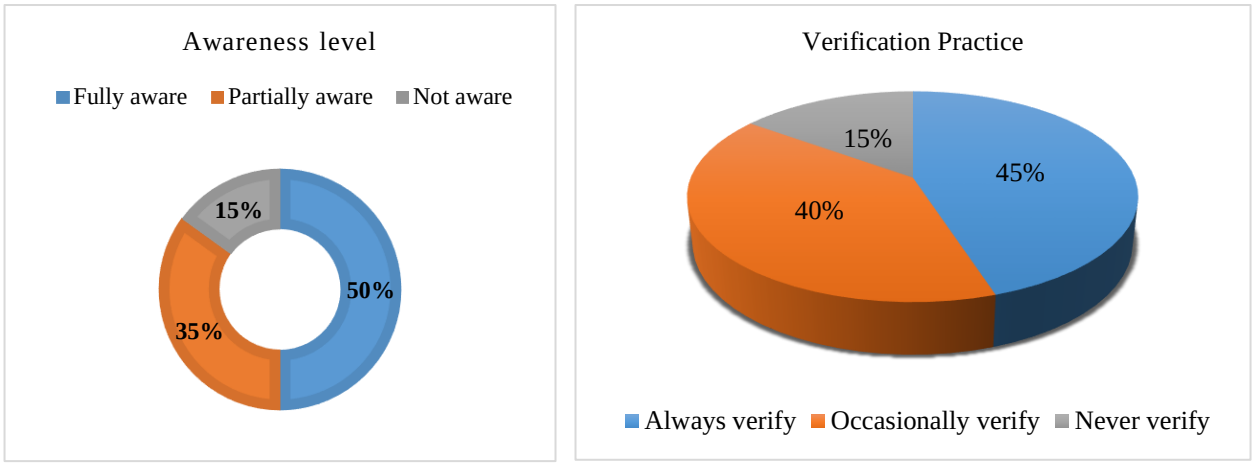
The fifth question of the survey was devoted to identifying the degree of students' dependence on chatbots, in their own opinion, and the sixth question revealed the ethical aspects of such dependence. Dependence on ChatGPT varies among students: 25% admitted that they depend on AI when completing academic tasks, 50% use it from time to time as an auxiliary tool, and 25% said that they do not depend on ChatGPT and use it exclusively to check their own knowledge. When asked to consider the ethical aspects of using ChatGPT, the students surveyed also had different opinions: 40% of students consider the use of AI completely acceptable for educational purposes, 45% believe that its use is acceptable only under certain conditions, such as mandatory verification of information or indication of the source, and 15% of respondents are sure that the use of ChatGPT in the academic environment is unacceptable (Diagram 3).

Diagram 3.
Dependence on ChatGPT and Ethical Aspects of ChatGPT Usage



The seventh and eighth questions assessed the students' awareness of the risks of academic misconduct and how often they check the information generated by AI. The awareness of the risks of academic dishonesty varies among students: 50% are fully aware of the possible threats associated with the use of AI, 35% of respondents partially understand these risks, while 15% of students do not see any threats in using ChatGPT in their academic activities. The verification of information from ChatGPT also demonstrates different approaches: 45% of students always double-check the information received from AI with additional sources, 40% do it from time to time depending on the complexity of the task, and 15% completely trust the data without checking its accuracy (Diagram 4).

Diagram 4.
Awareness of Academic Dishonesty Risks and Verification of Information from ChatGPT



In addition to structured responses, students were invited to provide open-ended comments reflecting their personal experiences and ethical considerations when using ChatGPT. Open-ended responses (n=62) were analyzed thematically using inductive coding. The analysis revealed four recurrent themes:

– Autonomy vs. Dependence – reflections on reliance on ChatGPT for task completion and concern over losing independence in academic work.

– Trust vs. Verification – statements showing either blind trust or a cautious approach to AI-generated content.

– Ethical ambivalence – emotional responses such as guilt, justification, or rationalization of AI use.

– Instrumental use for language support – focus on linguistic or structural assistance (grammar correction, idea generation).

These themes illustrate the cognitive dissonance and ethical complexity experienced by students as they navigate the benefits and drawbacks of integrating AI into their academic routines. The excerpts below are representative of these thematic patterns:

"I use ChatGPT mostly when I get stuck and don't know how to begin writing. It gives me ideas, but I never copy the answers directly." (2nd-year student, Pedagogy)

"Sometimes I trust it too much and later find mistakes. I realized I have to check facts more carefully." (1st-year student, Biotechnology)

"I feel guilty when I use it for homework, especially when it gives me the whole solution. But it's hard not to use it when you're tired." (2nd-year student, Information Systems)

"It helps with grammar and vocabulary, but I always try to rewrite the answer in my own way." (1st-year student, Psychology in Education)

"In my opinion, ChatGPT is just a tool. It depends on how we use it. If we use it wisely, it can be helpful and not harmful." (2nd-year student, Information Systems)

Additionally, some students demonstrated uncritical trust in ChatGPT or lacked awareness of its ethical implications in academic contexts:

"I don't really check the information from ChatGPT. It usually sounds correct, and it saves time." (1st-year student, Biotechnology)

"Why would it be a problem to use ChatGPT? It's just like asking Google or a friend." (2nd-year student, Information Systems)

"I use it for all writing tasks like essays, reports, everything. I didn't know it could be considered cheating." (1st-year student, Pedagogy)

"I thought as long as I change some words, it's not plagiarism. I'm not stealing somebody's work." (2nd-year student, Psychology in Education)

Beyond frequency and ethical reflections, student responses also revealed diverse functional patterns of ChatGPT use, reflecting the multifunctional role of generative AI in students' lives and underscore its impact not only on academic performance, but also on cognitive strategies and language development. These

patterns can be grouped into four major categories based on the type of academic activity and cognitive engagement involved:

– Academic utility tasks – ChatGPT was used for concrete academic outputs, such as essay writing, test preparation, source identification, and report structuring. These were the most frequently reported applications, often tied to high-stakes assignments or exams.

– Language and communication support – students employed the tool to improve their academic English, including grammar correction, vocabulary enhancement, and sentence rephrasing. For many students, this function was especially valuable given the English-medium instruction of their programs.

– Idea generation and cognitive scaffolding – several students reported using ChatGPT to brainstorm ideas, develop outlines, or clarify abstract concepts: thus, AI served as a cognitive partner, helping students approach tasks with more clarity.

– Non-academic and personal exploration – although less common, some responses pointed to using ChatGPT for non-curricular learning, personal interests, or casual information-seeking. This suggests that students may integrate AI into broader self-directed learning beyond formal education.

In summary, the data reveals a complex interplay between such dimensions as pragmatic, cognitive, and ethical and, generally speaking, in how dual-degree students engage with ChatGPT. The combination of structured responses, open commentary, and thematic categorization paints a multifaceted picture of AI integration into their academic routines. These findings serve as a foundation for deeper analysis in the following section.

Discussion

Our findings support global trends in integrating AI into education, highlighting both positive and potentially problematic aspects of AI use among dual degree students.

1. Widespread frequency of ChatGPT use: our survey found that over 75% of students use ChatGPT at least once a week (taking into account that 25% - once a week, 35% - more than once a week), which is consistent with international research (Chan & Hu, 2023), (RSR Online, 2024). These figures demonstrate that AI is becoming an integral part of the learning process, especially among students facing high course loads in dual degree programs. Intensive use of AI is associated with the need to optimize time for completing assignments and finding ways to simplify complex academic tasks. Furthermore, the frequency of use suggests that ChatGPT has become embedded not just in the students' academic routines but in their broader cognitive behavior. For many, the AI tool is no longer viewed as a temporary support but as a default mechanism for handling intellectual load. This shift reflects a deeper transformation in students' problem-solving strategies. While frequent usage may appear to signal efficiency, it may equally suggest avoidance of deeper engagement with course material. The distinction between strategic use and habitual reliance is thus essential for future curricular considerations because ChatGPT is now becoming an “invisible” assistant and students tend to rely on it too much. Thus, the question raises: “is frequency a marker of effectiveness or of avoidance behavior (of more complex tasks)?”

2. Main purposes of use and impact on the learning process: the majority of students use ChatGPT for essay writing (32%) and exam preparation (28%). This indicates that AI is perceived as a tool that can improve academic performance. At the same time, 40% of students note that ChatGPT makes it much easier to complete assignments, which confirms its functional value in the educational process. It indicates a risk of reducing student autonomy and developing academic laziness and corresponds with the opinions from X. Song’s research work (Song et al., 2024). The perceived simplification of academic tasks raises critical pedagogical concerns because when students repeatedly turn to AI to handle demanding assignments, the effort-reward structure of learning changes a lot. Cognitive endurance, creativity, and even reflective and critical thinking (obviously, qualities fostered through grappling with complex tasks) may be undermined. While students report increased ease in task completion, it is unclear whether this ease corresponds with meaningful knowledge acquisition. This presents a risk that students conflate task execution with learning, potentially leading to shallow engagement and overestimation of their understanding, in other words, there is the tension between surface-level performance and deep learning outcomes Educators must, in this case, distinguish between efficient support and cognitive outsourcing in how they interpret AI-related learning outcomes.

3. Ethical dilemmas and academic honesty: despite the widespread use of AI, the results of the study show the presence of ethical controversies. 40% of students consider the use of ChatGPT completely acceptable, while 45% allow its use only under certain conditions. Additionally, 50% of students are aware of the risks of academic dishonesty. The finding that nearly half of respondents perceive AI use as acceptable under certain conditions suggests that students are developing their own informal ethical frameworks, often detached from institutional policies. These justifications, such as modifying AI outputs or using them as templates, indicate a sliding scale of acceptability rather than a binary moral stance. To be more explicit, there is a certain ambiguity in students' understanding of what constitutes ethical AI use because students tend to demonstrate the "conditional acceptability" logic: what conditions students tend to impose (e.g., "as long as I check it," "as long as I rewrite it"), leading to normalization of AI involvement without recognizing it as a breach. This may reflect a broader cultural shift where digital assistance is normalized to such an extent that students no longer view it as academically questionable. Such an interpretive gap requires deliberate clarification and open discussion within academic programs to ensure alignment between student practices and institutional standards of academic honesty.

4. Technology addiction and critical thinking: a quarter of the students surveyed admitted to being addicted to ChatGPT, and another 50% use it as an auxiliary tool. Most of the students verify the information they receive (45% always check, 40% sometimes), 15% completely trust the AI without additional verification. Even though such students seem to be small in number, such behavior is unacceptable in the academic and scientific environment because it can lead to significant consequences in the professional activities of students. Therefore, fact-checking should become a priority skill of students turning to AI, since such a skill is extrapolated both to the professional activity and personal life of the future specialist.

Additionally, the issue of dependence on ChatGPT raises more than just ethical or regulatory questions; it strikes at the heart of academic identity formation emphasizing the need to differentiate between instrumental dependence (efficient use) and emotional or cognitive dependency (anxiety if not used). Students who rely on AI not just for language or structure, but for direction and decision-making, may gradually lose confidence in their own academic voice and such overreliance may affect the development of resilience, perseverance, and academic self-efficacy. Some participants even acknowledged feelings of guilt or confusion, suggesting that their internal sense of right and wrong is in tension with their actions. This conflict is a clear signal that ethical and emotional literacy around AI needs to be addressed alongside policy development. Moreover, when students begin to feel anxious or helpless without AI assistance, it reveals a deeper cognitive displacement that can compromise long-term educational goals. Strengthening students' self-regulatory abilities and reinforcing their confidence in their own academic competencies must be a parallel priority therefore.

5. Comparison with international studies: the results of our study are consistent with the findings of international studies [3], [7]. However, we also observe unique aspects related to the context of dual-degree programs, where high academic workload stimulates increased use of AI. In contrast to international data, students in our sample are more cautious about academic honesty and verification of information. One of the effective practices for raising students' awareness of the ethical aspects of using artificial intelligence is interactive work with the AI Incident Database (AIID). This method has been successfully applied in courses aimed at studying the ethical and social consequences of using AI [9]. We will describe our experience of introducing this practice into the educational process in foreign language classes as independent work of a student with a teacher. It is important to note that since this activity was carried out within the framework of English language teaching, it not only increases ethical awareness, but also develops the basic academic language competencies according to the curricula. Although this aspect is not the aim of our study, we will briefly provide examples of how this is carried out (Table 2).

Table 2.
Linguistic Value of the AI Incident Database Activity

Language Skill	Description	Examples
Academic Vocabulary Development	Expansion of professional and ethical terminology.	*bias, privacy breach, misinformation, algorithmic decision-making.*
Working with English-Language Sources	Critical reading and analysis of authentic academic texts.	Analyzing articles from *The Verge*, *Wired*, *BBC Tech*; identifying key ideas and arguments.
Argumentation, Discussion, and Presentation Skills	Formulating arguments, defending opinions, and public speaking.	Group discussions on AI ethics, presenting incident reports, using persuasive language.
Academic Writing Practice	Structuring formal texts and proper citation of sources.	Writing structured reports on incidents, using formal connectors (*therefore*, *in conclusion*).
Intercultural Communication	Understanding cultural differences in ethical issues and expressing them in English.	Comparing AI-related incidents from different countries, discussing cultural approaches to ethics.

The computer lab session begins with students learning the importance of analyzing real AI-related incidents. The teacher demonstrates the AIID database interface, the main incident categories, and shows students the basics of navigating the site. The teacher shows how to use filters to search for incidents by different categories (students can choose them themselves depending on their specialization, for example, autonomous vehicles, recommender systems, language models, identification systems, and more). The work in the class is divided into three stages: individual, group, and reflection.

Individual work was carried out according to the following instructions: each student is assigned a database page number to avoid analyzing the same incidents. Students go to the site https://incidentdatabase.ai and select 10 incidents on their page. Table 3 below provides examples of incidents that students selected and questions for analysis.

Table 3.
Relevant AI Incidents and Critical Thinking Questions

Incident	Field of Study	Questions for Analysis
Google Photos Mislabeling (2015)	Information Systems	What caused the mislabeling of images? How can bias in AI datasets be reduced? Who was responsible for this error?
Microsoft Tay Chatbot Incident (2016)	Pedagogy / Information Systems	How did user interaction lead to unethical outputs? What safeguards could prevent this? What are the educational lessons?
Tesla Autopilot Crash (2022)	Information Systems	How did the autopilot system fail? What are the ethical responsibilities of developers in ensuring safety?
TikTok Recommending Dangerous Content (2021)	Pedagogy	How can algorithms influence behavior, especially among youth? What role should regulation play in content moderation?
Meta's AI Misclassification Incident (2021)	Biotechnology / Pedagogy	How can AI misclassification affect social trust? What are the implications for future AI development in sensitive fields?

The group work was organized as follows:

– Students are divided into groups (in our case, four students per group using a randomizer).

– The task is the following: each group must find a new incident (from 2019 to 2025) that has not yet been entered into the AIID database or is fairly recent (2024-2025) and reported in other websites or mass media platforms.

Students are provided with step-by-step instructions for completing the task:

– Use news sites and specialized resources: The Verge (https://www.theverge.com), Wired (https://www.wired.com), TechCrunch (https://techcrunch.com), BBC Tech (https://www.bbc.com/news/technology) or AI Incident Database to check already registered incidents.

– Use keywords in the search: "AI incident", "AI ethical failure", "AI bias", "AI harm case study".

– Check the reliability of sources and the relevance of information.

– Report creation: groups compile a report on the incident found and present it to their classmates and optionally add it to the AIID database.

Discussion of the work done, as well as reflection, are important stages of this work and were carried out using the following prompts:

– Which sources of information are most often missing from the database?

– Were there any difficulties in finding incidents? Why?

– What conclusions can be made about the current state of ethics in AI based on the incidents found?

– What measures can be taken to prevent similar incidents in the future?

Another task based on the AI Incident Database (AIID) was implemented as part of the same course. The goal of this activity was to develop students' ethical reasoning skills and academic speaking abilities through analysis and public discussion of controversial real-world AI incidents. In this task, students were required to prepare and participate in a classroom debate using data from the AIID platform. One of the most engaging examples used in this activity was the "Apple Card Gender Discrimination" case, registered in the AI Incident Database under the following link https://incidentdatabase.ai/cite/56. For additional information students were told to turn to CNN, New York Times, the Guardian official web-sites. Students were given the following problem: "*Several customers began reporting that women were receiving much lower credit limits than men, even when both had similar financial backgrounds. One of the most public statements came from tech entrepreneur David Heinemeier Hansson, who claimed that his wife received a limit 20 times lower than his own, although she had a better credit score. Later, Apple co-founder Steve Wozniak reported the same situation. These stories quickly went viral and raised serious questions about bias in the AI algorithm responsible for calculating credit limits. Despite public pressure and a formal investigation launched by New York regulators, both Apple and Goldman Sachs denied any gender discrimination, stating that the algorithm was fair and did not use gender as a factor. However, many people remained unconvinced due to the lack of transparency in the algorithm's decision-making process*." This case was selected because it clearly demonstrates the complexity of AI ethics in real life. The same event was interpreted in different ways by the public, companies, media, and regulators. Some believed it showed clear gender discrimination by the algorithm, while others suggested it was a misunderstanding or a result of weak regulation. Such diversity of opinions made the case suitable for student debate and ethical reflection.

As part of their preparation for the classroom debate, students were asked to conduct a web-based investigation of the selected AIID case. The goal was to help them gather reliable, diverse, and up-to-date information and to practice using academic English for analysis and argument construction. Students were provided with guiding questions to structure their search and prepare meaningful arguments, such as: "*Use the AIID link provided and search for additional information using English-language news websites, expert blogs, or official company statements. Write short notes in English for each question. Be ready to discuss your findings in class.*"

Additionally, we suggested the following questions for their web-quest:

– What was the main complaint about the Apple Card in 2019? Who were the first people to report it? (Look for names, roles, quotes.)

– How did Apple and Goldman Sachs respond to these complaints? (Find official statements or interviews.)

– Did the companies or developers explain how the credit algorithm works? (Look for mentions of "transparency," "bias," or "factors used in the model.")

– Was there any investigation by government agencies or regulators? What did they find? (Find articles about the New York Department of Financial Services or other institutions.)

– What do experts say about algorithmic bias in finance? (Search for "AI bias in credit scoring" or "gender discrimination in financial algorithms.")

– Are there similar cases involving AI in other areas (e.g., hiring, housing, health)? Briefly describe one.

– What is your personal opinion: Was the algorithm biased, or was it a human misunderstanding? Why?

To support students in preparing for the debate, a focused **lexical set** was introduced to help students describe ethical issues, express opinions clearly, and participate in formal academic discussions. The words and phrases were practiced in class through short tasks before the debate session (see table 4).

Table 4.
Key Terms from the Incident

Term / Phrase	Definition / Use in Context
algorithmic bias	unfair outcomes caused by patterns in data used by AI systems. *E.g., "The case shows possible algorithmic bias in credit decisions."*
gender discrimination	treating people differently based on gender. *E.g., "Was this case an example of gender discrimination?"*
credit limit	the maximum amount of money a person can borrow. *E.g., "The woman received a lower credit limit than her husband."*
transparency	openness in how something works. *E.g., "The company refused to explain the algorithm, showing a lack of transparency."*
regulatory oversight	control or investigation by government institutions. *E.g., "The incident led to regulatory oversight by financial authorities."*

Students were given one week for preparation. They worked in groups of 4. Each group researched the Apple Card incident and prepared two sides: one defending the company, the other criticizing the AI decision-making. In-class debates took 45 minutes and were structured as following:

– Opening statements (2 min per side).
– Rebuttals (2 min per side).
– Q&A from audience.
– Final arguments (1 min per side).

The final stage was the post-debate reflection where each student submitted a short paragraph on what they learned and how their opinion changed.

This table below (see table 5) clearly outlines how students' performance was measured and emphasizes the interdisciplinary nature of the task (ethical literacy and language learning).

Table 5.
Assessment Criteria for the AI Ethics Debate Task

Assessment Area	Description	Max Points
Ethical Reasoning and Analysis	Demonstrates clear understanding of ethical issues in the incident; provides balanced, logical, and well-supported ethical arguments.	30
Use of Evidence and Research	Uses relevant data from the AIID and external sources; shows awareness of different viewpoints.	20
Academic English and Specialized Vocabulary	Uses appropriate ethical/legal/AI-related terminology; language is clear, formal, and well-structured.	15
Debate Performance	Clear structure, confident delivery, and effective response to opposing arguments and audience questions.	15
Team Collaboration and Participation	Equal participation in preparation and presentation; smooth role sharing in debate.	10
Reflective Writing	Insightful and honest personal reflection on what was learned and how perspectives evolved.	10
Total		**100**

As a result of this activity, students deepened their understanding of the ethical risks associated with AI-based decision-making, particularly in relation to fairness, transparency, social responsibility, etc. Also, students developed their ability to express and justify complex ideas using formal academic English, including ethical and technical vocabulary relevant to the field of artificial intelligence. In addition, the activity fostered critical thinking, as students were required to consider multiple perspectives on a controversial incident and evaluate the reliability of different sources. The structured debate also strengthened collaboration skills because students worked in teams to research, prepare, and deliver coherent arguments. The written reflection allowed students to connect ethical knowledge with personal values. We consider such activity essential for developing students' academic integrity and professional responsibility in

future contexts.

The AIID activities we presented are part of a series of educational practices aimed at raising students' awareness of the ethical principles of using AI in education. The activity not only demonstrated the importance of ethical considerations when using AI but also provided a platform for developing key language skills.

We asked students to share their thoughts about the activity: some of them, when reflecting on their experiences, noted both the challenges and the insights gained from analyzing real-life AI incidents. Many reflected on the complexity of ethical decision-making and the need for critical thinking when evaluating AI-generated information. Students discovered not only interesting and useful web resources, but also authentic vocabulary which can be used in their future professional field. We believe that this dual-focus approach of raising ethical awareness while simultaneously developing language competencies has the potential to be an effective educational strategy that could be further integrated into the curriculum on a more permanent basis.

Conclusion

The results of the study show that ChatGPT is playing an increasingly important role in the learning activities of dual-degree students. The data reveals characteristic patterns of AI use that highlight ethical controversies and varying levels of dependence on such tools. ChatGPT has become a habitual tool for many students. Indeed, this is a global trend that we cannot fight. Such regular use highlights the importance of AI as a learning assistant for students with a high academic workload. However, easy access to information may reduce the level of independent work and assimilation of necessary knowledge. AI makes it easier to complete academic tasks, and we are concerned that this tends to reduce engagement in the learning process and contribute to the development of dependence on technology. On the other hand, our study revealed differing views on the ethics of using ChatGPT: some students consider the use of AI entirely acceptable, while others believe that it should be used with reservations. The second important aspect is related to checking the information provided by AI: although many check the information received from AI, some students do not, which can lead to errors in their academic and future professional activities. Developing a habit of fact-checking is necessary to prevent excessive dependence on technology.

The integration of the AIID based activities into English language classes emerged as a productive method for enhancing both ethical awareness and language proficiency. Activities such as incident analysis and structured debate allowed students to engage with real-world dilemmas as well as to improve their language skills. This dual-focus strategy such as combining critical thinking with language acquisition proved effective in reinforcing academic integrity and preparing students for ethically responsible professional practice.

While this study has provided valuable insights, it also opens several ideas for future exploration:

– To learn more about the long-term effects of generative AI in education, future studies should look at how students' use of AI and their moral views change over multiple school years.

– Comparative research in different fields of study may show if students in technical, social science, or humanities subjects use AI technologies in different ways when it comes to ethics and reliance.

– Looking at how teachers feel about and are ready to deal with ethical problems connected to AI can help with making decisions about professional development programs and institutional policies.

– We need to find out how well certain digital literacy programs help students learn how to think critically about information created by AI and how to use these tools without becoming too dependent on them.

Conflict of Interest Statement

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Author Contributions

Murzalinova A.: Data curation, Writing – Original draft preparation, Software, Supervision, Writing - Reviewing and Editing, Investigation, Project administration. Shannon A., Yensegenova G.: Conceptualization, Methodology, Resources. Mochshenko Y., Bunina A., Zhaxylykova Y.: Validation,

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MICRO-CREDENTIALS IN HIGHER EDUCATION: INTERNATIONAL TRAJECTORIES OF INSTITUTIONALIZATION AND THE EMERGING KAZAKHSTAN MODEL

Abstract. Micro-credentials have become increasingly prominent in higher education, yet their institutional role remains unsettled across policy and academic contexts. This article examines how the concept has evolved internationally, how different trajectories of institutionalization have emerged across higher education systems, and how micro-credentials are being adapted within a transitional and regulated higher education system. The study combines a narrative literature review with comparative policy analysis of international policy documents, academic research, and Kazakhstan-specific regulatory and institutional materials. The findings show that micro-credentials do not follow a single global model but develop through different combinations of framework integration, market responsiveness, institutional mediation, and labor-market alignment. Four major international trajectories are identified – top-down regulated, supranational collaborative, decentralized market-driven, and hybrid – and Kazakhstan is analyzed as an emerging hybrid, multi-tiered model in which state-defined categories, qualifications frameworks, university-level implementation, and labor-function orientation are being assembled into a regulated but institutionally mediated system. To interpret these dynamics, the article proposes a Macro-Meso-Micro conceptual framework for transitional higher education systems, capturing the interdependence between regulatory architecture, institutional capability, and learner-facing recognition mechanisms. The study concludes that the credible integration of micro-credentials depends less on rapid expansion than on coordinated development across all three levels simultaneously.

Keywords: micro-credentials; higher education; lifelong learning; qualification frameworks; labor market; professional standards; Kazakhstan.

Introduction

Micro-credentials have become a prominent reference point in contemporary debates on higher education reform, lifelong learning, and workforce adaptation. Their growing visibility reflects a convergence of structural pressures: accelerating digital transformation, rapid skills obsolescence, and rising institutional and policy demand for shorter, more flexible, and more targeted forms of certified learning (Council of the European Union, 2022; OECD, 2021). In this context, higher education institutions face pressure to respond not only through full degree programs, but also through smaller learning units that can be completed, recognized, and, in some cases, accumulated toward larger qualifications over time. The appeal of micro-credentials lies in their apparent capacity to expand access to continuing education, support upskilling and reskilling at scale, and create more flexible pathways between formal education and labor-market needs (Cedefop, 2022; Brown et al., 2021; McGreal & Olcott, 2022). For this reason, they are increasingly discussed as a mechanism through which universities may diversify provision without abandoning the degree structure that remains central to higher education systems worldwide.

Yet rapid expansion has not produced conceptual clarity. What counts as a micro-credential, how it should be quality assured, whether it belongs inside formal higher education, and how it relates to national qualifications frameworks remain genuinely contested rather than settled questions. The 2022 Council of the European Union Recommendation sought to establish common principles for the development, recognition, and quality assurance of micro-credentials in the context of lifelong learning and employability, yet the literature consistently shows that their design, governance, and recognition are shaped by different

educational traditions, regulatory environments, institutional strategies, and stakeholder expectations (Oliver, 2019; Brown et al., 2021; UNESCO, 2022; Varadarajan et al., 2023). This lack of consensus is not a minor definitional issue. It shapes how micro-credentials are institutionalized across national and institutional settings and determines whether they become credible components of qualifications systems or remain fragmented at the margins of higher education.

Despite the rapid growth of research in this field, the literature remains concentrated primarily on mature, market-driven systems – particularly in North America, Australia, and Western Europe – and on general definitional, policy, and stakeholder questions (Brown et al., 2021; Kato, Galán-Muros, & Weko, 2020; Varadarajan et al., 2023). Significantly less attention has been paid to how micro-credentials develop within transitional and more strongly regulated higher education systems, where institutionalization depends not only on flexibility and employer demand, but also on state steering, qualification frameworks, stakeholder alignment, and institutional implementation capacity (Ahsan et al., 2023; McGreal & Olcott, 2022; Selvaratnam et al., 2024). In particular, there is still limited research on how universities in such contexts translate national policy mandates into credible and sustainable practices, how multiple stakeholders align around these reforms, and how the tension between regulatory control and educational flexibility shapes the institutionalization of micro-credentials (Kato, Galán-Muros, & Weko, 2020; Varadarajan et al., 2023).

This gap is especially consequential in the case of Kazakhstan, where micro-credentials are being introduced through a formally regulated, policy-driven model that differs substantially from the market-led approaches dominant in the existing international literature. The Concept of Development of Higher Education and Science for 2023–2029 explicitly promotes lifelong learning, minor programs, and micro-credentials, while the updated State Compulsory Standard of Higher Education institutionalizes stackable degrees, nano-credits, and micro-credentials at the regulatory level (Government of the Republic of Kazakhstan, 2023; Ministry of Science and Higher Education of the Republic of Kazakhstan, 2022). Alongside this policy architecture, the Law on Professional Qualifications and the Rules for Recognizing Outcomes of Non-Formal Learning establish legal pathways through which universities may evaluate and convert non-formally acquired learning into academic credit (Law of the Republic of Kazakhstan, 2023; Ministry of Education of the Republic of Kazakhstan, 2023). Despite this formally advanced architecture, the dynamics of Kazakhstan's emerging model – including its institutional implementation, governance tensions, and position within comparative international trajectories – have not yet been systematically analyzed in the international academic literature.

This article addresses three research questions. RQ1: How are micro-credentials conceptualized internationally, and what major institutional trajectories can be identified in their development across higher education and lifelong learning contexts? RQ2: How is the concept of micro-credentials being adapted and institutionally integrated into a transitional and regulated higher education system, with particular reference to Kazakhstan? RQ3: What institutional, policy, and pedagogical challenges must be addressed to support the credible and sustainable implementation of micro-credentials in such contexts? To address these questions, the article combines a narrative literature review with comparative policy analysis, proposes a Macro-Meso-Micro conceptual framework for transitional higher education systems, and draws on a dedicated national corpus of Kazakhstani regulatory, institutional, and empirical materials.

Methodology

This study adopts a qualitative design combining a narrative literature review with comparative policy analysis. The methodological purpose is to identify major conceptual approaches to micro-credentials, examine international patterns of institutionalization, and analyze how micro-credentials are being integrated into higher education systems and qualification frameworks, with particular attention to transitional and regulated contexts.

A narrative literature review was selected because micro-credentials represent an emerging and conceptually heterogeneous field shaped by both academic debate and policy development. In educational research, review-based approaches are widely used to synthesize developing bodies of knowledge, identify recurring themes, and clarify conceptual and institutional trends (Grant & Booth, 2009; Snyder, 2019). This approach is especially appropriate here because the field remains marked by definitional variation, uneven

institutionalization, and divergent policy interpretations across national settings (Brown & Nic Giolla Mhichíl, 2022; Varadarajan et al., 2023). The study does not follow the full procedure of a formal systematic review and does not claim exhaustive coverage. Rather, it applies a transparent, question-driven review logic designed to support conceptual synthesis and comparative analysis – an approach well-established for fields in which the research objective is analytically grounded interpretation rather than exhaustive retrieval (Snyder, 2019).

The analysis included academic publications, policy reports, and analytical documents published between 2015 and 2026, identified through Scopus, Web of Science, and EBSCOhost using keyword combinations including "micro-credentials," "alternative credentials," "digital badges," and "higher education." Sources were selected on the basis of their relevance to the research questions and their contribution to at least one of the following analytical dimensions: conceptual definitions, institutional models of implementation, higher education integration, qualification-framework alignment, stakeholder expectations, and implementation challenges. In addition to peer-reviewed literature, the source base included policy and analytical documents produced by the European Commission, OECD, UNESCO, and Cedefop, treated as primary evidence for formal definitions, governance arrangements, and recognition mechanisms. Academic studies were used primarily to interpret conceptual debates, implementation challenges, and comparative trajectories.

To address the Kazakhstan case, the study incorporated a focused national corpus comprising legal and regulatory documents, state standards, qualifications-framework materials, institutional regulations, monitoring reports, and recent empirical studies – including Sovetkanova et al. (2026) and Borgekova et al. (2026) as the most substantive peer-reviewed contributions currently available on the Kazakhstani context. These materials were used to examine how international micro-credentials discourse is being adapted within a regulated national context and to distinguish between policy intent, formal legal architecture, and actual institutional implementation. The use of grey and institutional sources – including university regulations, conference presentations, and national monitoring reports – is acknowledged as a limitation inherent to the analysis of an emerging policy field where peer-reviewed empirical evidence remains limited.

The analytical procedure combined thematic synthesis, interpretive analysis, and comparative policy interpretation. First, the literature was reviewed to identify recurring conceptual and policy themes, major patterns, and unresolved tensions, including definitions, scenarios of development, typologies, and models of integration. Second, these themes were interpreted comparatively to examine how different national and supranational contexts position micro-credentials in relation to higher education, lifelong learning, labor-market demand, and formal recognition. Third, the Kazakhstan case was analyzed as a policy-oriented example of a regulated and institutionally embedded model, situating national developments within the broader international discussion.

Literature Review

Interest in micro-credentials has grown significantly over the past decade as education systems and labor markets have undergone rapid transformation. Recent scholarship increasingly suggests that micro-credentials should not be understood as a single stable category, but rather as part of a broader and evolving credential ecology shaped by educational, economic, and policy change (Brown & Nic Giolla Mhichíl, 2022). Rather than representing a linear progression from digital badges to formalized short credentials, the literature reveals a set of unresolved tensions between flexibility and regulation, employability and academic coherence, stackability and standalone signaling, and innovation and recognition architecture. These tensions suggest that micro-credentials are not simply a new educational product, but a contested institutional form whose meaning varies across higher education systems.

One of the earliest strands of research emerged in the context of digital badges and alternative credentialing systems, where early studies highlighted the possibility of recognizing smaller and more granular forms of learning outside traditional degree structures (Gibson et al., 2016; Kato et al., 2020; Varadarajan et al., 2023). Over time, the concept expanded beyond digital badges to include a broader range of short learning programs offered by universities, training providers, and online platforms, reinforcing conceptual ambiguity as terms such as digital badges, alternative credentials, nanodegrees, and micro-credentials were used inconsistently or interchangeably. More recent literature has shifted attention toward

the institutional role of micro-credentials in higher education, where they are increasingly presented as a means of complementing traditional degrees by enabling learners to acquire more targeted professional competencies, strengthen employability, and participate in more flexible forms of lifelong learning (Wheelahan & Moodie, 2022; Bruguera et al., 2024; Pirkkalainen et al., 2023). Universities are correspondingly discussed as active actors in the design and delivery of micro-credentials, attempting to align academic provision with emerging policy agendas and labor-market demand, though institutional implementation depends heavily on governance, standards, resourcing, staff capacity, and assessment design (Selvaratnam & Sankey, 2021; Selvaratnam et al., 2024; Reed et al., 2024).

The literature contains a substantial critical strand that must not be overlooked. Wheelahan and Moodie (2022) argue that the expansion of micro-credentials may weaken the broader knowledge-based and developmental functions of higher education, particularly when short-form credentials are shaped primarily by immediate labor-market demand. Ralston (2021) similarly criticizes the growing commodification of higher education and warns against reducing education to short-cycle, market-oriented training detached from broader intellectual and civic purposes. Pollard and Vincent (2022) further suggest that micro-credentials risk becoming embedded in neoliberal policy narratives that reframe higher education primarily through employability and market responsiveness. These critical perspectives are analytically important because they establish the normative stakes of micro-credentials development: the question is not only what micro-credentials certify, but what kind of higher education system their expansion gradually normalizes.

Three further debates structure the field. First, whether micro-credentials can remain flexible while being integrated into systems of formal recognition. The more short-form learning is brought into formal qualifications systems, the greater the pressure to standardize it; the more it remains open and demand-responsive, the greater the risk of fragmentation and weak trust (Cedefop, 2022, 2023; Council of the European Union, 2022). Second, whether stackability – frequently presented as one of the defining strengths of micro-credentials – can be operationalized in practice. McGreal and Olcott (2022) caution that stackability may look persuasive in policy rhetoric while remaining highly difficult to implement across institutions and systems, a concern supported by recent evidence showing that credit transfer and accumulation remain contested and context-dependent (Parsons et al., 2025; Selvaratnam et al., 2024). Third, whether the value of micro-credentials depends primarily on employer signaling or on academic recognition, since learners, universities, employers, and governments often attach different and sometimes incompatible expectations to the same credential (Varadarajan et al., 2023; Oliver, 2019; Kalabuki & Uzorka, 2026).

The literature identifies three interrelated conditions for successful institutionalization. Higher education institutions require sufficient implementation capacity, including governance arrangements, standards, technological infrastructure, staffing, and assessment design. Micro-credentials depend on alignment among multiple stakeholders, since divergent expectations among learners, universities, employers, and governments must be actively managed rather than assumed away. And their long-term credibility is strengthened when they are linked to qualification frameworks and formal recognition mechanisms (Varadarajan et al., 2023; Selvaratnam et al., 2024; Brown et al., 2021). These conditions are especially important in more regulated and transitional systems, where formal recognition and quality assurance are expected to generate the institutional trust that fragmented credential markets struggle to produce (Kalabuki & Uzorka, 2026). Taken together, the literature indicates that micro-credentials are best understood as contested and context-dependent institutional arrangements rather than as a single stable educational form – a conclusion that makes comparative analysis of different national trajectories both necessary and analytically productive.

Results

The Global Credential Ecology: Definitions and Analytical Dimensions

The international development of micro-credentials has produced not a single stable concept, but a broader credential ecology marked by terminological expansion, policy experimentation, and increasing institutional differentiation. Early discussions often used micro-credentials interchangeably with digital badges, alternative credentials, MOOCs, and nanodegrees, reflecting the absence of a clear boundary between technological formats, short learning experiences, and formal recognition mechanisms (Brown et al., 2021; Kato et al., 2020; Varadarajan et al., 2023). Over time, the discussion shifted toward understanding

micro-credentials as more structured forms of certified learning with potential relevance for higher education, employability, and qualification systems. Despite this shift, no universally accepted definition has emerged. Instead, international organizations and academic authors frame micro-credentials in overlapping but analytically distinct ways, differing in their emphasis on assessment, stackability, qualification-framework integration, labor-market relevance, and higher education use.

Table 1 summarizes the main international framings and highlights their differences in emphasis and implications for higher education.

Table 1
International Framings of Micro-Credentials

Source	Core framing	Main emphasis	Implication for higher education
Council of the European Union (2022)	Record of learning outcomes acquired through a small volume of learning and assessed against transparent criteria	Learning outcomes, assessment, transparency, portability	Supports formal recognition and integration into qualification frameworks and higher education pathways
OECD (2023)	Smaller, more targeted, and more flexible credentials linked to organized learning activities	Lifelong learning, labor-market responsiveness, flexibility	Highlights institutional innovation and responsiveness, while also pointing to tensions with rigid quality assurance systems
UNESCO (2022)	Record of focused learning achievement awarded by a trusted provider after assessment against defined standards	Inclusion, lifelong learning, standalone value, stackability	Emphasizes flexible progression, recognition of prior learning, and broader access
Cedefop (2023)	Framework-oriented application of micro-credentials in labor-market and vocational contexts	Qualification frameworks, modularization, recognition, trust	Strengthens formal readability and employer trust through framework integration
Oliver (2019)	Certification of assessed learning that may be additional, alternative, complementary to, or a formal component of a qualification	Assessed learning, employer relevance, exchange value	Links micro-credentials to employability, recognition, and institutional credibility
Brown et al. (2021)	Unbundled, credit-bearing, and potentially stackable credentials within a broader and unsettled credential ecology	Conceptual heterogeneity, institutional diversity, system change	Frames micro-credentials as part of wider transformation in higher education and credential systems

Note. The table summarizes major international framings of micro-credentials across policy and academic sources.

As Table 1 shows, the European policy approach has been particularly influential in stabilizing the concept through learning outcomes, transparent assessment, portability, and links to qualification frameworks (Council of the European Union, 2022). OECD publications frame micro-credentials more strongly in relation to flexibility, lifelong learning, and workforce responsiveness (OECD, 2023). UNESCO emphasizes focused learning achievement, inclusion, and the possibility of both standalone value and cumulative potential (UNESCO, 2022). Cedefop places stronger emphasis on qualification frameworks, modularization, recognition, and trust within labor-market and vocational contexts (Cedefop, 2023). In academic literature, Oliver (2019) emphasizes assessed learning and exchange value in relation to employers, whereas Brown et al. (2021) highlight the broader and still unsettled credential ecology in which

micro-credentials operate.

For analytical purposes, the most important differences across these framings can be grouped into four dimensions. The first concerns learning outcomes and assessment – whether micro-credentials are understood primarily as records of rigorously assessed achievement or as more flexible forms of certified learning. The second concerns stackability and progression – whether micro-credentials are expected to accumulate into larger qualifications or retain value as standalone signals of competence. The third concerns qualification-framework integration, which varies from strong alignment with formal frameworks to more open and decentralized forms of recognition. The fourth concerns labor-market relevance and higher education use – whether micro-credentials are framed primarily as instruments of employability and rapid upskilling or as components of formal university provision. These dimensions show that micro-credentials occupy a variable position between formal and non-formal learning, between institutional curriculum and external provision, and between short-cycle skill signaling and regulated qualification structures. This analytical framing shifts attention from definitional disagreement alone to the more consequential question of institutional positioning – how different systems institutionalize micro-credentials in practice – which the following section examines comparatively.

Trajectories of Institutionalization: A Comparative International Analysis

Comparative analysis shows that micro-credentials do not follow a single pathway of institutionalization. Across international contexts, they are being embedded in higher education through different balances of policy steering, market demand, qualification-framework integration, and institutional initiative. The reviewed literature points not to one dominant model, but to several recurring trajectories shaped by different governance arrangements, educational traditions, and quality-assurance logics (Brown et al., 2021; Kato et al., 2020; Orr et al., 2020; Cedefop, 2022, 2023). Table 2 summarizes these trajectories and compares them in terms of governance, framework integration, stackability, institutional drivers, and implications for higher education.

Table 2

Comparative Trajectories of Micro-Credentials Institutionalization in Higher Education

Trajectory / model	Illustrative systems	Governance and regulatory logic	Integration with qualification frameworks	Stackability / credit architecture	Primary drivers and institutional actors	Implications for higher education
Top-down regulated and integrated	New Zealand, Malaysia, partly Australia	Strong statutory or agency-led regulation; centralized approval and quality assurance	Strong or explicit integration into national frameworks; formal listing and recognition	More formalized and potentially credit-bearing; progression is structured and supervised	National quality agencies, ministries, regulated providers, HEIs	Supports trust, readability, and formal recognition, but may reduce agility
Supranational collaborative	European Union / EHEA	Policy steering through recommendations, shared principles, and cross-border coordination rather than one national mandate	Strong alignment with EQF, ECTS, Bologna tools, and national frameworks	Strong emphasis on portability, accumulation, and recognition across systems	EU institutions, university alliances, member states, HEIs	Encourages comparability and mobility while preserving higher education legitimacy

Decentralized market-driven	United States, partly Canada	Minimal centralized regulation; coordination depends on market demand, employer trust, and voluntary registries	Weak or uneven integration; no single unified national architecture	Often standalone, non-credit, or provider-specific; stackability is uneven	Platforms, employers, corporate issuers, entrepreneurial universities, registries	Maximizes innovation and responsiveness, but increases fragmentation and variability in trust
Mixed / hybrid policy-supported	Australia, Ireland, Singapore, provincial Canada	Combination of state support, institutional autonomy, and targeted policy steering	Partial, selective, or negotiated framework integration	Mix of stackable and standalone forms depending on system design	HEI consortia, governments, sector initiatives, universities, employers	Balances flexibility with coordination, but often produces uneven system coherence
Note. The table summarizes major trajectories of institutionalization identified in the reviewed source set. It compares systems by governance logic, qualification-framework integration, stackability, leading actors, and implications for higher education.						

A first trajectory may be described as top-down regulated and integrated institutionalization. In this model, micro-credentials are embedded formally within national education systems through statutory rules, centralized approval processes, and explicit quality-assurance requirements. New Zealand is the clearest example: micro-credentials were incorporated into the New Zealand Qualifications and Credentials Framework, and providers must demonstrate industry or community need and undergo formal approval before a credential can be recognized (New Zealand Qualifications Authority, 2018, 2019, 2023; Parsons et al., 2025). Malaysia similarly operates through national guidance issued by the Malaysian Qualifications Agency linking credit-bearing micro-credentials to the Malaysian Qualifications Framework (MQA, 2020; Ahmat et al., 2021). Australia belongs partly to this trajectory in a more mixed form, having promoted a National Microcredentials Framework while deliberately avoiding full integration into the Australian Qualifications Framework in order to preserve institutional flexibility (Department of Education, Skills and Employment, 2021; OECD, 2023, 2024; Selvaratnam & Sankey, 2021). This trajectory prioritizes trust, formal readability, and regulatory coherence, but raises the question of how much agility can be preserved once short-form learning is tightly governed.

A second trajectory is supranational collaborative institutionalization, most clearly associated with the European Union and the broader European Higher Education Area. Here, institutionalization is driven not by one national authority, but by coordinated policy guidance, shared principles, and common recognition instruments. The 2022 Council Recommendation frames micro-credentials as complementary to existing qualifications and promotes transparency, portability, and recognition across borders (Council of the European Union, 2022), relying heavily on alignment with the European Qualifications Framework and ECTS to support comparability and stackability (European Commission, 2020, 2022; Lantero et al., 2021; Cedefop, 2023). European university alliances and consortia seek to keep micro-credentials anchored within higher education values rather than allowing the field to be shaped entirely by external providers (Orr et al., 2020; Cirlan & Loukkola, 2020; Bideau & Kearns, 2022). Compared with the top-down regulated model, this trajectory relies more on consensus and soft-law steering than on statutory control, yet still seeks strong framework alignment and formal recognition. Finland and Poland further illustrate that some European systems emphasize consensus-based coordination without collapsing into a single institutional formula (Trepule et al., 2021; Dybaś-Stronkowska & Pieńkosz, 2019; Cedefop, 2022).

A third trajectory is decentralized market-driven development, most strongly associated with the

United States and, in a more mixed form, Canada. Micro-credentials circulate in a fragmented landscape shaped by employers, digital platforms, technology companies, and independent institutional initiatives rather than by a unified national qualifications architecture (Kato et al., 2020; McGreal & Olcott, 2022; OECD, 2021, 2023). In the United States, universities act as entrepreneurial actors within an open marketplace, frequently partnering with MOOC platforms and corporate issuers to offer standalone badges, certificates, and short-cycle credentials whose value depends heavily on market signaling and employer trust rather than statutory recognition (Brown et al., 2021; Fong et al., 2016; Credential Engine, 2021; Shah, 2021; Kumar et al., 2022). Canada presents a more hybrid case: Ontario and British Columbia have moved toward stronger policy support through provincial portals, funding mechanisms, and targeted upskilling initiatives, but without creating a single national model (McGreal & Olcott, 2022; Government of Ontario, 2020; eCampusOntario, 2023; OECD, 2024). This trajectory maximizes responsiveness and innovation, but produces the strongest concerns about fragmentation, uneven quality assurance, and weak comparability across providers.

The comparative material also points to mixed and hybrid models that do not fit neatly into a single category. Ireland combines university-led development with state support and framework alignment through the MicroCreds initiative, government funding, and ECTS-bearing, quality-assured provision linked to the National Framework of Qualifications (Irish Universities Association, 2020; Nic Giolla Mhichíl et al., 2020; McCoshan, 2023; OECD, 2024). Singapore represents another hybrid configuration in which state steering and labor-market alignment are combined through SkillsFuture, producing a system that is simultaneously government-steered and highly responsive to industry demand (Government of Singapore, 2023; OECD, 2023). These mixed cases show analytically that institutionalization is not simply a matter of choosing between regulation and market responsiveness – in practice, many systems combine elements of both, with different outcomes for coherence, trust, and portability (Pouliou, 2024; Brown, McGreal, & Peters, 2023).

Taken together, the international evidence suggests that micro-credentials are institutionalized through different balances of state control, supranational coordination, institutional autonomy, and market dynamics. What varies across systems is not simply whether micro-credentials exist, but how they are governed, recognized, stacked, funded, and trusted. This comparative pattern is especially important for the present study because it establishes that Kazakhstan does not fit a purely market-driven or loosely coordinated model. Rather, as the following section demonstrates, Kazakhstan is best interpreted as an emerging hybrid trajectory that combines top-down framework integration with decentralized university implementation and labor-market-oriented content making it especially relevant for understanding micro-credentials institutionalization in transitional systems.

The Kazakhstan Case: A Hybrid, Multi-Tiered Model of Regulated Institutionalization

In comparative terms, Kazakhstan is best understood as a hybrid, multi-tiered model of micro-credentials institutionalization. At the macro level, the system is state-framed and framework-oriented: the government defines the relevant units in official regulatory documents, links short-form learning to the National Qualifications System, and embeds reform in strategic policy. At the meso level, implementation is decentralized and university-led, since higher education institutions are formally empowered to recognize non-formal learning, approve micro-credential programs, and convert them into formal academic value. At the content level, the model is strongly labor-market-oriented, because micro-credentials are explicitly tied to labor functions, professional standards, and employer participation. This configuration differs from Malaysia, where national framework integration preceded and shaped institutional implementation through centralized agency guidance (MQA, 2020; Ahmat et al., 2021), and from Ireland, where university-led development preceded formal state coordination (Nic Giolla Mhichíl et al., 2020; McCoshan, 2023). In Kazakhstan, by contrast, regulatory architecture and institutional experimentation have developed simultaneously and interactively, producing a model that is neither purely top-down nor purely bottom-up but genuinely hybrid in its governance logic (Borgekova et al., 2026; Government of the Republic of Kazakhstan, 2023; Kato et al., 2020).

The formal regulatory architecture is the first distinguishing feature of the Kazakhstani model. The State Compulsory Standard of Higher Education defines a micro-credential as a volume of knowledge, skills, and competencies sufficient to perform one distinct labor function acquired during short-term training; a nano-credit as a unified unit of measurement for a small and self-contained volume of learning; and

stackable degrees as an accumulation of skills and competencies obtained through formal and non-formal education (Ministry of Science and Higher Education of the Republic of Kazakhstan, 2025). Unlike many international framings that begin with small units of assessed learning, the Kazakhstani model defines short-form credentials through their sufficiency for one distinct labor function and their place within a larger accumulation logic. The Concept of Development of Higher Education and Science for 2023–2029 further mandates that micro-credentials and nano-learning outcomes be recognized across educational levels and that certificates and credits obtained through short-term courses be translated into stackable degrees, while also calling for a unified system of academic and non-credit learning and an updated National Qualifications Framework (Government of the Republic of Kazakhstan, 2023). The Law on Professional Qualifications and the Rules for Recognizing Outcomes of Non-Formal Learning provide the legal pathway through which universities may evaluate non-formally acquired learning and convert it into formal academic credit (Law of the Republic of Kazakhstan, 2023; Ministry of Education of the Republic of Kazakhstan, 2023). This legal architecture is closely tied to the qualifications framework and professional standards system: the updated National Qualifications Framework supports transitions between levels through recognition of formal, non-formal, and informal learning, while professional standards define the labor requirements to which micro-credentials must correspond (National Qualifications Framework of the Republic of Kazakhstan, 2025; Atameken, 2016; Cedefop, ETF, UNESCO, & UIL, 2019).

Importantly, the Kazakhstan case can no longer be described only in terms of policy intent – there is now clear evidence of actual institutional implementation across multiple universities and fields. Almaty Technological University has developed 25 micro-credential programs in cooperation with industry (Nurakhmetov, 2023). Satbayev University has formalized internal regulations governing the development and recognition of micro-credentials, including the issuance of microcertificates and open badges (Satbayev University, 2025). Astana IT University and IITU have implemented technology-focused micro-credentials such as Python Developer and ML Specialist, including a documented 16-credit, 480-hour certificate. Toraighyrov University has embedded engineering-oriented micro-credentials into bachelor's programs linked to regional industrial demand, while other institutions have launched targeted programs in STEM pedagogy, speech therapy, and economic-crime investigation (Sadykov et al., 2023). The national monitoring data further indicate that implementation extends beyond isolated pilots: 64,451 learners studied on Coursera within educational programs across 37 higher education institutions practicing credit transfer, while 187,104 learners completed Huawei ICT courses with 95,873 certificates issued across 33 universities (National Center for Higher Education Development, 2025). These data show that the recognition of externally acquired platform-based learning is already an operational feature of the system, not merely a policy aspiration.

The most substantive empirical evidence currently available is provided by Sovetkanova et al. (2026), whose study of a Stackable Degree pilot in graduate teacher education documents five implemented micro-credential programs and identifies the conditions required for portability and stackability in the Kazakhstani context. The authors demonstrate that practical portability depends on alignment of learning outcomes with the NQF, clear rules for credit transfer and stackability, established recognition-of-prior-learning procedures, enforceable quality assurance requirements, and verifiable digital credentials – thereby bridging the gap between macro-level policy and meso-level implementation and showing that state mandates alone are insufficient without interoperable recognition procedures and credible digital verification (Sovetkanova et al., 2026; McGreal & Olcott, 2022).

At the same time, the evidence points to important systemic tensions. Despite visible institutional uptake, Kazakhstan still lacks a unified national registry of micro-credentials, and the source base indicates heterogeneity of approaches across universities, the absence of a single republican accreditation standard, and persistent reluctance among some institutions to integrate micro-credentials into traditional programs (Jomartova, 2025; Borgekova et al., 2026). Two limitations must be stated explicitly. First, employer recognition remains insufficiently documented at the system level: although many programs are designed around labor-market demand and employer participation, the evidence does not yet establish how consistently employers interpret, trust, and reward these credentials. Second, learner-outcome evidence remains partial: beyond the teacher-education pilot and selected survey results, longitudinal evidence on wage returns, career mobility, or inclusion effects is still limited (Varadarajan et al., 2023; McGreal &

Olcott, 2022; Wheelahan & Moodie, 2022).

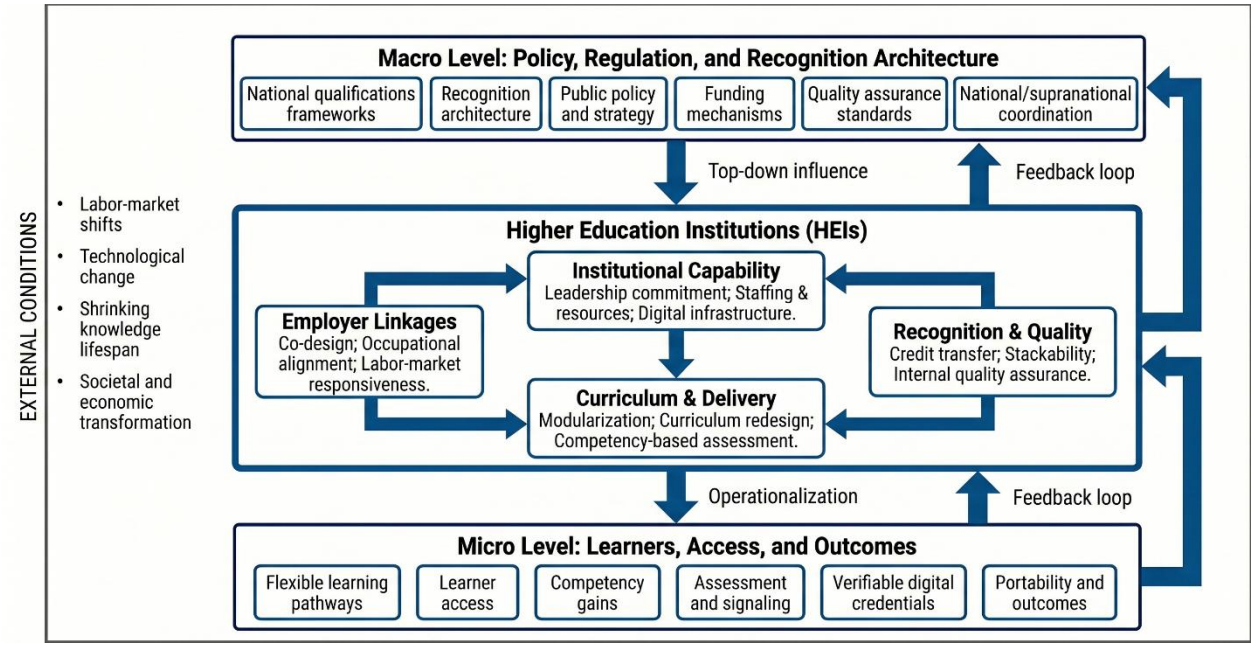
Taken together, Kazakhstan illustrates a distinctive pathway in which official definitions, qualification frameworks, university autonomy, and labor-market alignment are being assembled into a hybrid governance model. Its main strength lies in the existence of a formal legal basis, a clear state strategy, and already visible institutional uptake across multiple universities and recognition channels. Its main weakness lies in uneven implementation, fragmented institutional practice, the absence of unified accreditation and registry infrastructure, and still limited evidence on employer trust and long-term outcomes. Kazakhstan is therefore best interpreted not as a completed model, but as an emerging regulated and institutionally mediated trajectory at a critical juncture: the macro-level architecture is largely in place, the meso-level implementation is underway but uneven, and the micro-level outcomes remain insufficiently documented. This three-level unevenness is precisely what the Macro-Meso-Micro framework proposed in the following section is designed to capture – and what makes Kazakhstan an analytically productive case for understanding the conditions under which transitional higher education systems can move from regulatory ambition to credible and sustainable micro-credentials integration.

A Conceptual Framework for Micro-Credentials Integration in Transitional Higher Education Systems

The preceding analysis suggests that the integration of micro-credentials in transitional higher education systems cannot be explained adequately through definitions or country cases alone. What is required is a framework that captures the vertical interdependence between state regulation, institutional implementation, and individual learning outcomes. For the purposes of this article, a Macro-Meso-Micro (MMM) framework is the most analytically appropriate because it captures both hierarchy and interaction: macro-level policy settings shape meso-level institutional possibilities, which in turn structure micro-level learner pathways and outcomes (Varadarajan et al., 2023; Brown et al., 2021). This multi-level logic is well-established in educational research, where systemic change is understood as inherently cross-level – neither reducible to policy design alone nor to individual institutional choices (Ehlers, 2018; Selvaratnam et al., 2024). Figure 1 visualizes the framework and shows how the three levels interact within a transitional higher education system under external pressures of labor-market change, technological shifts, and shrinking knowledge lifespans.

Figure 1

Conceptual Framework for Micro-Credentials Integration in Transitional Higher Education Systems



Note. *The figure presents micro-credentials integration as a Macro-Meso-Micro ecosystem. The Macro level includes regulation, qualifications frameworks, recognition architecture, and public policy conditions. The Meso level places higher education institutions at the center of implementation and shows their interaction with employers, institutional capability, curriculum redesign, quality assurance, and recognition procedures. The Micro level captures learner access, assessment,*

portability, digital credentials, and individual outcomes. The framework also acknowledges external conditions, including labor-market change, technological shifts, and the shrinking lifespan of knowledge, as cross-cutting pressures on all three levels. This structure is supported by the literature on stakeholder ecosystems, institutional readiness, and multi-level educational change, and is especially relevant for transitional systems where state regulation, institutional mediation, and learner-facing mechanisms must develop in coordination (Brown et al., 2021; Varadarajan et al., 2023; Selvaratnam et al., 2024; Cedefop, 2022, 2023).

At the Macro level, micro-credentials integration depends on state policy, qualifications governance, and national or supranational regulatory architecture. This level establishes the legal and systemic conditions under which short-form learning can become credible, portable, and recognized. The literature consistently highlights the role of National Qualifications Frameworks, standardized credit architectures, public funding mechanisms, and formal recognition systems in creating order within an otherwise fragmented credential ecology (Council of the European Union, 2022; Cedefop, 2022, 2023; OECD, 2021). In transitional systems, the macro level is especially consequential because rapid labor-market change and skills mismatches create simultaneous pressure for flexible learning and for regulatory coherence. Excessive rigidity may suppress innovation, so macro-level integration must balance quality assurance and comparability with sufficient space for institutional adaptation (OECD, 2021; Cedefop, 2022, 2023).

At the Meso level, the core issue is institutional and organizational capacity. Universities occupy the central mediating position in the ecosystem because they translate regulatory frameworks into actual curricula, assessment procedures, recognition systems, digital infrastructure, and employer partnerships (Varadarajan et al., 2023; Selvaratnam et al., 2024). Successful institutionalization at this level depends on leadership commitment, sustainable financial and staffing models, curriculum redesign, interoperable technological infrastructure, and the capacity to align micro-credentials with quality assurance and credit-transfer systems (Selvaratnam & Sankey, 2021; Brown, McGreal, & Peters, 2023). This is also the level where most operational friction appears – faculty resistance, workload pressures, weak digital capacity, and uncertainty about business models and institutional incentives – and where the tension between academic legitimacy and labor-market responsiveness must be actively managed rather than assumed away (McGreal & Olcott, 2022; Varadarajan et al., 2023).

At the Micro level, the framework focuses on learners, assessment design, and individual educational trajectories. Micro-credentials function here as flexible units that can support upskilling, reskilling, personalized pathways, and alternative routes into or through higher education (Tamoliune et al., 2023; Pirkkalainen et al., 2023; West & Cheng, 2023). The literature provides reasonably strong support for short-term learner motivations and competency gains, especially where learners value flexibility, targeted skill acquisition, and transparent signaling of specific competencies (Thi Ngoc Ha et al., 2024). However, long-term claims – seamless stackability, durable labor-market returns, democratizing effects – remain context-dependent and unevenly evidenced. The micro level should therefore be conceptualized not as a zone of guaranteed outcomes, but as the point where institutional and regulatory arrangements are experienced by individuals, often with unequal results depending on affordability, digital access, and employer recognition.

These three levels are not separate layers but interdependent dimensions of one transitional ecosystem. Macro-level frameworks define the legal and recognition environment. Meso-level institutions operationalize that environment through program design, partnerships, and administrative procedures. Micro-level learners encounter the resulting system through access, assessment, portability, and labor-market signaling. The framework is therefore not simply a stakeholder map but a causal model: it shows how micro-credentials move from policy architecture through institutional practice to individual educational and professional trajectories, and – critically – how failure at any one level destabilizes the others. Regulatory architecture without institutional capability produces formalism without delivery; institutional experimentation without recognition architecture produces fragmentation without legitimacy; and robust policy and institutional systems without learner-facing trust mechanisms produce credentials that are formally valid but practically inert.

The Kazakhstan case confirms the analytical value of this framework. At the Macro level, Kazakhstan already has state-defined terminology, qualifications-framework integration, and legal recognition of non-formal learning. At the Meso level, universities have begun implementing internal regulations, employer-linked programs, and credit-recognition procedures, but unevenly across institutions. At the Micro level, learners already receive microcertificates, digital badges, and recognized short-form credits, yet employer

trust, long-term outcomes, and equitable access remain unresolved. The MMM framework thus explains why transitional systems can simultaneously display regulatory advancement, institutional experimentation, and persistent gaps in system coherence – and why coordinated development across all three levels, rather than sequential progress through them, is the defining condition for sustainable micro-credentials integration (Sovetkanova et al., 2026; Government of the Republic of Kazakhstan, 2023; National Center for Higher Education Development, 2025).

Systemic Risks, Implementation Barriers, and Policy Implications

The preceding sections show that the institutionalization of micro-credentials in transitional systems is no longer merely a conceptual issue. However, expansion alone does not guarantee system coherence, public trust, or long-term sustainability. Across international practice, micro-credentials often grow faster than the recognition, quality assurance, and governance structures needed to stabilize them (Brown et al., 2021; Cedefop, 2022, 2023). In transitional systems, this risk is more pronounced because reform is expected to satisfy several objectives simultaneously – labor-market responsiveness, qualification-framework integration, institutional modernization, and learner flexibility – without the institutional maturity that more established systems have developed incrementally (Varadarajan et al., 2023; Selvaratnam et al., 2024).

At the Macro level, the central barrier is the structural tension between flexibility and regulation. Under-regulation produces fragmentation, inconsistent signaling, and weak public trust, whereas over-regulation reduces institutional responsiveness and undermines the agility that makes micro-credentials attractive in the first place (Cedefop, 2022, 2023; OECD, 2021). Kazakhstan reflects this tension clearly. On one hand, the country already has a legal and regulatory basis for micro-credentials, recognition of non-formal learning, and qualifications-framework integration – formal definitions in the State Compulsory Standard of Higher Education, recognition procedures, and policy commitments to stackability (Government of the Republic of Kazakhstan, 2023; Ministry of Science and Higher Education of the Republic of Kazakhstan, 2022). On the other hand, the system still lacks full coherence in critical areas: unified accreditation standards, a functioning national registry, and consistent recognition architecture across institutions remain incomplete (Borgekova et al., 2026; Jomartova, 2025). Kazakhstan has therefore moved beyond the purely declarative stage, but its macro-level architecture remains only partially consolidated.

At the Meso level, the most serious barriers concern uneven institutional readiness. Universities need more than policy authorization to implement micro-credentials effectively – they also require leadership commitment, internal regulations, sustainable staffing and funding models, interoperable digital systems, workable modularization strategies, and credible procedures for assessment, stackability, and credit recognition (Varadarajan et al., 2023; Selvaratnam & Sankey, 2021; Selvaratnam et al., 2024). This is also the level where operational friction is most visible: faculty resistance, workload pressures, uncertainty about business models, and tensions between academic rigor and labor-market responsiveness (McGreal & Olcott, 2022; Brown, McGreal, & Peters, 2023). The Kazakhstan evidence confirms these barriers in concrete form. Universities have developed internal regulations, employer-linked programs, credit-recognition practices, and digital badging mechanisms, as documented at Satbayev University, Almaty Technological University, Astana IT University, IITU, and Toraighyrov University (Satbayev University, 2025; Sadykov et al., 2023; National Center for Higher Education Development, 2025; Nurakhmetov, 2023). Yet the evidence also points to heterogeneity of approaches, the absence of a common standard, and persistent reluctance among some universities to integrate micro-credentials into traditional programs (Jomartova, 2025). In transitional systems, this produces a recurring risk of institutional fragmentation, where similar forms of short-form learning are designed, weighted, and recognized differently depending on the institution.

At the Micro level, the key risks concern trust, access, and the limits of current evidence. The literature provides reasonably strong support for short-term learner motivations and competency gains, especially where micro-credentials offer flexibility and targeted skill acquisition (Tamoliune et al., 2023; West & Cheng, 2023). However, long-term outcomes – wage returns, sustained employability, durable mobility – remain weakly evidenced across most contexts (McGreal & Olcott, 2022; Varadarajan et al., 2023). In Kazakhstan, learners are already receiving microcertificates, digital badges, and recognized short-form credits, and national monitoring data show large-scale participation through Coursera and Huawei ICT modules (National Center for Higher Education Development, 2025). Yet employer acceptance remains uneven, especially in regulated fields where the traditional diploma still functions as the dominant hiring

filter (Jomartova, 2025). Possible equity risks also arise if micro-credential programs become predominantly fee-based, and infrastructural barriers persist in regions with weaker digital connectivity (Jomartova, 2025).

A further systemic challenge is the gap between formal commitments and actual implementation. In Kazakhstan, policy and law have already introduced the language of micro-credentials, nano-learning, stackability, and non-formal recognition (Government of the Republic of Kazakhstan, 2023; Ministry of Science and Higher Education of the Republic of Kazakhstan, 2025). Yet the evidence still points to fragmented recognition, incomplete accreditation architecture, and unresolved interoperability issues across institutions (Borgekova et al., 2026; Jomartova, 2025). Where state steering, university autonomy, and labor-market alignment remain weakly synchronized, the result is not a coherent ecosystem but a partially connected system marked by variable portability, uneven trust, and incomplete quality assurance.

One major policy implication that follows directly from the MMM framework is the need for a dedicated registry mechanism for university micro-credential programs within Kazakhstan's national register of higher and postgraduate education programs. Comparative evidence confirms that registry-like mechanisms play a central role in strengthening transparency, verification, and public trust. New Zealand's public register of NZQA-approved micro-credentials standardizes title, framework level, credit volume, provider, and review dates, thereby supporting formal recognition (OECD, 2021, 2023; Kato et al., 2020). In Europe, the Europass and European Digital Credentials for Learning infrastructure supports authenticity, metadata standardization, and cross-border portability (PPMI Group, 2020). In the United States, Credential Engine seeks to improve transparency in a fragmented market by standardizing credential descriptions (Credential Engine, 2021; OECD, 2021, 2023). Analogous functions are visible in Australia's MicroCred Seeker, Ireland's MicroCreds.ie, Germany's hoch & weit portal, and Poland's Odznaka+ system (OECD, 2023; Cedefop, 2023). For Kazakhstan, a dedicated registry module could require standardized information on program code and title, implementation format, partner organization, professional standard, labor function, learning outcomes, final assessment, and the document confirming results – directly addressing the fragmentation identified at both macro and meso levels of the MMM framework.

Discussion

This study contributes to the literature on micro-credentials in three main ways. First, it demonstrates that micro-credentials are best understood as a heterogeneous and evolving field shaped by different governance logics, institutional traditions, and recognition architectures rather than as a single stable educational format (Brown et al., 2021; Kato et al., 2020). Second, it shows that cross-national variation is not merely terminological but reflects deeper differences in how short-form learning is embedded in qualifications systems, linked to labor-market needs, and mediated by higher education institutions (Council of the European Union, 2022; Cedefop, 2022, 2023). Third, it highlights the analytical importance of transitional systems such as Kazakhstan, where the tensions between flexibility and regulation, policy ambition and institutional readiness, and labor-market responsiveness and academic legitimacy become especially visible and consequential (Varadarajan et al., 2023; McGreal & Olcott, 2022).

With regard to RQ1, the findings confirm that international trajectories of micro-credentials institutionalization are patterned rather than random. The comparative analysis identified four distinct trajectories – top-down regulated, supranational collaborative, decentralized market-driven, and hybrid – that differ systematically in governance, framework integration, stackability, and institutional drivers. This supports an analytical shift away from definitional debates alone and toward recognition architecture, provider roles, and relations to formal qualifications systems as the more consequential dimensions of comparison (Brown et al., 2021; Kato et al., 2020; McGreal & Olcott, 2022). The trajectory typology proposed here extends existing comparative work by Orr et al. (2020) and Cedefop (2022, 2023) by incorporating non-Western and transitional contexts alongside the more commonly studied European and Anglophone systems.

With regard to RQ2, the Kazakhstan case shows how global micro-credentials discourse is adapted within a more regulated national context in ways that existing literature has not yet systematically captured. Kazakhstan is neither a purely market-driven case nor a purely institution-led one. Rather, it is a hybrid, multi-tiered arrangement in which state-defined categories, qualifications frameworks, legal recognition of non-formal learning, university autonomy in implementation, and labor-market-oriented content are

assembled into a distinctive governance model (Government of the Republic of Kazakhstan, 2023; Ministry of Science and Higher Education of the Republic of Kazakhstan, 2025; Borgekova et al., 2026). This extends the literature by moving the discussion beyond mature systems in the Global North and toward contexts where state steering remains strong and qualifications reform is closely tied to occupational standards and national development priorities (Muravyeva & Oleynikova, 2024; Kato et al., 2020).

The Kazakhstan evidence also complicates any simplistic reading of regulated systems. Formal legal definitions, qualifications-framework integration, and policy mandates may coexist with uneven implementation, fragmented institutional practice, incomplete accreditation architecture, and uncertain employer recognition (Borgekova et al., 2026; Jomartova, 2025). This is precisely why the MMM framework is analytically useful: it demonstrates that successful integration depends on coordinated development across policy, institutional, and learner-facing levels rather than on regulatory ambition alone (Sovetkanova et al., 2026; Selvaratnam et al., 2024). In this sense, the study supports and extends the argument of McGreal and Olcott (2022) that state mandates are necessary but insufficient conditions for sustainable micro-credentials ecosystems.

With regard to RQ3, the findings point to three interdependent conditions for credible implementation in transitional systems. At the macro level, regulatory frameworks must balance quality assurance with sufficient flexibility for institutional adaptation. At the meso level, universities require not only authorization but genuine organizational capacity – governance, digital infrastructure, employer partnerships, and workable assessment models. At the micro level, learner-facing mechanisms of trust, portability, and digital verification must be developed in parallel with, not after, regulatory and institutional structures. These conditions align with and reinforce recent empirical findings on institutional readiness and maturity in Australasian contexts (Selvaratnam et al., 2024) and with employer-oriented evidence showing that credential value depends heavily on how consistently it is interpreted and rewarded in labor markets (Gauthier, 2020; Oliver, 2019).

This study also has clear limitations. The evidence across countries remains uneven, and the Kazakhstan-specific corpus, while substantially stronger than in earlier literature, still combines regulatory texts, institutional materials, monitoring reports, and a limited number of peer-reviewed empirical studies (Sovetkanova et al., 2026; Borgekova et al., 2026). The available evidence is stronger on policy architecture and institutional arrangements than on long-term learner outcomes and employer behavior (Varadarajan et al., 2023; McGreal & Olcott, 2022). The article is based on a narrative and comparative design rather than on systematic review methods or original stakeholder fieldwork, so its contribution lies in conceptual synthesis and policy analysis rather than causal measurement of effects (Grant & Booth, 2009; Snyder, 2019).

Future research should focus more directly on employer recognition, digital verification, institutional capability, and learner outcomes in transitional systems. Kazakhstan in particular would benefit from longitudinal studies on labor-market mobility, wage returns, and access to further education, as well as from comparative institutional research on how universities operationalize recognition, stackability, and partnership models (Sovetkanova et al., 2026; National Center for Higher Education Development, 2025). More broadly, regulated and transitional systems deserve much closer scholarly attention because they expose the governance conditions under which micro-credentials either become integrated into qualifications ecosystems or remain fragmented at the margins of higher education (Muravyeva & Oleynikova, 2024; Borgekova et al., 2026).

Conclusion

This article examined how micro-credentials are conceptualized internationally, how they are institutionalized across different higher education systems, and how these processes are unfolding in Kazakhstan. Three findings stand out.

With regard to RQ1, international trajectories of micro-credentials institutionalization vary systematically – not randomly – in governance logic, recognition architecture, stackability, and the role of higher education institutions. No single global model has emerged, and the variation is structurally grounded in different educational traditions, regulatory environments, and stakeholder configurations (Brown et al., 2021; Kato et al., 2020; Council of the European Union, 2022; Cedefop, 2022, 2023).

With regard to RQ2, Kazakhstan emerges as an analytically distinctive case of an emerging hybrid,

multi-tiered model in which state steering, university implementation, and labor-market-oriented content are being assembled into a regulated but institutionally mediated system. This model differs from both market-driven and consensus-based trajectories and illustrates how global micro-credentials discourse is adapted under conditions of strong state regulation and occupational framework alignment (Government of the Republic of Kazakhstan, 2023; Ministry of Science and Higher Education of the Republic of Kazakhstan, 2025; Borgekova et al., 2026; Sovetkanova et al., 2026).

With regard to RQ3, the principal risks arise when regulatory architecture, institutional capability, and learner-facing recognition mechanisms do not develop in coordination. The Macro-Meso-Micro framework proposed in this article captures this interdependence and shows that credible integration requires simultaneous progress across all three levels – not sequential development through them (Varadarajan et al., 2023; Selvaratnam et al., 2024; McGreal & Olcott, 2022).

A central practical implication is that transitional systems require stronger public infrastructures of transparency, recognition, and verification if micro-credentials are to move beyond fragmented experimentation. For Kazakhstan, this includes the need for a dedicated registry mechanism for university micro-credential programs as a foundational step toward a transparent, interoperable, and trusted national ecosystem. More broadly, this article argues that the future value of micro-credentials in transitional higher education systems will depend less on the speed of proliferation than on whether regulatory ambition, institutional capacity, and learner-facing trust mechanisms can be developed as a coordinated whole rather than as disconnected parts.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT (OpenAI) to improve language clarity, refine academic phrasing, and support structural editing of author-written text. After using this tool, the authors reviewed, revised, and verified the content as needed and take full responsibility for the content of the publication.

Conflict of Interest Statement

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Author Contributions

AN: Conceptualization, Methodology, Validation, Supervision, Writing – Original Draft, Writing – Review and Editing. RB: Conceptualization, Methodology, Investigation, Formal Analysis, Resources, Writing – Original Draft, Writing – Review and Editing, Project Administration. AM: Resources, Project Administration, Writing – Review and Editing. BR: Resources, Writing – Review and Editing. KT: Resources, Writing – Review and Editing. KB: Resources, Validation, Writing – Review and Editing. All authors have read and approved the final version of the manuscript.

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DEVELOPMENT AND EVALUATION OF STEM PROJECTS BASED ON THE INTEGRATION OF MACHINE LEARNING AND THE INTERNET OF THINGS (IOT).

Abstract: The paper considers theoretical and practical underpinnings of integrating machine learning and Internet of Things (IoT) technologies into the educational process of STEM (Science, Technology, Engineering, and Mathematics). The research shows that when IoT devices are included in STEM projects, the ability of learners to process, analyze and automate processes significantly increases. Besides, the paper gives assessment standards of how to design and evaluate STEM projects. A sample study with 44 students resulted in a STEM project that combines the use of IoT hardware and machine learning algorithms. The main goal of the project is the development of fire safety and evacuation management system. The study provides suggestions towards the successful implementation of the modern technologies in STEM education and also seeks to streamline the methodological approach to evaluating STEM projects. Moreover, project-based work-related activities enable learners with analytical thinking abilities and develop their ability to solve real-world problems.

Keywords: STEM education; project-based learning; machine learning; Internet of Things; assessment.

Introduction

In the modern educational context, STEM-based approaches to instruction provide students with both scientific and technological literacy and help them to adjust to the fast-changing technological settings. Combining machine learning as one of the subfields of artificial intelligence with Internet of Things (IoT) technologies enhances the functional potential of STEM projects and proactively promotes the skills of creative and logical thinking, data processing, predictive modeling, and automated decision-making in learners (Abichandani et al., 2022; Zhai et al., 2021).

At the same time, rapid technological transformation has created an increasing need of qualified STEM professionals. Kazakhstan is one of the developing countries in Central Asia that showed the understanding of the significance of STEM education. In this regard, colleges in the country have collaborated with the European Erasmus+ programme to develop a new program based on STEM teacher training. This program is being carried out as part of a two-year long program, «7M01525 - STEM Education» , whose purpose is to develop the professional knowledge of future STEM educators (Serik et al., 2022).

The curricula of the 7M01525 - STEM Education - course have several subject areas, such as robotics in education, circuit design, the Internet of Things, and STEM project management, among others (L. N. Gumilyov Eurasian National University, n.d.). These sciences help in formation of the STEM education system and improvement of the professional competencies of future specialists. In the international practice, it is always proven that STEM projects development promotes the development of practical skills in learners and makes them oriented towards scientific inquiry. The current paper not only discusses the theoretical foundations of applying machine learning and IoT in STEM projects but also the assessive standards that can be applied to project preparation in practice.

Research objective: to carry out a theoretical study of the methodological strategies of the integration of machine learning into different IoT technologies, and to create the practical assessment criteria of the design of STEM projects.

By using IoT-based devices, learners can acquire skills in programming, sensor management, and data processing, and implementing machine learning algorithms can broaden intellectual capabilities of projects and allow them to make decisions automatically. This approach is consistent with modular IoT-based

STE(A)M learning practices that support hands-on sensing, data collection, and analysis (Cappelle et al., 2022).

There are multiple academic papers devoted to the exploration of applying machine learning and IoT to STEM projects. The work of Thakur et al. (2024), focusing on the implementation of the IoT and machine learning approaches in robotics education can be listed among the most striking ones. The study is based on the improvement of robotic systems with the help of real-time analysis of sensor data and reports that an RNN model reached the predictive accuracy of 96.7 in the student behaviour modelling. A study by Sahu et al. (2024) on the possible uses of IoT and machine learning in energy management and precision agriculture has shown how these technologies can enhance operational efficiency, but has not dealt directly with the design and evaluation of STEM projects. Ali and Rani (2024) explore the role of machine learning in guaranteeing the safety of the IoT, detect weak points, and suggest the protective against cyber-attacks, which is a major contribution to information security development in STEM projects. Akintayo et al. (2024) examined how machine learning and IoT integration impact the data analysis and decision-making processes.

Methodology

The experimental and practical work was conducted at L.N. Gumilyov Eurasian National University and at East Kazakhstan University named after S. Amanzholov in the city of Ust-Kamenogorsk. Study participants comprised a total of 44 Master's students enrolled in the «7M01525 - STEM Education» programme. Each participant held a Bachelor's degree in one of the following disciplines: Computer Science, Engineering Informatics, Physics, or Mathematics. The practical work was carried out in accordance with the following three principal phases (Figure 2).

During the preparatory phase, introductory sessions were delivered to familiarise learners with the fundamentals of IoT technologies and machine learning. This phase extended over a period of five weeks, with each practical session lasting three hours.

During the design phase, learners selected and implemented project topics addressing real-world social challenges. Project development was grounded in the stages of the system life cycle methodology, and each student received a STEM project preparation guide. By fulfilling the requirements of each phase as set out in the guide, students ultimately submitted written reports documenting the progress of their project work.

During the evaluation phase, the submitted project reports were assessed against the established evaluation criteria (Table 1). In addition, students received feedback on their work through formal project defence presentations.

Table 1.

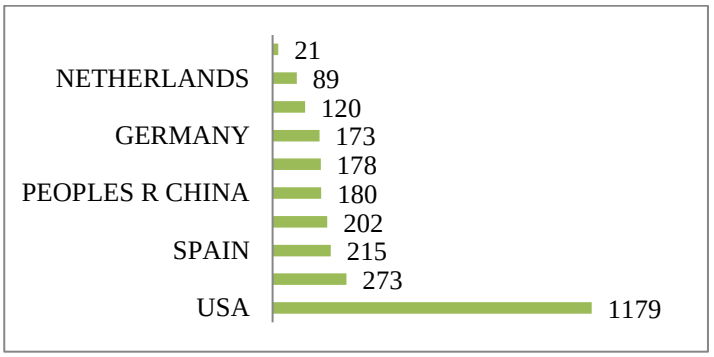
STEM Project Evaluation Criteria

STEM Project Evaluation Criteria (Technical / Content)				
	(1-2 points) Unsatisfactory	(3-5 points) Satisfactory	(6-7 points) Good	(8-10 points) Very good
Analysis	Organisation description and methods used in the selected project area.	Evidence from attempts to interview the client, some of which are described.	Ensure good client engagement and record the interview(s). Most of the required items are covered, with a thorough analysis of alternative approaches.	There is evidence of high client engagement with comprehensive requirements documentation. Alternative approaches have been identified and a systematic analysis has been conducted.
Design	It is accompanied by some unclear information about what the new system does, along with a brief schematic diagram.	The new system has objectives. The data structures (block diagram, diagram) have been defined, but there are sections that do not meet the requirements.	The complete technical requirements for the assigned tasks have been included, although there may be logical inconsistencies. Each of the implemented design requirements has concrete evidence.	The project's technical content is fully covered and its technical requirements are logically structured. A complete description of each process is clearly provided.

Implementation, programming	Software and description of IoT devices. The proposed algorithm does not conform to the design specifications.	The software code for the input and output algorithms is shown. The proposed algorithm has logical flaws.	The input and output algorithms, together with the codes for establishing connections with the data structure, largely conform to the design specifications of the proposed solution.	The communication for IoT devices and data processing is properly configured. It demonstrates strong technical proficiency in programming. The annotated code explains the logic.
Testing	Test results may be without a test plan or vice versa.	There is minimal evidence of testing, and no link between development and testing.	There must be printed copies of the results of at least eight different tests.	A complete implementation plan, including system migration, training and testing phases, with evidence provided.
Documentation	Incomplete guide; not all steps are described.	All options, except for one or two, are fully described.	A fully recommended user manual with an index and glossary.	A comprehensive, well-organised user manual with an index and glossary.
Assessment	Discussing the success of the work without referring to the design objectives.	Discussing some of the design objectives with insufficient explanations.	A comprehensive discussion, beginning with the design section, for each objective, presenting supporting evidence from the project or explaining the reasons for objectives that were not met.	A fully user-friendly system has been released. The user indicates that the system's section design fully complies with the specification.

The search of the Web of Science Core Collection database, with the restrictions of the period 2020-2025 and open-access articles, and the type of article searched among the categories Education, it became evident that the topic of study has been discussed by many scholars over a variety of countries. A prolonged search also helped to determine the quantity of publications produced in Kazakhstan (Figure 1).

Figure 1.
Geographic distribution analysis of sources in Web of Science



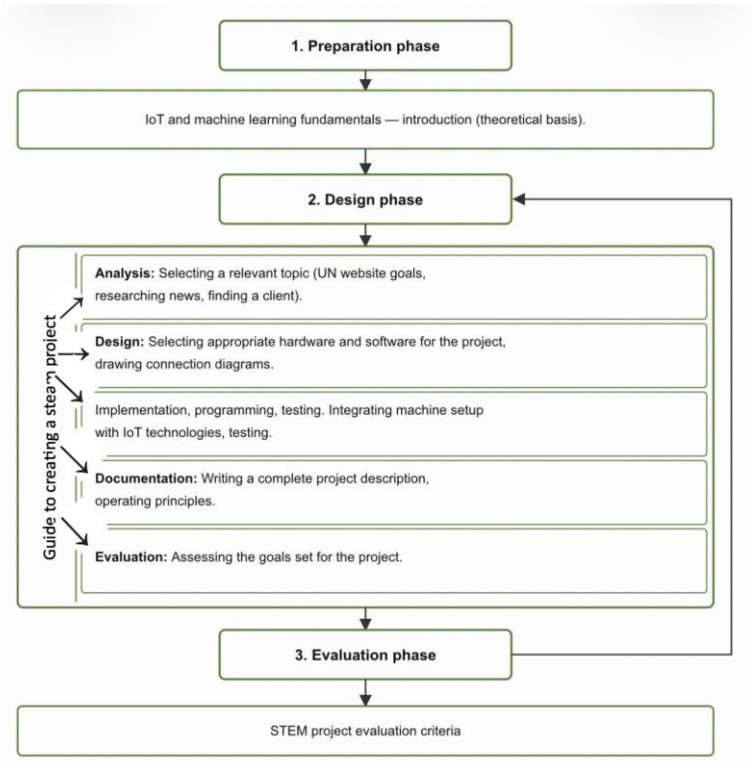
In the United States, the application of IoT technologies in educational settings has emerged as a significant priority for the improvement of the instructional process. In this context, particular attention has been drawn to the following works. Bondaryk et al. (2021) demonstrated that IoT-based sensor systems enable students at secondary educational institutions to observe scientific phenomena in concrete terms. Their proposed IoT Dataflow system features a software interface that ensures transparency in data collection and processing, thereby fostering learners' computational and scientific research competencies. Similarly, Ahmed et al. (2022) describe the experience of integrating IoT technologies into a computer science curriculum, whereby new instructional modules were introduced to develop the practical skills necessary for designing intelligent IoT systems. This approach was found to increase students' interest in the IoT domain and to strengthen their professional competencies in this field.

Research from the United Kingdom demonstrates the impact of artificial intelligence and machine learning on the educational system, revealing their potential for enhancing both academic and technical knowledge, and highlights the importance of policy measures aimed at encouraging enrolment in STEM-related engineering disciplines. More specifically, the study conducted by Kara et al. (2021) assessed the effect of class size on students' academic achievement across STEM and non-STEM disciplines in UK universities. The findings indicate that students in larger classes tend to achieve lower grades, underscoring the importance of accounting for the impact of policies aimed at increasing student participation in STEM fields on overall educational quality.

The works of Kazakhstani researchers attest to the significance of integrating IoT technologies into the educational process. Notably, Tutkyshbayeva and Zakirova (2024) analysed the effectiveness of IoT-based digital educational materials in developing students' digital competencies. Through a comparison of experimental and control groups, the study demonstrated that IoT-integrated instructional methods yield superior outcomes compared to traditional approaches. Research into the factors influencing academic achievement in STEM and non-STEM disciplines is equally important. Sultanova and Shora (2024) analysed the influence of non-cognitive skills—such as perseverance and information-processing ability—on achievement in mathematics, physics, language, and history within Kazakhstan's secondary education system. Their findings indicate that information-processing ability and perseverance play a particularly significant role in STEM subjects, whereas responsibility and collaborative skills are more prominent in the humanities. Furthermore, STEM teacher preparation has a direct bearing on the quality of education. Zhumabay et al. (2024) investigated the effects of STEM courses on teachers' sense of self-efficacy and instructional practice, concluding that such courses play a crucial role in teachers' professional development.

Accordingly, the body of research reviewed above indicates that the application of IoT technologies, the role of non-cognitive skills, and the preparation of STEM educators constitute key factors in improving educational quality. On this basis, the present study is directed towards investigating the effectiveness of instructional methods that combine IoT technologies with machine learning algorithms.

Figure 2.
Phases of the experimental and practical work



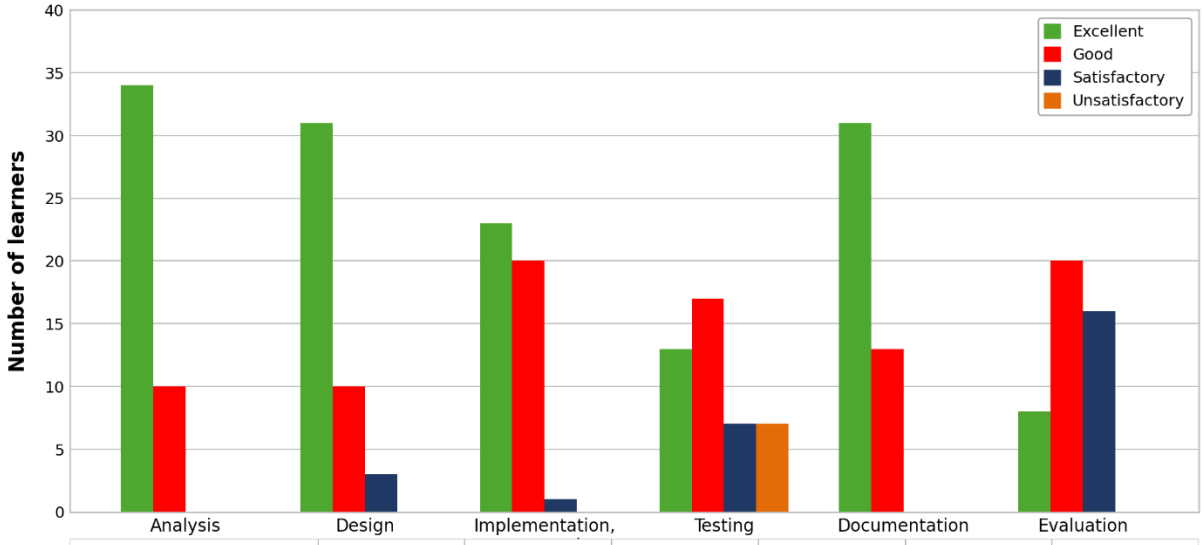
As an experimental work, the additional modules about the integration of the IoT technologies with machine learning were included into the course of the programme 7M01525 - STEM Education at the L. N. Gumilyov Eurasian National University, as well as into the course of the programme Robot Programming at the East Kazakhstan University named after S. Amanzholov.

Results and Discussion

The study has led to a thorough exploration of ways of combining machine learning and IoT technologies, which have led to the creation of STEM projects. Students were able to integrate hardware-software technology within their projects and had to make progress reports. These reports were organized in the following ways: analysis, design, implementation, programming, testing, documentation, and evaluation. The results were measured at four levels (unsatisfactory, satisfactory, good, and excellent) based on the evaluation criteria that had been set

Figure 3.

Evaluation results based on the phases of the system life cycle



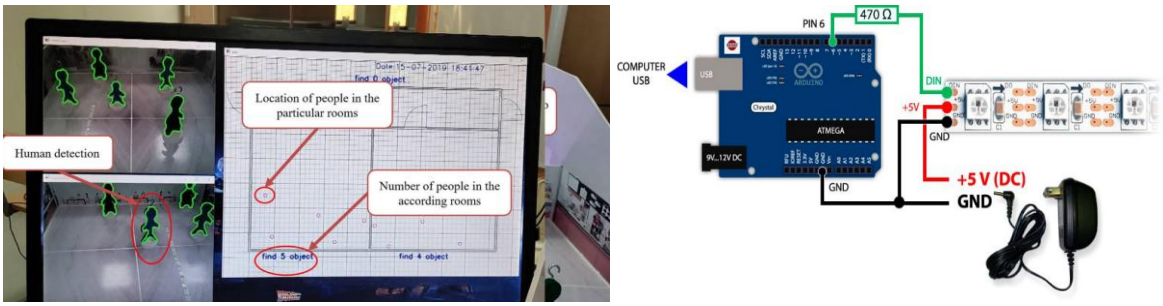
	Analysis	Design	Impl., prog.	Testing	Docum.	Evaluation
Excellent	34	31	23	13	31	8
Good	10	10	20	17	13	20
Satisfactory	0	3	1	7	0	16
Unsatisfactory	0	0	0	7	0	0

In the course of the project work, students demonstrated the highest results in the analysis (93%) and documentation (91%) stages. During the design phase, they presented the external structure of their STEM projects and achieved 89%. However, in the implementation stage, the performance decreased to 82%, as some of the developed functions did not fully correspond to the initial project plan. The lowest average score (80%) was observed in the evaluation stage, which can be explained by difficulties in completing self-assessment and collecting client feedback. These results indicate that future iterations of the course should place greater emphasis on developing students' skills in independent evaluation and client-oriented analysis.\

Sample Student STEM Project

Students of the STEM Education programme at L.N. Gumilyov Eurasian National University developed a project aimed at solving two important modern challenges: fire prevention and rapid evacuation of large supermarkets in case of fire. The project was implemented using an Android-based microcontroller as an IoT device, combined with machine learning algorithms.

Figure 4.
STEM project developed through the integration of IoT technology and machine learning



The figure shows a high-occupancy building fire safety and evacuation management system, which is built by the students using the combination of the IoT technology and machine learning algorithms. To detect fire, the flame recognition algorithm developed by Garrido et al. (2020), namely OpenCV and texture feature analysis was used. Their model provided experimental results which showed that it performed at a 95% accuracy in real-world conditions. Adaptive LED signage systems were deployed to realise evacuation optimisation. A study conducted by Kim et al. (2022) revealed that smart LED systems can be relied upon to visibly influence the evacuation speed, and the ability to decrease evacuation time by up to 40 percent. IoT sensors were incorporated with cloud technologies to monitor the system. As the results of Patel and Singh (2020) reveal, the implementation of IoT devices into the fire safety systems can make the response time of fire detection three times shorter. Their experiment revealed the use of IoT sensors to transfer data on temperature, smoke concentration, and carbon monoxide levels to cloud services, which could be analyzed later. In the case of fire prediction, machine learning was utilized. Wei et al. (2023) came up with a prediction algorithm of fires in multi-storey buildings using neural networks. Their model examines past fire records and determines possible risks that can be pre-emptively used to employ safety nets; experimental findings indicated that they can predict with a 92% accuracy.

Conclusion

The findings of the study demonstrate that the proposed methodology effectively develops learners' creative and analytical thinking skills through the integration of Internet of Things (IoT) technologies and machine learning into STEM education. The results confirm that incorporating IoT devices into STEM projects enables students to work with real-time data while simultaneously enhancing their engineering and problem-solving competencies. Furthermore, the application of machine learning techniques provides students with practical experience in processing, analyzing, and predicting large datasets, thereby preparing future specialists to work confidently with advanced digital technologies.

The research also revealed several important educational benefits of combining IoT and machine learning within STEM projects. Practical interaction with real hardware significantly strengthens students' theoretical understanding and facilitates the acquisition of applied skills. The integration of machine learning algorithms with IoT sensor data promotes the development of data processing and analytical competencies, while the design and optimization of intelligent systems foster algorithmic thinking and automation skills. In addition, the use of interactive, project-based learning approaches increases students' motivation to study STEM disciplines, encourages active engagement in the learning process, and stimulates interest in future scientific and engineering careers.

As part of the study, a set of evaluation criteria for assessing STEM projects was developed and successfully validated, demonstrating the effectiveness of the proposed educational approach. However, the sustainable implementation of such practices requires further modernization of pedagogical methods, continuous professional development of teachers, and the systematic integration of emerging digital technologies into the educational process.

Overall, the integration of machine learning and Internet of Things technologies into STEM education contributes to improving the quality of professional training, fostering digital, engineering, and analytical

competencies among future specialists, and supporting the broader digital transformation of the education system in Kazakhstan.

Conflict of Interest Statement

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

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Author Contributions

Meruert Serik, Kymbat Tleuzhanova, and Celal Karaca contributed equally to the conception and design of the study, methodology development, project implementation, data collection and analysis, interpretation of results, and preparation of the manuscript. All authors participated in writing, reviewing, and editing the article and approved the final version for publication.

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AI IN DEVELOPING WOMEN'S LEADERSHIP: RECOMMENDATIONS FOR THE AI IMPLEMENTATION IN HR POLICY OF HIGHER EDUCATION INSTITUTIONS

Abstract. The article discusses how artificial intelligence works in career management and gives ideas on how to use artificial intelligence in the university human resources (HR) policy. The study looks at the issues that stop women from advancing in their careers and view it as a group of connected problems that are rooted in the institution culture and HR management. Based on the results of an empirical study and literature review related to the topic of women's leadership and AI impact specific recommendations for the implementation of AI in HR policy of higher education institutions have been made. The purpose of the study is aimed at summarizing the results of the survey conducted focusing on barriers to women's career advancement rooted in institutional, cultural, and individual structures. The article talks about how artificial intelligence can help women become leaders. The paper also contributes with the review of the relevant literature on AI in women's leadership. The author wants to show how artificial intelligence can help make sure that women have the opportunities to become leaders with the AI assistance. The article gives a summary of specific recommendations for the implementation of AI in HR policy of higher education institutions based on literature review and results of conducted survey in 3 universities SDU, BTU and Narxoz University in Kazakhstan.

Keywords: artificial intelligence (AI), HR policy, women's leadership, career management and advancement, gender inequality, digital tools, soft skills.

Introduction

Women's leadership is very important in managing an organization. The things that affect women's careers are complicated due to barriers to women's career advancement, including structural, institutional and individual factors. These factors work together to create a system that keeps gender inequality in place. Historically women have not had leadership roles in both private and public organizations around the world. The article shows that women mostly develop leadership skills from life experience and being part of organizations not just from formal education. Management experience plays a key role, indicating a shift toward a practice-oriented model of leadership development. At the same time, digital tools, soft skills, and the gender agenda are undervalued, despite their central place in modern leadership theories, highlighting a gap between notions of leadership and actual development practices. People do not value digital tools, soft skills and the idea of gender equality as much as they should. These things are important in ideas about leadership, but they are not being used in real life. In other words, it shows that there is a gap between what people think leadership should be and what is actually happening.

According to UN Women they are underrepresented in leadership and senior roles and do not hold senior positions. The World Economic Forum reports that in 2023 than 30% of women hold senior leadership positions globally. Women's leadership has changed with the use of Artificial Intelligence (AI), where AI helps improve skills for making complex decisions and increase engagement in leadership development. The field of leadership studies is characterized by AI implementation to improve analytical skills in complex decision-making and increased engagement in leadership development. Nowadays AI is seen as a way to make human resources work better to select and train employees and to personalize training. The data shows that people are using technology to make things more efficient, but not to change how society works.

Different organizations understand intelligence in different ways depending on what is important to them and how comfortable they are with technology. Female executives think that artificial intelligence can be very helpful with training assessing employees and finding talent. However, they are more careful when it comes to using AI for career development.

In the result of investigation, the author suggested some practical ideas and recommendations for HR policy how to help women develop their leadership skills and manage their careers. These ideas are about how to use AI in universities HR policies. Women's leadership and AI are topics that need to be addressed, and women's career advancement and artificial intelligence can work together to create change. In the context of AI women leaders can be seen as AI mediators and play a great role in interpreting and implementing AI outputs for diverse audiences, fostering trust, inclusivity, and a shared understanding of AI supported decisions.

Methodology and methods

The research design of the article uses a data analysis methodology and comparative analysis to see how AI helps women in career growth and leadership. The analysis was conducted using a combination of theoretical and practical approaches aimed at identifying strategies in HR policy to the development of women's leadership in the context of integrating AI technologies. The study employed methods of analysis, synthesis, comparison, and statistical data processing. At the analytical stage, the relevant scientific and methodological literature was analyzed. The empirical base was compiled by surveys conducted in 3 universities in Kazakhstan: SDU, BTU and Narhoz. In the result of investigation findings confirm the recommendations based on the literature review and data analysis, gained from the survey and supporting the aims of the study.

Literature review

The literature review shows how important Artificial Intelligence is for helping women get jobs in companies and making sure there are more women in leadership positions. The results of studies conducted are about how Artificial Intelligence affects the decisions that are made and how it can help make things more equal for women.

In 2024 Ramchandani and other people looked into how Artificial Intelligence can help women and found out that Artificial Intelligence can really help women get jobs. They also found out that Artificial Intelligence can help women have rights and be more involved in the important parts of companies.

A study done by McKinsey & Company in 2015 showed that companies like Apple and IBM do better when they have women in leadership positions. Young and others did a study in 2023 that looked at the jobs that are available in data science and Artificial Intelligence. They found out that there are still some problems with fairness in these areas of computer world for a long time. Petrat et al. (2022) looked at what executives think about using Artificial Intelligence in leadership positions. They found out that Artificial Intelligence helps leaders make decisions and gives them feedback based on data. They also highlight that Artificial Intelligence can help leaders take care of their teams and make decisions. The literature review shows how Artificial Intelligence can help women get jobs and make companies better. Artificial Intelligence is very important for women's leadership roles and for making sure that companies are fair in their HR policies.

Hunt et al. (2022) found out that new things are happening under AI influence. They are concerned that people will lose their jobs because of AI. The authors highlighted the lack of research on the actual effects of AI-enabled tools in businesses. Karyotaki et al. (2022) have talked about women in business and society and how they use modern technology. They found out what causes the digital skills gap and questioned why there aren't enough women working in the growing digital business.

Petrat et al. (2022) have highlighted that people can use intelligence to solve simple and hard problems by analysing massive volumes of data. Some businesses are already using intelligence to help with things like human resources. People who are good with technology have trouble imagining what artificial intelligence will be like in the workplace or in leadership roles that show the need to do research on this topic. Plato and others (2021) studied the role of women in positions in cybersecurity companies. They investigated the experiences of these women and the problems they faced. They found out that employers need to support women and help them develop their leadership skills by helping women in their organizations writing job descriptions.

Santiago and others (2019) predicted that the artificial intelligence and big data analytics markets will grow a lot. They investigated the problems with intelligence and how they affect the people who make important decisions in businesses. They were worried about the fact that artificial intelligence can make its

decisions, which could mean that humans are not in control anymore. This shows how important it is for leaders to be aware of what's happening and to make sure that artificial intelligence is used in a way that is fair and transparent.

Ahn, H. And Kim S. wrote a study in 2023 that talks about how artificial intelligence can affect women leaders and how artificial intelligence can sometimes show women in a way that's not fair. For example, women are often described as being emotional or supportive. At the time the study says that artificial intelligence can be a tool to help make things more fair for women.

Black, J. And Turner R. Wrote (2024) investigates the women role as leaders in universities. They stated that having women leaders is very important because they bring ideas and perspectives. The authors also draw attention to the challenges that women face when they want to be leaders and need to be supported and mentored so they can succeed. The article emphasizes that diversity in leadership should be viewed as a strength because women leaders bring inclusive perspectives, innovation, collaboration, and ethical awareness to AI-related decision-making in universities. Sharma, P. And Mehta, R. Wrote in 2024 stated how artificial intelligence can help women be leaders and make sure that women are not discriminated against when they apply for jobs. Artificial intelligence can also help women balance their work and personal life. The authors stated that artificial intelligence can be a tool to help women succeed as leaders.

Verma, N. And Singh T. (2025) viewed intelligence and human resources for diversity and inclusion. The study stated that companies need to be careful and make sure that it is fair and does not discriminate against anyone. Artificial intelligence can be a tool to help create a fairer and more inclusive workplace.

So, literature reviews demonstrate different approaches in AI role in the development of women's leadership and its impact and implementation in practice. The literature review highlights that AI can positively support women's employment, leadership, and participation in business by creating job opportunities, improving leadership development, and promoting fair treatment in organizations. Studies show that companies with women in leadership positions are often more successful, innovative, and collaborative. AI also helps managers make better decisions through data analysis, feedback systems, team management, and improved human resource practices. However, the review also identifies ongoing gender inequality in AI and data science fields. Women remain underrepresented in digital industries, cybersecurity, and AI-related careers because of barriers such as limited digital skills opportunities, workplace discrimination, and unfair practices. Researchers further warn that AI systems may contain gender bias and reinforce stereotypes about women, which can negatively affect women leaders and decision-making processes.

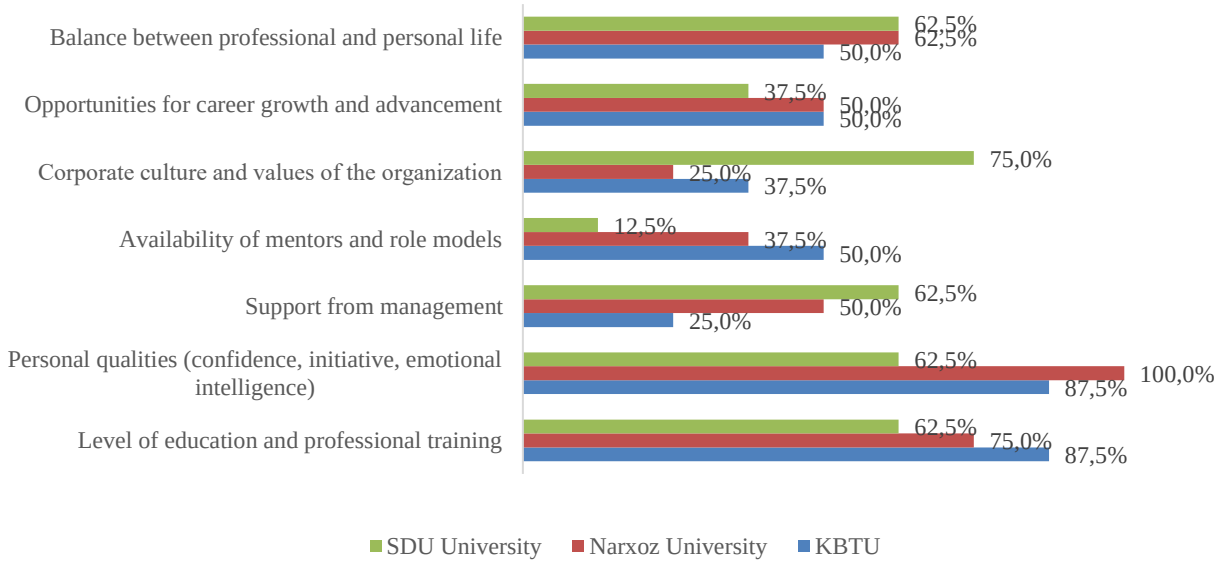
Authors also emphasize the importance of ethical and transparent AI use. While AI has the potential to create fairer and more inclusive workplaces, it can also lead to job replacement, biased decisions, and reduced human control if not carefully managed. Therefore, organizations must ensure that AI systems are inclusive, transparent, and free from discrimination. Finally, most studies conclude that mentorship, leadership development, supportive work environments, and fair recruitment practices are essential for helping women succeed in leadership roles. Diversity and inclusion are seen as key strengths for organizations, as women leaders contribute different perspectives, innovation, collaboration, and ethical awareness, especially in AI-related decision-making.

Discussion

The study was evenly distributed across three educational institutions: KBTU, Narxoz University, and SDU. The women-leaders of these universities have been interviewed on the issues related to key factors most significantly influence the formation and development of leadership qualities in women, main barriers women leaders face in their career advancement, most effective sources of women leadership development, the current level of use of AI tools in organization's HR policies, most effective AI tools for identifying and developing women's leadership potential, the implementation of AI tools in the assessment, promotion, and career development processes, the use of AI contribute to greater transparency and fairness in corporate governance etc.

Figure 1

What key factors, in your opinion, most significantly influence the formation and development of leadership qualities in women?



The data obtained demonstrate that barriers to women's career advancement are not isolated factors, but rather a system of interconnected constraints rooted in institutional, cultural, and individual structures. The high prevalence of gender stereotypes (up to 75%) indicates the persistence of a gender order in which leadership continues to be associated with "masculine" characteristics. Leadership chances for women often get limited by rules and unseen biases about their abilities. Differences between universities show mostly fixed systems blocking progress, while elsewhere it's unwritten norms or job expectations holding them back. The data confirms that gender inequality is not universal but depends on the specific institutional context.

Table 1.

What are the main barriers women leaders face in their career advancement?

	KBTU	Narxoz University	SDU University
Gender stereotypes and bias	75,0%	50,0%	62,5%
Limited access to management positions	50,0%	37,5%	37,5%
Lack of support and mentorship	25,0%	25,0%	25,0%
Opaque evaluation and promotion procedures	75,0%	50,0%	25,0%
Combining professional and family roles	50,0%	62,5%	62,5%
Lack of confidence in one's own leadership competencies	25,0%	50,0%	50,0%
Institutional restrictions (rules, company policies)	-	25,0%	25,0%

The data obtained allows us to assert that women's career barriers are formed at the intersection of three levels: macro, meso, and micro.

Table 2.

Distribution of barriers to women's career growth at the macro-, meso- and micro-levels.

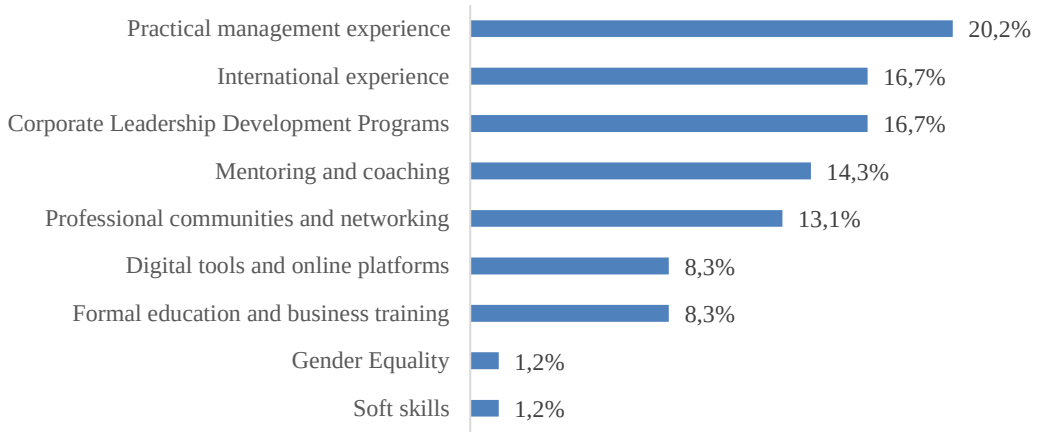
Level of analysis	***Contents of barriers***
Macro level	gender norms and stereotypes
Mesolevel	organizational practices and institutions
Micro level	internalized attitudes and confidence

The table demonstrates the multi-layered nature of barriers to women's career advancement. Structural,

institutional, and individual factors mutually reinforce each other, creating mechanisms of gender inequality and unfairness between genders.

The data obtained show that respondents understand the development of women's leadership skills as practical experience and organizational involvement. Management experience, corporate programs, and international mobility play a key role. It indicates a shift toward a practice-oriented model of leadership development. At the same time, digital tools, soft skills, and the gender agenda are paid less attention despite their central place in modern leadership theories. It also highlights a gap between normative notions of leadership and actual development practices.

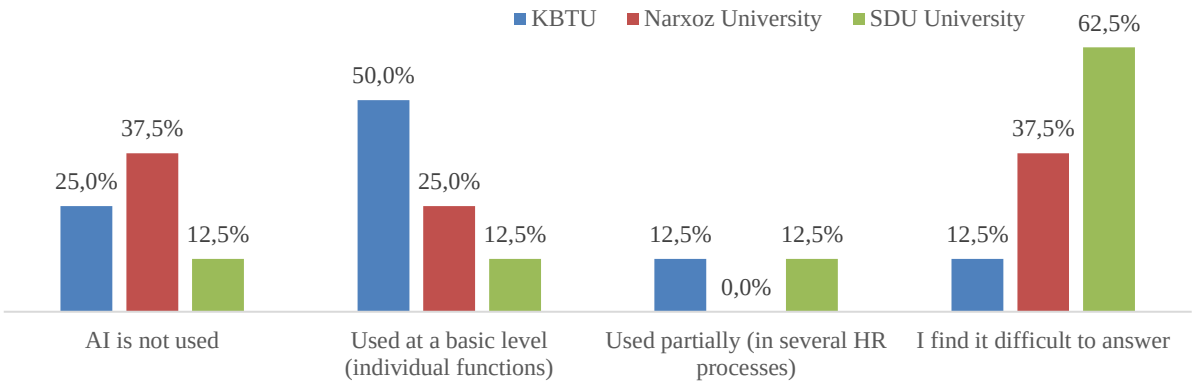
Figure 2.
What sources of leadership development do you consider most effective for women?



The data obtained indicate that the implementation of artificial intelligence in HR practices is in its early stages of development and is characterized by a high degree of heterogeneity both between and within organizations. Overall, 25.0% of respondents do not use AI, 29.2% use it at a basic level, 8.3% use it partially (in a few processes), and 37.5% were undecided. KBTU shows half of its users apply fundamental AI tools (50%), indicating the presence of a basic digital within HR systems. Narxoz University is characterized by a polarized distribution, one group skips AI entirely (37.5%), another equally large portion simply does not know its application (37.5%). SDU University is characterized by most people hesitating (62.5% of respondents were undecided), which might reflect unclear communication, a lack of transparency in digital HR practices or missing tech in personnel management.

The implementation of AI in HR policy is in a transitional phase, between declarative digitalization and the actual practice of its use.

Figure 3.
How do you rate the current level of use of AI tools in your organization's HR policies?



Analysis of the distribution of responses across organizations reveals that the perceptions and

intended functions of AI tools in HR policy are institutionally determined. In one organization, AI is primarily associated with career analytics and recruitment tools (62.5% each), followed by learning support and digital assistants (50.0% each), indicating a focus on using AI in managerial and analytical tasks related to decision-making and career trajectory support. In the second group, AI is seen as a means of personnel hiring and assessment, as shown by high values for recruitment (75.0%) and judging skill levels (62.5%), with relatively less attention paid to development and career support tools. In the third group, the stress is shifted toward using AI for training and development (62.5%) and potential assessment (62.5%), while actual hiring tasks drop sharply (12.5%), indicating that AI is perceived primarily as a resource for skills development and professional growth.

Table 3.

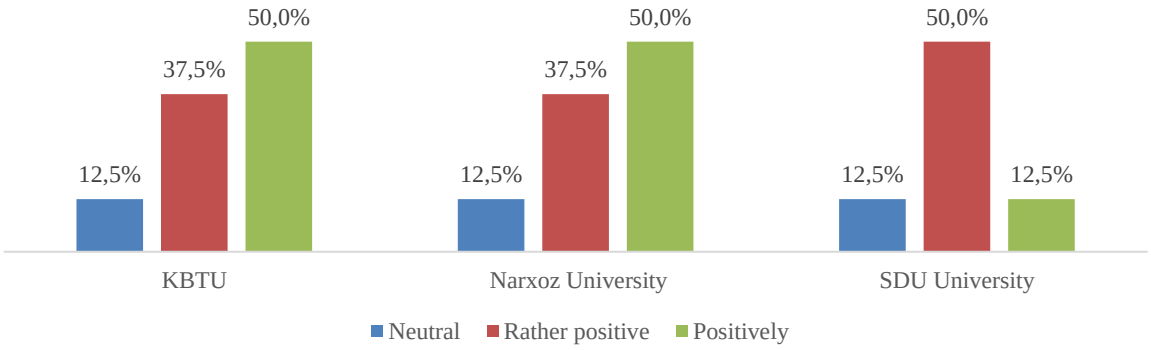
Which AI tools do you think are most effective for identifying and developing women's leadership potential?

	KBTU	Narxoz University	SDU University
AI-based resume selection and analysis systems	62,5%	75,0%	12,5%
Competency and potential assessment tools	37,5%	62,5%	62,5%
Personalized learning and development platforms	50,0%	50,0%	62,5%
Career planning and talent analytics	62,5%	37,5%	37,5%
HR chatbots and digital assistants	50,0%	25,0%	12,5%
Bias and Gender Balance Analysis Tools	12,5%	12,5%	-
I find it difficult to answer	-	-	12,5%

Overall, most women in leadership roles see AI as tool used in hiring, promotions and career growth in a favorable light. Still, opinions differ widely based on company environment. According to the group studied, nearly four out of ten views the impact as clearly beneficial - positive (37.5%) and somewhat positive (41.7%) This suggests that many believe AI can make personnel decisions fairer and more efficient. Their views come from experience, shaped by working closely with digital systems in managing people and understanding of the important role of digital technologies in human resources management.

Figure 4.

How do female managers generally perceive the implementation of AI tools in the assessment, promotion, and career development processes?

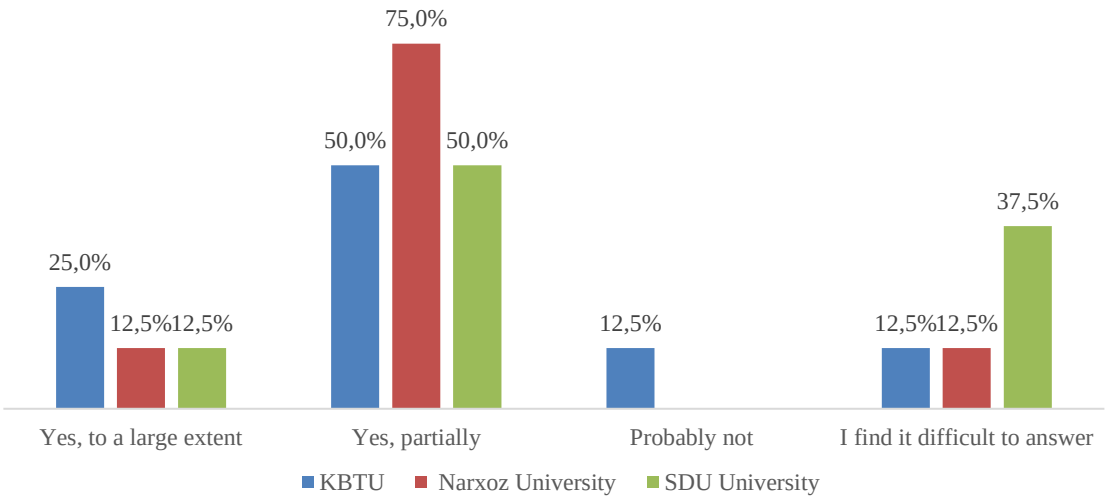


** Note: For clarity, the "I don't know" category is not shown in the diagram.*

The study results show that female leaders tend to see promise in artificial intelligence when it comes to making company leadership more open and balanced. Of the total sample, 16.7% believe AI can contribute significantly to this, while the majority (58.3%) think it might help, but only to some extent. Only a small fraction doubts its role altogether (4.2%). However, there is relatively high proportion of those who were undecided (20.8%). This indicates persistent uncertainty in assessing the actual effects of AI

implementation. It may reflect both limited practical experience with its use and the difficulty of interpreting its impact on management processes.

Figure 5.
Can the use of AI contribute to greater transparency and fairness in corporate governance?



The study results show that female executives view the potential of AI in HR policy as most achievable in training, assessment, and talent pool development, while its use in career development is assessed much more cautiously.

Taken together, the data suggests that training and development is a priority area for AI application (up to 87.5%), reflecting a perception of technology as a tool for personalization and increased effectiveness of professional development. Performance assessment (up to 50%) is also seen as a significant area where AI can improve the objectivity of procedures. Talent pool development demonstrates high importance in some organizations (up to 75%). It indicates the use of AI for strategic HR tasks. Hiring shows mixed interest rating (37.5% across all organizations). That indicates recognition of its potential, but not its dominant role. Career advancement remains the least supported area (12.5%), indicating limited trust in AI in decision-making affecting status and sensitive management aspects.

The differences revealed show that some organizations (e.g., those with a high percentage of talent pools) view AI as a strategic talent management tool, while others focus on training and development, reflecting a more "soft" integration of technologies. In all cases, however, there is a cautious attitude toward the use of AI in career advancement.

Table 4.
In which processes are this most possible?

	KBTU	Narxoz University	SDU University
Recruitment	37,5%	37,5%	37,5%
Evaluation of effectiveness	50,0%	37,5%	50,0%
Career advancement	12,5%	-	12,5%
Formation of a personnel reserve	75,0%	25,0%	25,0%
Training and development	62,5%	87,5%	50,0%
I find it difficult to answer	-	-	12,5%

An analysis of respondents' open-ended responses revealed key criteria for assessing the effectiveness of AI tools in developing women's leadership. Unlike closed questions, these responses reflect an expert understanding of the multidimensional nature of this process. The indicators proposed by respondents can be grouped into several interrelated categories. First, great attention is paid to career quantitative indicators. It includes increased representation of women in leadership positions, career advancement, and a narrowing gender gap. Second, a focus on individual development is highlighted,

focusing on developing leadership competencies, increasing confidence, and developing soft skills. Third, respondents emphasize the importance of organizational effects, such as shifting workplace norms, seeing more women in leadership roles. Special attention is paid to process characteristics, including how deeply teams get involved and how often they rely on AI tools. Furthermore, a significant area of focus is assessing whether AI behaves fairly, makes choices that can be understood, and earns real confidence from users. Finally, the role of accessibility and inclusiveness is highlighted. It reflects the ability of AI to reduce structural barriers and expand opportunities for women.

Findings

The study sample was conducted across three educational institutions: KBTU (33.3%), Narxoz University (33.3%), and SDU University (33.3%). This ensures balance and allows the results to reflect the diverse organizational contexts.

An analysis of the distribution of responses across universities KBTU, Narxoz University, and SDU University) revealed both general patterns and significant institutional differences in the perception of women's leadership factors. The most significant factors overall are level of education and professional training (up to 87.5% at KBTU; 75.0% at Narxoz; 62.5% at SDU), and personal qualities (confidence, initiative) (up to 100% at Narxoz; 87.5% at KBTU; 62.5% at SDU). Every institutions, puts a consistent emphasis and weight on personal strengths. Narxoz (100%) is particularly indicative. Leadership there is presented entirely through the prism of personal characteristics and reflects a pronounced meritocratic approach.

The analysis of the survey demonstrates that respondents perceive women's leadership as the result of a combination of individual resources, organizational conditions, and weakly defined digital and network mechanisms. Gender inequality in leadership is reproduced not through individual barriers, but through their combination. Cultural norms, institutional practices, and individual attitudes affect each other.

Women's leadership is formed primarily through practice and institutional mechanisms. But digital resources and soft skills remain secondary and play smaller roles and matter so little. It is particularly important to emphasize that the low significance of digital tools and soft skills points to a structural gap between new ideas about theories on leading and what really happens in practice.

Even though AI could help streamline HR tasks and lessen gender gaps, it often sits unused or only partly applied. Instead of reshaping how gender dynamics play out at work, current AI efforts mostly track employee performance, which means little progress emerges in advancing female leaders. The use of AI in HR policy is focused mostly on human capital management rather than on transforming gender relations, limiting its potential in women's leadership development.

Most women in leadership roles see AI in HR work positively. Still, their actual experience with the technology shapes their views less. This confirms the gap between the positive perception of digitalization and its actual level of implementation in organizations. The survey results also demonstrate that AI is viewed by the expert community as a significant, but not universal, tool for increasing the transparency and fairness of corporate governance, the effectiveness of which is determined by the quality within existing systems.

AI is perceived as an effective and helpful tool for streamlining routine HR tasks and processes. Most people see AI as being used in strategic decisions, such as career advancement. Thus, the effectiveness of AI in developing women's leadership is viewed by respondents as a multidimensional phenomenon. It also includes not only career outcomes but also individual, organizational, and ethical issues.

At the same time, significant differences and clear gaps between universities in the degree of support for AI implementation were identified. Some organizations within 3 universities demonstrate a more positive position. Others demonstrate a more reserved and a higher degree of uncertainty. This may indicate differences in institutional maturity, the degree of adoption of digital solutions, and the level of critical reflection regarding their application.

To sum up, A cross-organizational analysis reveals differences in the degree of the assessments. Some organizations are more confident regarding the effectiveness of AI (specifically, a higher proportion of "to a large extent" responses), while others are more cautious, expressed as "partially," or express greater uncertainty. And it demonstrates the heterogeneity of institutional experience in implementing digital

technologies and differences in the level of trust in them.

The authors of the article based on the findings resulting from the survey and analysis of the literature review suggests strategies of using AI to support women leaders and enhance their visibility and in HR policy. The proposed recommendations for practical implications are aimed at inclusive leadership of women and help them become leaders and manage their careers. To make some changes to how universities use their resources in HR policy it is necessary to expand institutional resources for developing women's leadership and career management. The following practical recommendations for integrating AI into the HR policies of higher education institutions are proposed.

First of all, AI can be used to make sure everyone is treated fairly and has the same chances to succeed by means of using artificial intelligence to check if there is any bias in hiring, evaluating and promoting people and making sure everyone knows how their career is going.AI tool can be effective for ensuring equal career opportunities via including algorithms for analyzing gender balance in hiring, assessment, and promotion processes, auditing personnel decisions for hidden gender issues, and ensuring career trajectory transparency.

AI tools also should be used in a fair way by being open and honest through applying "ethical AI" to HR policies based on principles of transparency and non-discrimination in algorithms and developing internal regulations for the use of AI in HR decisions.

Using AI will be helpful to eliminate gender inequality through analyzing differences in pay, career dynamics, and access to leadership positions. Artificial intelligence can help get rid of the differences between men and women by looking at how people are paid how their careers are going and if they have a chance to become leaders.

The results of investigation also demonstrate that universities should integrate digital and soft skills into leadership development models through developing digital literacy, managing AI tools, and analytical thinking in leadership development programs as well as developing soft skills based on digital simulations and AI coaching. Universities can use AI platforms to find mentors and plan their careers by using artificial intelligence to find and develop talented people and use gender diversity indicators in HR management policy.

It is also helpful to launch pilot HR projects for the AI practical application, creating a digital culture for the AI successful use in developing women's leadership. Artificial intelligence can create a culture where people feel comfortable using AI to help women become leaders. Using HR metrics can be also effective in evaluating the effectiveness of AI implementation as an indicator of gender effectiveness, such as the proportion of women in the talent pool and in leadership positions, and women's participation in digital leadership programs. The integration of AI into HR policy should be viewed as a tool for the institutional transformation of the organizational environment. Using AI in human resources is not just about using new technology, it is about changing how the whole organization works.

Conclusion

The conducted research has demonstrated that the use of AI technologies make a complex and multifaceted influence on the administration functioning, shaping innovative methods of decision-making, personnel development, and HR strategy formation. Having women leaders is really important because it makes sure that everyone has an opportunity to make decisions which leads to new ideas. This paper also suggests that, despite the general focus on human capital assessment and development tools in women’s leadership, the functional understanding of AI varies depending on the organizational context, from a selective-evaluative logic to a managerial and developmental one, reflecting differences in institutional priorities and the level of digital maturity of organizations. Encouraging and elevating women into leadership based on AI tools is crucial for creating a more balanced, equitable, and forward-thinking educational system. Studies done displays that in universities women get stuck with jobs that help others but don't get the recognition they deserve. In the field of AI, there are many ongoing challenges faced by women. Despite their contributions, women remain underrepresented in leading positions.

Study results demonstrates that women who are leaders in institutions especially in technology and artificial intelligence they point out how important it is to be an inclusive leader and they talk about the challenges of being seen and recognized and the need to be careful when it comes to changing technology.

When AI is introduced, it can make female specialists feel anxious about technology and worried that their experience and knowledge are not valued much. The author of the article comes to conclusion that management practices and career advancement mechanisms for developing women's leadership can be realized through a combination of digital solutions and AI potential. This approach can ensure a transition from the fragmented use of AI to its strategic integration into HR policy. A metrics system will allow educational institutions to evaluate not only the effectiveness of automation but also the contribution of AI to the development of inclusive leadership. Furthermore, the use of "ethical AI" in HR policy will reduce the risk of institutional barriers through digital systems. Based on the data obtained, specific recommendations for the implementation of AI in HR policy of higher education institutions to developing women's leadership have been proposed. So, the effectiveness of AI in promoting gender equality and women's leadership is highlighted through its ability to support fair hiring, evaluation, promotion, and career development processes. AI can help reduce bias, improve transparency, and analyze gender gaps in pay, leadership opportunities, and career growth. Ethical and transparent use of AI in HR policies is essential to ensure non-discrimination and fairness. The research also shows that universities and organizations can effectively use AI to develop digital, analytical, and leadership skills, support mentorship, and identify talented women leaders. In addition, pilot HR projects, digital culture development, and HR metrics can help measure the success of AI implementation in improving women's leadership. The results of the research can be successfully integrated into the HR policy of higher education institutions to develop women's leadership.

Conflict of Interest Statement

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

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DEVELOPING RESEARCH-ORIENTED TEACHING PRACTICE AND RESEARCH CULTURE OF FUTURE HISTORY TEACHERS THROUGH LESSON STUDY

Abstract. This study examines the development of research-oriented teaching practice and research culture in the preparation of future history teachers within the framework of contemporary research-based teacher education. The research addresses the persistence of reproductive and teacher-centered models of pedagogical training that often emphasize lesson delivery rather than inquiry into students' learning, historical reasoning, and disciplinary thinking. In this context, Lesson Study is considered not as an end, but as a pedagogical and research tool supporting the formation of reflective, inquiry-oriented, and evidence-informed professional competencies among pre-service history teachers.

The study employed a qualitative practitioner-research design involving future history teachers participating in Lesson Study cycles during their pedagogical practicum. Data were collected through reflective journals, lesson observations, interviews, lesson plans, students' written responses, and collaborative reflection transcripts. Thematic analysis was used to identify changes in pedagogical thinking, reflective practice, inquiry-oriented instruction, and approaches to historical thinking.

The findings demonstrate that participation in collaborative lesson inquiry contributed to the transition from descriptive reflection toward analytical and evidence-informed pedagogical reasoning. Future history teachers increasingly focused on students' interpretation of historical evidence, argumentation, source analysis, and inquiry-based learning processes. The study also revealed that Lesson Study supported the development of collaborative professional learning, practitioner inquiry, and research culture within teacher preparation. Particular significance of the research lies in the integration of Lesson Study into graduation research projects of final-year students, which enabled the connection between academic research, pedagogical reflection, and classroom practice.

Keywords: history teacher education, Lesson Study, research-oriented teaching, reflective practice, practitioner inquiry, historical thinking, inquiry-based learning, civic education, collaborative professional learning, research culture.

Introduction

Over the past three decades, significant changes have occurred in approaches to teacher education. Contemporary research demonstrates that effective teaching can no longer be reduced to mastering a set of instructional techniques for content delivery, a tendency that is also reflected in the current regulatory framework of the Republic of Kazakhstan. In particular, the State Mandatory Standard of Higher and Postgraduate Education of the Republic of Kazakhstan emphasizes a competency-based model of education, the development of students' research, analytical, and reflective competencies, the integration of theoretical preparation with pedagogical practice, and the implementation of student-centered and research-oriented approaches (Ministry of Science and Higher Education of the Republic of Kazakhstan, 2022).

Additional significance is attached to the Professional Standard for Teachers of the Republic of Kazakhstan, approved by Order No. 31 of the Minister of Education of the Republic of Kazakhstan on February 24, 2025, which highlights the importance of research, methodological, and reflective dimensions of pedagogical activity (Ministry of Education of the Republic of Kazakhstan, 2025). The standard defines professional competencies related to the design and implementation of educational activities and emphasizes

continuous professional development, analysis of learning outcomes, and the application of contemporary pedagogical approaches.

The professional standard specifically stresses the need to design educational activities based on the analysis of achieved learning outcomes, employ research and experimental skills, develop methodological materials, disseminate best teaching practices, and engage in mentoring. Furthermore, teachers are expected to apply innovative methodologies, contemporary approaches, and digital technologies, while planning instruction based on research findings and students' individual educational needs. Thus, the regulatory framework of teacher education in Kazakhstan reinforces the demand not only for methodologically competent teachers but also for professionals capable of investigating their own practice, interpreting educational data, and making pedagogical decisions based on evidence-informed reasoning.

An analysis of contemporary teacher professional development programs indicates that effective professional learning is characterized by content focus, active participation, collaborative engagement, the use of models of practice, coaching and expert support, as well as feedback and reflection (Arani et al., 2007; Darling-Hammond et al., 2017; Friedrich, 2017). These characteristics – particularly active participation, collaboration, and reflection – often contrast with traditional professional development models based on lecture formats detached from authentic classroom practice. Research on professional learning communities emphasizes that educators should examine their own practice, evaluate its impact on student learning, and use the findings to improve instruction. Such communities provide a robust foundation within which teachers collaboratively design lessons, identify research strategies, analyze learning outcomes, and revise instructional decisions through collective reflection (Pirtle & Tobia, 2014).

Against this background, teacher education is increasingly shifting from reproductive models of preparation toward inquiry-based and research-oriented teacher education. Within this paradigm, Lesson Study is viewed not merely as a form of peer observation but as a mechanism for collaborative inquiry, practitioner research, and reflective professional learning. Originating in the Japanese educational system, Lesson Study is based on the collaborative design, observation, analysis, and revision of a research lesson using evidence derived from students' learning activities. Unlike traditional models of methodological training, Lesson Study focuses less on evaluating teacher performance and more on investigating students' learning processes, thinking, and interactions. This makes the approach particularly valuable for developing research-oriented teaching practice and fostering the research culture of future history teachers (Lewis et al., 2006; Dudley, 2014).

Contemporary studies indicate that Lesson Study in teacher education programs is most commonly implemented as a practicum-centered model embedded within pedagogical practice, mentoring, and collaborative lesson planning. In their systematic review of English-, Japanese-, and Chinese-language studies, Tan, Goei, and Willemse (2024) identified diverse forms of Lesson Study in initial teacher education and highlighted challenges related to mentoring relationships, institutional integration, and cultural adaptation. Similarly, Almacıoğlu and Arslan (2026) describe Lesson Study as a mechanism for developing professional vision, reflection, collaborative learning, and the capacity of pre-service teachers to analyze student learning rather than merely their own teaching behavior.

Particular attention has been given to studies linking Lesson Study with the development of research culture among pre-service teachers. Botes, Moreeng, and Mosia (2022) demonstrate that Lesson Study creates a safe environment for collaborative lesson planning, discussion of pedagogical challenges, and post-lesson reflection. For the Kazakhstani context, the work of Yermekbayeva, Kuzembayeva, Maydangalieva, and Goncharenko (2024) is especially relevant. Examining research-based learning in Kazakhstan's pre-service teacher education, the authors argue that the development of research competence requires systematic engagement with formulating research questions, reviewing literature, selecting methodologies, collecting data, and interpreting findings. In this regard, Lesson Study may be viewed as an applied form of research-based learning because it translates research preparation from an abstract academic activity into the analysis of authentic classroom practice.

The literature on historical thinking pedagogy and inquiry-based history education likewise emphasizes the need for disciplinary adaptation of Lesson Study in the preparation of history teachers. Van Boxtel, Voet, and Stoel (2021) argue that inquiry learning in history involves posing authentic historical questions, reading, analyzing, and synthesizing multiple sources, and constructing interpretations of the past.

Kainulainen, Puurtinen, and Chinn (2025) further contend that inquiry-based history learning should reflect a broader understanding of historians' practices, including archival work, language use, tools, epistemic virtues, and the social processes involved in the production of historical knowledge. Miralles-Sánchez, Rodríguez-Medina, and Sánchez-Ibáñez (2024) demonstrate that historical thinking requires deliberate pedagogical design, active learning strategies, and connections to citizenship education. Similarly, López-Fernández, Tirado-Olivares, Mínguez-Pardo, and Cózar-Gutiérrez (2023) show that active pedagogies and historical thinking approaches can contribute significantly to the development of students' critical thinking.

Kager, Kalinowski, Jurczok, and Vock (2024) note that many Lesson Study studies provide insufficiently transparent descriptions of observation and reflection stages, the types of evidence collected, and the procedures used for data analysis. Therefore, the present study explicitly focuses on describing data sources, coding procedures, thematic analysis categories, triangulation strategies, peer debriefing, and audit trails. Methodologically, this approach is consistent with the framework of thematic analysis proposed by Braun and Clarke (2021), as well as the criteria of credibility, transferability, dependability, and confirmability commonly employed in qualitative research to ensure trustworthiness (Ahmed, 2024; Stahl & King, 2020).

The literature review reveals several important research gaps. First, most contemporary studies on Lesson Study in initial teacher education focus on mathematics, science, or language education, where research lessons are typically analyzed through the lens of subject-matter explanation, classroom interaction, student engagement, or professional noticing. Second, even within studies on pre-service teacher education, Lesson Study is often examined as a means of supporting pedagogical practice, improving lesson planning, and developing reflective skills rather than as a mechanism for fostering a sustainable research culture among future teachers. Third, research on historical thinking pedagogy and inquiry-based history education provides detailed accounts of evidence use, source analysis, contextualization, corroboration, and argumentation but rarely connects these disciplinary practices to the cyclical process of collaborative lesson inquiry characteristic of Lesson Study.

The originality of the present study lies in integrating four research traditions that are typically examined separately: Lesson Study in teacher education, pre-service teacher research culture, historical thinking pedagogy, and qualitative evidence in teacher professional learning. The article demonstrates how future history teachers, during their pedagogical practicum, move beyond describing lessons toward analyzing learning evidence specifically related to students' historical thinking, including source interpretation, causal reasoning, comparison of historical perspectives, and argument construction.

Moreover, the study situates Lesson Study within the context of undergraduate thesis development, enabling it to be viewed as a bridge between academic research, pedagogical practicum, and classroom-based practitioner inquiry. Unlike studies that primarily describe Lesson Study as a mechanism for improving lesson planning, classroom management, or general pedagogical reflection, the present research demonstrates how Lesson Study can be directed specifically toward the analysis of students' historical thinking. The study also offers a novel perspective by conceptualizing Lesson Study as a mechanism for developing the research culture of future history teachers. In this study, research culture is understood not merely as the ability to read academic literature or write a thesis but as a professional disposition to formulate research questions about one's own teaching practice, collect qualitative evidence, discuss findings collaboratively, revise lesson design, and connect pedagogical decisions to evidence about students' learning processes.

This research gap is particularly significant within the context of teacher education in Kazakhstan, where policy documents increasingly emphasize the development of teachers' research, analytical, and reflective competencies, while discipline-specific mechanisms for their implementation in history teacher education remain underdeveloped. The present study contributes to the existing literature by examining Lesson Study not only as a professional learning model but also as a tool for fostering a subject-specific research culture among future history teachers in authentic classroom settings. Such an approach connects the broader agenda of research-oriented teacher education with the disciplinary demands of history teaching, where source analysis, evidence interpretation, historical reasoning, and the development of responsible civic attitudes toward the past occupy a central position.

The purpose of this study is to examine the potential of Lesson Study for developing research-oriented

teaching practice and fostering the research culture of future history teachers. Specifically, the study seeks to answer the following research question: How does participation in Lesson Study influence the development of research-oriented teaching practice among future history teachers?

Research Methodology and Methods

The present study aimed to examine how participation in Lesson Study contributed to future history teachers' understanding and rethinking of teaching practices oriented toward the development of students' historical thinking. Accordingly, the research question focused on how participants' perceptions of the content, organization, and assessment of learning activities designed to foster historical thinking evolved through the processes of collaborative lesson planning, observation, discussion, and revision of research lessons. Unlike the earlier formulation of this section, the revised version consistently distinguishes between the overall research focus of the study and the analytical focus emerging at particular stages and cycles of the Lesson Study process.

The study employed a qualitative, interpretive, and practice-oriented research design and was grounded in Lesson Study as a form of collaborative professional inquiry embedded within pedagogical practice. This choice was informed by the contemporary literature, which conceptualizes Lesson Study not as a tool for external teacher evaluation but as a structured process of collaborative investigation of teaching and learning that integrates lesson planning, implementation of a research lesson, observation of student learning, collective interpretation of evidence, and subsequent lesson improvement (Lewis et al., 2006; Dudley, 2014; Lewis et al., 2019). Within initial teacher education programs, practicum-centered models of Lesson Study are particularly valuable because they connect pedagogical experimentation, an inquiry stance, and the analysis of authentic evidence concerning students' learning processes (Tan et al., 2024). The adoption of a qualitative practitioner-research design is also aligned with the traditions of reflective practice and the teacher-as-researcher approach, which regard professional knowledge as emerging not only from the application of established theory but also from systematic reflection on one's own practice and its empirical manifestations (Schön, 1983; Stenhouse, 1975; Elliott, 1991). A more comprehensive theoretical framework is presented in a separate section of the article; only those concepts directly informing the research design, data collection procedures, and analytical strategies are discussed here.

From a disciplinary perspective, the study was grounded in the understanding of historical thinking as a domain-specific set of practices for engaging with the past, including the analysis of historical significance, the use of evidence, the identification of continuity and change, causal reasoning, perspective-taking, and ethical reflection on historical interpretations (Seixas & Morton, 2013). Contemporary research on inquiry learning in history suggests that learning in this field involves not the reproduction of predetermined historical narratives but the construction and evaluation of interpretations of the past through engagement with questions, multiple sources, reasoning, and argumentation (Wineburg, 2001; Van Boxtel et al., 2021). Consequently, the study adopted historical thinking as its overarching research focus throughout all Lesson Study cycles, whereas analytical distinctions such as source interpretation, evidence-based argumentation, and student historical reasoning were employed at a more applied level to guide observation, analysis, and lesson revision.

The study was conducted within the context of pedagogical practicum and involved seven participants: five undergraduate students and two master's students enrolled in history teacher education programs. The group worked collaboratively over a fifteen-week practicum period, during which participants repeatedly planned, taught, observed, discussed, and revised research lessons. This context reflects the trend identified in international scholarship toward integrating Lesson Study into initial teacher education as a means of fostering an inquiry stance, professional noticing, and stronger connections between university-based preparation and school practice (Tan et al., 2024; Van Katwijk et al., 2023; Matjašič & Vogrinc, 2024).

Given the qualitative and context-dependent nature of the study, the sample was not intended to be statistically representative. Its rationale was based on the principle of substantive relevance: all participants were engaged in authentic history teaching practice, had opportunities to complete the full cycle of collaborative planning and reflection, and simultaneously occupied the roles of future teachers and research participants. In this sense, the study sought not statistical generalization but an analytically rich description of professional learning processes within a particular educational setting, consistent with the aims of

qualitative inquiry in educational research (Lincoln & Guba, 1985; Stahl & King, 2020).

To avoid terminological ambiguity, this article makes a clear distinction between stages and cycles. Stages refer to the six sequential procedural steps within a single Lesson Study cycle, whereas cycles denote complete repetitions of the six-stage process throughout the study. Thus, the research involved multiple Lesson Study cycles, each consisting of the same six stages: (1) identifying the research focus; (2) collaboratively designing the research lesson; (3) developing an observation protocol; (4) implementing the research lesson while other participants conducted observations; (5) conducting a post-lesson discussion based on the collected evidence; and (6) revising the lesson plan and formulating implications for the subsequent cycle. This distinction is consistent with the theory and international practice of Lesson Study, where a cycle is understood as a recurring iteration of inquiry, planning, teaching, and reflection, while the stages specify the internal organization of collaborative work within each iteration (Lewis et al., 2006; Lewis et al., 2019; Dudley, 2014).

During the first stage of each cycle, the group identified a research focus that remained constant throughout the study and was centered on students' historical thinking. During the second stage, participants collaboratively designed the research lesson by specifying learning objectives, tasks, anticipated student responses, and potential areas of difficulty. During the third stage, an observation protocol was developed that focused not primarily on teacher actions but on manifestations of student learning processes. Observers documented how students read and interpreted sources, what forms of evidence they employed, how they formulated explanations and arguments, where difficulties emerged, whether they progressed from description to interpretation, and how they responded to alternative perspectives and evidence. This shift in attention from teacher performance to student learning is considered one of the defining methodological features of Lesson Study and is particularly important in initial teacher education, where observation is often reported in overly general and insufficiently transparent ways (Dudley, 2014; Larssen et al., 2018; Kager et al., 2024).

At the fourth stage, one participant taught the research lesson while the remaining members of the group acted as observers. Observation was conducted according to the previously agreed protocol, and the collected data included students' written and oral responses, time-stamped records of significant episodes, moments when difficulties emerged, patterns of source use, and forms of evidential reasoning. During the fifth stage, a post-lesson discussion was conducted using reflective journals, observation notes, student written responses, lesson artefacts, and, where available, transcripts of collaborative discussions. It was at this stage that the analytical focus deepened most noticeably: the group moved from discussing the overall organization of the lesson and task structure toward a more discipline-specific examination of source interpretation, evidence-based argumentation, and student historical reasoning. Finally, during the sixth stage, the lesson plan was revised and the findings were translated into hypotheses and practical decisions for the subsequent cycle. In other words, students' historical thinking remained the overarching research focus throughout the study, while the analytical focus became progressively more specific as empirical evidence accumulated and the process evolved from planning to observation and subsequently to collective interpretation of data.

This logic helps eliminate the conceptual confusion between stages and cycles. Stages do not represent separate or independent research foci; rather, they denote the sequence of actions within a single Lesson Study cycle. The analytical focus, in contrast, is not mechanically attached to any individual stage but develops and becomes refined through transitions between planning, observation, and post-lesson discussion. In the early cycles, analytical attention naturally concentrated on the overall lesson structure and the extent to which tasks made historical thinking visible. In later cycles, following the accumulation of evidence and the revision of instructional designs, the analysis became more discipline-specific and increasingly focused on source interpretation, evidence-based argumentation, and manifestations of students' historical reasoning. Such progressive refinement is consistent with contemporary understandings of inquiry learning in history, according to which tasks, sources, and instructional scaffolds should be aligned with the intellectual processes that teachers and researchers seek to promote among students.

Data collection was organized as a multi-component process and extended across all Lesson Study cycles. The data corpus included original and revised lesson plans; observation protocols and observation notes recorded during research lessons; participants' reflective journals; materials from post-lesson

discussions and collaborative reflections; semi-structured interviews conducted after completion of the practicum; student written responses, student feedback, and lesson artefacts produced during classroom activities. This range of sources enabled the researchers to document both the intended lesson design and the learning processes actually observed among students, thereby facilitating comparisons between instructional intentions, classroom implementation, and subsequent interpretations of outcomes. In Lesson Study research, such data richness is considered particularly valuable because it links observation, pedagogical reflection, and evidence-based lesson revision.

To enhance transparency and analytical coherence, all materials were organized within an analytical matrix that functioned not as an independent method but as a tool for systematization. Within the matrix, each unit of data – a lesson-plan excerpt, observation note, reflective journal entry, participant statement from a post-lesson discussion, or student written response – was linked to: (a) the corresponding Lesson Study stage and cycle; (b) the data source; (c) the observed event or statement; (d) a preliminary code; (e) an analytical category; and (f) an interpretation related to the development of historical thinking. This organizational structure facilitated the comparison of evidence from multiple sources, the identification of recurring patterns, and a more transparent transition from empirical observations to analytical conclusions. Such an approach is consistent with contemporary expectations regarding the reporting of observation and reflection stages in Lesson Study research and broader standards of transparency in qualitative analysis.

Table 1.
Data Sources and Analytical Matrix

Data Source	What Was Recorded	Timing of Collection	Analytical Function	Position in the Analytical Matrix
Original and revised lesson plans	Learning objectives, tasks, anticipated responses, modifications after discussion	Before and after each research lesson	Comparison of lesson intentions and revisions	Stage/cycle, design decision, code, category, interpretation
Observation protocol и observation notes	Student responses, source use, learning difficulties, argumentation, time markers	During the research lesson	Documentation of students' learning processes	Stage/cycle, observation episode, code, category, interpretation
Participants' reflective journals	Individual reflections, uncertainties, professional insights	After the lesson and discussion	Identification of changes in professional understanding	Stage/cycle, reflective excerpt, code, category, interpretation
Post-lesson discussion and collaborative reflection materials	Collective interpretation of observations, proposals for lesson revision	Immediately after the lesson	Transition from observation to explanation and decision-making	Stage/cycle, discussion excerpt, code, category, interpretation
Semi-structured interviews	Retrospective evaluation of Lesson Study and professional learning	After completion of the practicum	Synthesis of perceived changes and limitations	Source, theme, code, category, interpretation
Student written responses, feedback и lesson artefacts	Written responses, arguments, interpretations, use of evidence	During and after the lesson	Examination of observable manifestations of historical thinking	Episode, artefact, code, category, interpretation

Note. The table reflects the original logic of data collection, retained and refined during the revision of the methodology section. The analytical matrix functioned as a tool for comparing lesson design, observation, reflection, and student artefacts rather than as an independent methodological framework.

Data analysis was conducted as a staged thematic analysis adapted to the aims of the study and organized into five interconnected steps. It is important to emphasize that the five-step framework used in

this study represents an operationalization of the broader procedures of thematic analysis described by Braun and Clarke and Nowell et al.; it was selected not to simplify the method but to ensure that the analytical procedures remained proportional to the data corpus and clearly aligned with the logic of Lesson Study (Braun & Clarke, 2021; Nowell et al., 2017).

The first step involved immersion in the data through repeated reading of all materials, preparation of analytical memos, and preliminary comparison of data sources. During the second step, open coding was conducted. Data excerpts were assigned codes related to lesson organization, work with historical sources, argumentation, student difficulties, changes in instructional decisions, and participants' reflections. The third step focused on grouping codes into preliminary categories and broader conceptual clusters. During the fourth step, these categories were compared across multiple data sources within the analytical matrix, discussed among members of the research team, and refined through consideration of convergent evidence, contradictions, and negative cases. The fifth step involved the generation of final themes and subthemes, which subsequently formed the basis for the presentation and discussion of the findings.

Within this process, the analytical matrix functioned as a bridging mechanism between coding and interpretation. It enabled not only thematic grouping of the data but also identification of situations in which the same phenomenon manifested differently across sources. For example, a lesson plan might incorporate opportunities for evidence-based argumentation, while observation notes indicated limited implementation of this objective, and student written responses demonstrated only partial understanding of the task. Such cross-source comparison prevented a linear reading of individual datasets and supported a more robust interpretation of recurring and divergent patterns. Consistent with principles of qualitative rigor, codes and preliminary categories were discussed among multiple researchers, while reflective notes were used to document assumptions associated with the dual role of the researcher as both a participant in the professional learning community and an analyst of the data.

To ensure trustworthiness, the study was guided by the classical criteria of credibility, transferability, dependability, and confirmability proposed by Lincoln and Guba (1985), as well as their subsequent application in educational research (Stahl & King, 2020). Credibility was strengthened through methodological and data-source triangulation. Findings were not derived from a single form of evidence but emerged through comparison of lesson plans, observation records, reflective journals, post-lesson discussions, interviews, and student artefacts. Researcher triangulation was achieved through collaborative examination of codes, categories, and analytical interpretations within the research team. Dependability was supported by maintaining a systematic audit trail: the analytical matrix, coding versions, analytical memos, and revised lesson plans made it possible to reconstruct the progression from raw data to final conclusions. Confirmability was enhanced through reflective documentation of researchers' expectations, professional assumptions, and potential biases. Transferability was supported through rich description of the context, participants, procedures, and analytical processes, allowing readers to judge the applicability of the findings to similar settings in initial teacher education.

Reflexivity held particular importance in this study because participants and researchers were engaged in a shared professional process. Consequently, interpretation of the data could not be regarded as neutral in a positivist sense. Reflective journals and analytical memos were therefore treated not as supplementary materials but as integral components of methodological transparency. They enabled researchers to make explicit the foundations of their interpretations and to distinguish between empirically observed phenomena and analytically derived conclusions. At the same time, this procedure was consistent with the principles of reflective practice, in which professional learning and change are documented through deliberate reconsideration of one's actions, decisions, and their consequences within educational contexts (Schön, 1983; Braun & Clarke, 2021).

From an ethical perspective, the study was guided by the principles of voluntary participation, confidentiality, informed consent, and data anonymization. During data processing, all participant names, school names, and any information that could identify individual students were removed or anonymized. Student written responses and lesson artefacts were used exclusively for analytical purposes and were not incorporated into assessment procedures. Because the study is qualitative and context-dependent in nature, its findings are intended to support analytical rather than statistical generalization. This limitation does not diminish the value of the study but establishes an appropriate framework for interpreting the results.

During the preparation of the manuscript, the authors used ChatGPT (OpenAI, GPT-5.5) as an auxiliary tool for academic language refinement, translation support, and improvement of text coherence. The use of artificial intelligence was limited to editorial assistance and did not involve the generation of empirical data, analytical results, or scientific conclusions. All research design, interpretation, and final decisions regarding the content of the article were made by the authors, who assume full responsibility for the integrity and accuracy of the study.

Results and discussion

To ensure analytical transparency, this section is structured around three interconnected levels of analysis. The first level presents the empirical findings of the study and documents changes identified in reflective journals, lesson plans, observation protocols, collaborative discussions, and student responses. The second level explicates the evidentiary basis of these findings by linking interpretations to specific thematic categories and data sources. The third level situates the findings within the broader literature on Lesson Study, research-based teacher education, historical thinking pedagogy, and qualitative practitioner research. This structure enables a systematic demonstration not only of what changes were identified, but also of how these changes were established and interpreted.

The relevance of such an approach is closely connected to the nature of history education. Unlike disciplines primarily concerned with the reproduction of knowledge, history education seeks to develop a complex set of intellectual practices associated with the analysis of the past. Within the framework of the Historical Thinking Project, historical thinking is understood as the ability to determine the historical significance of events, analyze causes and consequences, identify continuity and change, work with historical sources, and consider the ethical dimensions of historical experience. Historical literacy, in this context, is not viewed as the accumulation of factual knowledge but as the capacity to critically evaluate historical claims, assess the reliability of sources, and use historical evidence in constructing interpretations and conclusions (Seixas, 2006). This perspective has become widely accepted within contemporary scholarship on historical literacy and history education.

A significant contribution to understanding the nature of historical thinking was made by Sam Wineburg, who conceptualized historical thinking as a disciplinary practice fundamentally different from everyday reasoning. According to Wineburg, interest in the past may be natural, but historical understanding requires specialized intellectual procedures involving critical source analysis, evaluation of interpretations, and comparison of different forms of evidence (Wineburg, 2001). Furthermore, Wineburg highlighted the dangers of presentism, the uncritical projection of contemporary values and assumptions onto the past – which can hinder meaningful historical explanation and interpretation (Wineburg, 1991). Consequently, the preparation of future history teachers should extend beyond mastery of subject content and include the ability to investigate how students develop historical thinking, analyze patterns of reasoning, and design learning environments that foster evidence-based historical reasoning.

This issue becomes particularly important within the context of citizenship education. History education serves not only a cognitive but also a social function by cultivating students' capacity to critically examine social processes, evaluate the consequences of historical decisions, and participate responsibly in civic life. A historically literate citizen is capable of recognizing the complexity of historical experience, identifying manipulative interpretations of the past, and understanding the influence of historical memory on contemporary society. Therefore, the development of historical thinking constitutes an essential condition for fostering civic responsibility and a culture of democratic dialogue.

Despite growing interest in research-based teacher education and reflective practice, numerous studies indicate that many teacher education programs continue to retain a predominantly reproductive orientation. Within such models, emphasis is placed on lesson organization and delivery, while students' learning processes and the mechanisms through which thinking develops remain peripheral to professional analysis. Research on teacher education suggests that the concepts of the teacher-researcher and the reflective teacher emerged precisely as attempts to bridge this divide between teaching and the systematic investigation of educational practice (Fagundes, 2016). Nevertheless, the integration of research activities into teacher education remains fragmented in many contexts. As a result, future teachers frequently focus on implementing curricula and delivering lessons rather than analyzing evidence related to student learning.

This contradiction is particularly visible in history education, where novice teachers often reproduce textbook narratives and traditional instructional approaches instead of organizing inquiry-based learning and evidence-based historical inquiry.

In this context, Lesson Study is of particular interest as a form of professional inquiry into teaching practice. Originating in Japan as jugyō kenkyū ("lesson research"), Lesson Study was initially conceived as a collaborative process in which teachers jointly identify a research problem, design a lesson, observe students' learning activities, analyze evidence, and refine subsequent instructional decisions. Contemporary research suggests that the effectiveness of Lesson Study extends beyond improving individual lessons and includes the development of sustainable mechanisms of professional learning grounded in collaborative analysis, reflection, and investigation of student learning processes (Lewis et al., 2019). Unlike traditional peer observation models, Lesson Study focuses not on evaluating the teacher but on examining how students engage with content, interpret information, and solve learning tasks.

Peter Dudley conceptualizes Lesson Study as a highly structured form of classroom action research aimed at developing teachers' professional knowledge through systematic investigation of student learning (Dudley, 2014). Such a perspective allows Lesson Study to be understood not merely as a teaching technique but as a form of collaborative inquiry and practitioner research. Its significance derives from the integration of several characteristics associated with effective professional learning: subject specificity, collaborative analysis, active participation, reflection, and cyclical improvement of practice. Within Lesson Study, professional knowledge emerges not through the transmission of predetermined recommendations but through the analysis of authentic evidence concerning student learning and the collective interpretation of educational outcomes. For this reason, the approach holds particular promise for the preparation of future history teachers whose professional work is closely connected to fostering students' disciplinary thinking.

Despite the widespread adoption of Lesson Study internationally, its potential for developing the research culture of future history teachers remains insufficiently explored. Most existing studies focus on improving subject-specific instruction, enhancing professional reflection, or organizing collaborative professional learning. Considerably less attention has been devoted to understanding how Lesson Study contributes to the development of research-oriented teaching practice specifically within history education, where the primary object of inquiry is students' historical thinking. This gap highlights the need for more detailed examination of the relationships among Lesson Study, analytical reflection, evidence-informed pedagogical reasoning, and the development of research culture among future history teachers.

To strengthen the empirical grounding of the study, findings were generated through thematic analysis of data collected from multiple complementary sources, including reflective journals, lesson plans, observation protocols, student artefacts, interviews, planning sessions, and collaborative reflection transcripts. The use of diverse forms of evidence made it possible not only to identify changes in participants' professional thinking but also to trace the mechanisms through which those changes emerged during Lesson Study. Unlike traditional accounts of teaching practicum experiences, the analysis focused on identifying recurring analytical categories that reflected the transformation of research-oriented pedagogical practice among future history teachers.

The thematic analysis revealed several interconnected dimensions of professional development, reflecting changes in pedagogical reflection, decision-making processes, understandings of historical thinking, and attitudes toward research. Importantly, these categories were not predetermined on the basis of existing theoretical models. Rather, they emerged inductively through analysis of reflective journals, observation protocols, lesson plans, student artefacts, interviews, and collaborative discussions. At the same time, the resulting categories demonstrated strong conceptual alignment with contemporary research on Lesson Study, practitioner inquiry, and research-oriented teacher education.

The most prominent trend was a transition from descriptive to analytical reflection. Initially, participants tended to focus on external aspects of teaching, such as lesson pace, classroom organization, adherence to timing, and their own actions as instructors. However, as Lesson Study progressed, the content of reflective writing changed substantially. Attention shifted from teacher behaviour toward students' thinking, the nature of their difficulties, and the relationships between pedagogical decisions and learning outcomes. The analysis demonstrated that participants increasingly viewed classroom evidence as a resource for improving future instruction rather than as a record of lesson implementation.

A second recurring theme was the development of evidence-informed pedagogical reasoning. In contrast to traditional practice, where pedagogical decisions are often based primarily on intuition or accumulated experience, participants increasingly relied on observation data, students' written responses, and analyses of historical sources as a basis for modifying lesson design. As a result, instructional decisions were progressively justified not by personal preferences but by concrete evidence collected during the research lesson.

A third category was associated with the development of source-based historical inquiry. Participants gradually moved away from using historical sources as merely illustrative materials and began to treat them as instruments of historical investigation. Revised lesson plans included a growing number of tasks requiring students to examine the origin of sources, their historical context, authorial perspective, and reliability. A transition was observed from the analysis of single documents to the comparison of multiple sources and discussion of discrepancies among them.

A fourth theme reflected the development of collaborative professional learning. During the initial stages, interaction among participants was largely limited to the distribution of responsibilities and discussion of organizational issues. Over time, however, collaborative discussions increasingly took the form of collective professional inquiry. Participants learned to pose clarifying questions, analyze evidence, critically examine assumptions, and jointly develop decisions concerning modifications to lesson design.

Finally, a distinct category concerned the development of elements of research culture. Analysis of thesis materials, research notes, and reflective journals demonstrated that Lesson Study gradually came to be perceived not only as a means of improving instruction but also as a method of generating research data. Participants began to formulate research questions, systematically collect evidence, document observations, and interpret findings within the context of their professional development.

Particularly revealing was the pattern of change documented in participants' reflective journals. Analysis of these journals showed that professional learning did not occur as an immediate transformation. Rather, change developed gradually through increasingly sophisticated ways of interpreting pedagogical experience.

During the first Lesson Study cycle, participants' reflections focused predominantly on their own performance as teachers. Most comments concerned lesson organization, time management, classroom discipline, and the quality of explanation. Typical statements included: "I explained the material too quickly," "Time should be distributed more effectively between lesson stages," and "Students were not sufficiently active." Such comments exemplify procedural reflection, in which the primary object of analysis is the teacher's own activity.

During the second cycle, a gradual shift toward the analysis of students' learning difficulties became evident. Reflective journals increasingly included observations related to students' understanding of tasks, interpretation of historical sources, and construction of arguments. Participants began to document not only what occurred during the lesson but also potential reasons underlying observed difficulties. For example, one participant noted that students were able to complete a task but were unable to explain why they considered a particular source trustworthy. Observations of this kind prompted revisions to lesson structure and the introduction of questions addressing source origin, authorship, purpose, and historical context.

The most substantial changes were observed during the third Lesson Study cycle. By this stage, reflection had acquired a distinctly analytical character and became oriented toward the interpretation of evidence. Participants began connecting observable features of students' historical thinking with specific elements of lesson design. They examined how teachers' questions influenced the quality of student argumentation, which tasks supported the development of sourcing and corroboration, and which tasks limited opportunities for historical reasoning.

The following excerpt from a reflective journal is particularly illustrative: "When analyzing the photograph, students focused almost exclusively on political leaders and paid little attention to representatives of other social groups. This suggests that the question directs them toward identifying obvious information and therefore requires revision". In this case, the participant's attention was directed not toward personal teaching performance but toward the mechanism linking instructional design and students' historical thinking. Another participant observed: "We initially assumed that the problem stemmed from insufficient factual knowledge. However, students' written responses indicated that they struggled to use the

source as evidence". Statements of this kind demonstrate a shift toward evidence-informed reasoning, in which pedagogical conclusions are derived from empirical evidence rather than prior assumptions.

The findings indicate a gradual transformation in the very nature of pedagogical reflection. Whereas reflection initially functioned primarily as a form of teacher self-evaluation, it increasingly became a tool for investigating learning processes. In other words, participants came to view the lesson not as an opportunity to assess their own effectiveness but as a context for examining how students construct historical knowledge, use evidence, and develop arguments.

This transformation is consistent with Donald Schön's conception of the transition from technical rationality to reflective professional practice. Through Lesson Study, future teachers gradually moved beyond a simplified understanding of teaching as the transmission of knowledge and began to perceive the lesson as an inquiry situation requiring continuous analysis, interpretation, and revision of pedagogical decisions. These findings also align with the ideas of Lawrence Stenhouse, who viewed teachers as researchers of their own practice and as creators of professional knowledge through systematic inquiry.

Changes in professional reflection were accompanied by a noticeable transformation of lesson planning and instructional design. Analysis of original and revised lesson plans demonstrated that Lesson Study influenced not only the interpretation of evidence but also participants' understanding of the structure of history lessons themselves. If, at the outset, most participants focused primarily on the sequential delivery of content, lessons increasingly came to be viewed as spaces for historical inquiry and the development of students' historical thinking.

The initial lesson plans generally followed a traditional teacher-centered model. Lessons typically began with teacher explanations, followed by work with textbooks or individual historical documents, and concluded with brief discussions or checks of factual knowledge acquisition. The primary emphasis was placed on reproducing historical information and covering curricular content. Historical sources functioned largely as illustrations supporting an already established narrative. Questions posed by teachers were predominantly designed to elicit factual recall and confirm knowledge acquisition.

However, observations and analysis of student responses revealed that this structure did not consistently support the development of historical thinking. Although many students were able to reproduce information, they frequently encountered difficulties when interpreting historical sources, explaining causal relationships, and constructing evidence-based arguments. Written responses often lacked explicit connections between claims and evidence, and historical documents were commonly treated as repositories of information rather than objects of analysis.

These observations became the basis for substantial revisions of research lessons. In revised lesson plans, participants moved away from a linear content-transmission model toward an approach grounded in the principles of historical inquiry. Central positions within lessons were increasingly occupied by problem-based questions requiring the analysis of evidence and the construction of interpretations. Participants began introducing inquiry questions at the beginning of lessons to guide subsequent investigation and structure students' learning activities.

The shift toward inquiry-oriented lesson design is particularly evident in the nature of the questions incorporated into revised lesson plans. Although many inquiry questions were derived from topics specified in the national curriculum, they were reformulated to require investigation rather than factual recall. For example, instead of simply studying the revolt of Spartacus, students were asked: "How does the revolt of Spartacus reveal the nature of slavery in Ancient Rome?" Similarly, lessons on the Huns included the inquiry question: "Why did Modu Chanyu argue that land constituted the foundation of the state?" Such formulations required students to analyze historical evidence and construct arguments rather than reproduce textbook information.

Substantial changes also occurred in the organization of work with historical sources. Whereas early lesson plans typically relied on a single document serving an illustrative function, later versions incorporated multiple sources of different origins. Students were asked to compare documents, identify differences in authors' perspectives, analyze the context in which sources were produced, and evaluate their reliability. As a result, historical sources gradually shifted from being supplementary materials to becoming central tools of historical investigation.

Particular importance was assigned to the incorporation of sourcing, contextualization, corroboration,

and multiperspectivity. Participants increasingly designed activities that required students to identify the authorship of sources, examine the purposes for which they were created, analyze their historical context, and compare multiple accounts of the same event. These elements were no longer treated as isolated exercises but became integrated into a broader process of historical inquiry. Consequently, students were provided with opportunities to engage with historical documents in ways that more closely resembled the practices of professional historians.

Changes were also observed in the nature of teachers' questions. During the early stages of the project, questions were predominantly reproductive in character, such as: "What happened?", "When did the event occur?", and "Who participated?" In revised lesson plans, these were increasingly replaced by analytical questions, including: "Which evidence from the source supports this interpretation?", "Why do different sources explain the event differently?", and "What evidence suggests that one source may be more reliable than another?" Questions of this kind required the use of evidence and encouraged the development of historical argumentation.

The nature of assessment tasks also changed considerably. Initially, final activities were largely limited to retelling historical content or providing brief answers to factual questions. Following participation in Lesson Study, however, participants increasingly employed argumentation-based tasks. Students were required to formulate a claim, identify supporting evidence, explain the significance of that evidence, and develop a reasoned conclusion. This structure promoted evidence-based reasoning and more deliberate engagement with historical sources.

Taken together, these findings indicate that Lesson Study contributed to a fundamental shift in participants' understanding of instructional design. Lesson planning ceased to be viewed primarily as the organization of content and classroom time. Instead, it became understood as the construction of conditions under which students could analyze evidence, formulate historical interpretations, and develop historical thinking. In this respect, the transformation of lesson design reflects a broader transition from content-centered instruction toward inquiry-based history education.

Student artefacts and written responses constituted a particularly valuable source of evidence because they made it possible to trace changes in students' historical thinking as manifested through their engagement with learning tasks. Analysis of student responses suggested that initial difficulties were associated less with a lack of factual knowledge than with underdeveloped procedures of historical reasoning.

During the first Lesson Study cycle, most student responses were predominantly descriptive. Students tended to identify isolated features of a source, summarize the content of a document, or list factual information without moving beyond simple reproduction. For example, when analyzing a historical image, students frequently provided comments such as: "The picture shows rulers and ordinary people" or "The image depicts an important historical event." Such responses demonstrated attention to the content of the source but contained little evidence of interpretation or analytical reasoning.

Across subsequent cycles, the structure of student responses became increasingly sophisticated. Following the introduction of tasks emphasizing sourcing and contextualization, students more frequently referred to the origins of sources, the circumstances of their creation, and the possible perspectives of their authors. Written responses began to include statements indicating attempts to analyze historical perspective and evaluate the credibility of information.

The most notable changes were documented during the third Lesson Study cycle. At this stage, students' written work increasingly displayed elements of evidence-based reasoning. Historical sources were no longer treated solely as objects of description but were used as evidence in the construction of arguments. Students wrote statements such as: "This source reflects the perspective of the authorities and therefore should be compared with other accounts." and "The author may have exaggerated the significance of the event because the account was written after the victory." Such responses demonstrate the emergence of sourcing, corroboration, and historical argumentation.

It is important to emphasize that these findings do not suggest the complete development of historical thinking within the relatively limited duration of the study. Rather, they indicate a meaningful shift in the orientation of students' learning activity. Whereas students initially viewed sources primarily as illustrations of already-known information, they increasingly came to use them as evidence for explaining historical

phenomena and evaluating competing interpretations of the past.

Analysis of student responses also revealed gradual development in historical argumentation. In earlier work, claims were often unsupported by evidence, or the connection between a claim and its supporting evidence remained implicit. In later responses, students more frequently identified specific details from sources, explained their significance, and used them to justify their interpretations. This progression reflects a movement from information reproduction toward more sophisticated forms of historical reasoning.

The findings therefore suggest that changes in lesson design were accompanied by corresponding changes in students' learning activity. The use of inquiry-based tasks, multiple sources, and argumentation-oriented assignments created conditions conducive to the expression and development of key components of historical thinking. These results support the proposition that instructional design, task structure, and opportunities for evidence use are closely connected to the quality of students' historical reasoning.

The findings indicate that participation in Lesson Study supported a transition from descriptive reflection toward analytical examination of student learning processes among future history teachers. Whereas participants initially focused primarily on their own actions and organizational aspects of teaching, their attention increasingly shifted toward students' historical thinking, the quality of argumentation, and the use of evidence. This tendency is consistent with Donald Schön's conception of the reflective practitioner, according to which professional development is grounded in the continuous analysis and reinterpretation of practice.

The results also support the ideas of Lawrence Stenhouse and John Elliott concerning the teacher as a researcher of practice. Lesson Study created conditions for systematic analysis of classroom evidence, collaborative discussion of findings, and revision of instructional decisions based on empirical data rather than intuition. In this sense, inquiry became integrated into the everyday professional activity of participants.Особое значение имеет влияние Lesson Study на развитие evidence-informed pedagogical reasoning. Анализ lesson plans и student responses показал переход от teacher-centered instruction к элементам inquiry-based history education. Участники стали чаще использовать исторические источники как инструмент исследования, включать задания на sourcing, contextualization и corroboration, а также ориентировать учащихся на построение аргументации на основе evidence. Это согласуется с современными представлениями о historical thinking как ключевой цели исторического образования.

A further important finding concerns the influence of Lesson Study on the development of evidence-informed pedagogical reasoning. Analysis of lesson plans and student responses demonstrated a gradual shift from teacher-centered instruction toward elements of inquiry-based history education. Participants increasingly employed historical sources as instruments of investigation, incorporated tasks focused on sourcing, contextualization, and corroboration, and encouraged students to construct arguments grounded in evidence. These developments are consistent with contemporary conceptions of historical thinking as a central goal of history education.

Another significant outcome was the emergence of collaborative professional inquiry. Joint lesson planning, observation, and discussion created opportunities for professional interaction grounded in the analysis of evidence and collective problem-solving. Over time, participants increasingly came to view teaching not as an individual activity but as a process of collaborative professional investigation. This finding aligns with contemporary studies emphasizing the role of professional learning communities in supporting sustainable professional growth and reflective practice.

Taken together, these findings suggest that Lesson Study, when embedded within teaching practicum experiences, has considerable potential as a mechanism for developing research-oriented teaching practice and fostering the research culture of future history teachers. The results indicate that Lesson Study can be understood not only as a means of improving lesson quality but also as a framework for integrating pedagogical practice, professional reflection, and inquiry-based professional learning.

The findings also contribute to the broader discussion concerning the relationship between teacher education and research. International scholarship has increasingly emphasized that effective teacher preparation requires future teachers not merely to consume research but to engage in systematic inquiry into their own practice. Within this perspective, research competence is viewed as a professional capability that enables teachers to formulate questions, gather evidence, interpret data, and make informed pedagogical

decisions. The present study demonstrates that Lesson Study can provide a practical structure through which these competencies are developed in authentic classroom settings.

The study further suggests that the development of research-oriented practice in history education possesses distinctive disciplinary characteristics. Unlike many other school subjects, history requires students to engage with evidence, evaluate competing interpretations, and construct reasoned historical explanations. Consequently, future history teachers must learn not only how to teach historical content but also how to investigate students' historical reasoning. Participation in Lesson Study encouraged future teachers to focus their attention on these disciplinary dimensions of learning and to use classroom evidence as a basis for refining instructional decisions.

An important implication of the findings concerns the relationship between historical thinking and teacher inquiry. The results indicate that when teachers systematically examine how students interpret sources, use evidence, and construct arguments, they become more capable of designing learning experiences that support disciplinary thinking. Thus, Lesson Study functioned simultaneously as a mechanism for professional learning and as a methodology for investigating the development of historical thinking. This dual role may be particularly valuable in history teacher education, where the boundaries between teaching, reflection, and inquiry are often less clearly articulated than in research-intensive professional preparation programs.

At the same time, several limitations should be acknowledged. First, the study was conducted with a relatively small group of participants within a single teacher education context. As a result, the findings are intended to support analytical rather than statistical generalization. Second, the study focused primarily on participants' perceptions, reflections, and documented practices during the practicum period. Although student artefacts provided evidence of changes in historical reasoning, the research was not designed to measure long-term effects on student learning outcomes. Third, the dual role of participants as both practitioners and researchers may have influenced the interpretation of events and observations despite the use of triangulation, reflexive documentation, and collaborative analysis procedures.

Despite these limitations, the study offers several contributions to the literature. It extends existing research on Lesson Study by examining its role in the preparation of future history teachers rather than in the professional development of in-service teachers. It also contributes to scholarship on research-based teacher education by demonstrating how inquiry can be integrated into pedagogical practicum through collaborative investigation of classroom learning. Finally, it enriches research on historical thinking by showing how the development of disciplinary reasoning can become an explicit focus of teacher inquiry and professional reflection.

Conclusions

The study demonstrates that Lesson Study can function as an effective mechanism for developing research-oriented teaching practice and research culture among future history teachers. Participation in collaborative lesson inquiry contributed not only to methodological improvement but also to significant transformations in reflective thinking, pedagogical reasoning, and the understanding of teaching as a research-oriented professional activity.

One of the central findings concerns the transition from descriptive and teacher-centered reflection toward analytical and evidence-informed reflective practice. Participants increasingly focused on students' learning processes, historical reasoning, and evidence interpretation. Lesson Study therefore created a structured environment for developing reflective pedagogical thinking grounded in collaborative inquiry and classroom evidence.

The research also revealed substantial changes in instructional design and pedagogical decision-making. Participants integrated inquiry-based approaches, source-based learning, and evidence-oriented argumentation tasks into classroom instruction. Historical sources became tools for interpretation, multiperspectivity, and disciplinary inquiry rather than simple illustrations.

Another important outcome was the development of collaborative professional culture. Participation in collaborative planning, classroom observation, and reflective discussion enabled future and practicing teachers to perceive teaching as collaborative professional inquiry rather than isolated individual practice.

The study additionally demonstrates that Lesson Study contributed to changing participants'

understanding of teaching as research. Participants gradually moved away from viewing teaching as the implementation of predetermined instructional techniques and began perceiving classroom practice as an ongoing inquiry into students' thinking and learning.

Particular significance of the research lies in the integration of Lesson Study into graduation research projects of final-year students. Lesson Study was not treated as an additional component of pedagogical practice but as part of students' research activity connected with inquiry-based history teaching, historical thinking, and classroom evidence analysis. Integrating Lesson Study into graduation projects enabled the combination of academic research and pedagogical practice while fostering students' research autonomy and evidence-informed professional thinking.

At the same time, the study identified several limitations related to the short duration of pedagogical practice, the limited number of participants, difficulties in interpreting classroom evidence, insufficient experience with reflective practice, and the persistence of teacher-centered instructional tendencies.

The theoretical significance of the study lies in demonstrating the potential of Lesson Study to integrate reflective pedagogy, practitioner inquiry, and disciplinary approaches to history education within a unified research-oriented framework. The practical significance of the research is associated with the possibility of integrating Lesson Study into teacher education programs as a mechanism for developing reflective, collaborative, and inquiry-oriented professional culture.

Overall, the findings suggest that Lesson Study should be understood not simply as a pedagogical technique or a model of peer lesson observation but as a form of collaborative professional inquiry that supports the development of research culture, reflective pedagogical thinking, and evidence-informed teaching practice among future history teachers.

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Author Contributions

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DIGITAL GAME-BASED LEARNING IN SCHOOL CHEMISTRY AND MATHEMATICS: DUAL CASE STUDIES IN STOICHIOMETRY AND PROBABILITY THEORY AND IMPLICATIONS FOR HIGHER EDUCATION TEACHER PREPARATION IN KAZAKHSTAN

Abstract. This article reports on two complementary multi-year case studies of integrating open-access PhET Interactive Simulations into the teaching of two notoriously demanding topics in the Kazakhstani school curriculum – stoichiometry in chemistry and probability theory in mathematics – and translates the resulting evidence into a unified set of design principles and curricular recommendations for higher education teacher preparation. Case 1 examines the use of "Reactants, Products and Leftovers" in 8th-grade chemistry across three Almaty schools; Case 2 examines the use of "Plinko Probability" in 10th-11th-grade mathematics across two Almaty institutions. Both interventions used a structured Predict-Observe-Explain design with parallel 15-item pre/post-tests, student questionnaires, and lesson-time logs. Across both subjects, simulation-supported instruction was associated with substantial gains in conceptual understanding (median Cohen's d ≈ 1.0-1.1), increased intrinsic engagement, and a measurable reduction in the time required to reach class-level mastery. Crucially, the same four cross-cutting themes emerged in both subjects: visualisation of abstract sub-microscopic and stochastic phenomena, productive failure under low-stakes simulation, the limited appeal of competitive game elements, and the centrality of teacher coaching. We argue that this convergence across two very different STEM subjects strengthens the case for embedding digital game-based learning (DGBL) into Kazakhstani higher education through a four-component framework – conceptual orientation, simulation literacy, gamified lesson design and reflective practicum – applicable equally to chemistry and mathematics teacher preparation. Implications are discussed for university curriculum developers, methodologists and policymakers seeking to scale evidence-based gamification across the school-university continuum.

Keywords: digital game-based learning; PhET simulations; stoichiometry; probability theory; mathematics education; chemistry education; higher education; teacher preparation; gamification.

Introduction

The digitalization of higher education has become a strategic priority and is explicitly recognised as one of the core directions of the State Programme for the Development of Education and Science of the Republic of Kazakhstan. Within this agenda, science and mathematics teacher preparation occupies a particularly demanding position: future chemistry and mathematics teachers must master both the discipline and a rapidly expanding portfolio of digital pedagogies that they will be expected to deploy in classrooms upon graduation.

Two topics in the school STEM curriculum are routinely identified by Kazakhstani methodologists and international researchers alike as among the most cognitively demanding: stoichiometry in chemistry and probability theory in mathematics. Stoichiometry requires students to coordinate macroscopic, sub-microscopic and symbolic representations of matter, and to perform proportional reasoning over balanced equations. Probability theory requires students to reason under uncertainty, to coordinate empirical relative frequencies with theoretical models, and to overcome a set of robust intuitive misconceptions documented since Fischbein (1975). International studies report persistent learner difficulties in both subjects – difficulties that propagate upward into university and that pre-service teachers tend to replicate in their own classrooms. In the Kazakhstani context, Kaiyngbayeva et al. (2021) describe "the methodological unpreparedness of teachers" as the central obstacle to teaching probability and statistics in secondary schools, while parallel concerns are documented for chemistry teacher preparation by Karmanova et al. (2024).

The need to strengthen teacher preparation specifically for these two topics is rooted in documented

school. Kazakhstan's performance in successive international assessments illustrates the scale of the problem: in PISA 2022, 15-year-olds scored 425 in mathematics and 423 in science, well below the OECD averages of 472 and 485, and only about half reached at least Level 2 proficiency in mathematics, compared with roughly two-thirds across the OECD (OECD, 2023). Such outcomes are concentrated also in the kinds of proportional, multi-step and probabilistic reasoning that stoichiometry and probability theory demand. At the level of everyday classroom practice, both topics are routinely taught as formula-driven, symbol-manipulation exercises: stoichiometry is reduced to mechanical mole calculations divorced from the particulate nature of matter, and probability is reduced to combinatorial formulae applied without any experimental or simulation experience. Probability and statistics is, moreover, a comparatively recent addition to the Kazakhstani school curriculum and no dedicated university course on its teaching methodology (Kaiyngbayeva et al., 2021). The result is a self-reinforcing cycle in which teachers reproduce the formal, non-conceptual instruction. The low baseline pre-test scores recorded in both of our own cases means of 6.8 out of 15 in chemistry and 5.9 out of 15 in probability (see Results) quantify this problem directly in the very classrooms studied here. It is this concrete gap in school practice the present study seeks to address by preparing future teachers to teach these specific topics differently.

Digital game-based learning (DGBL) and gamification have emerged as one of the most actively researched responses to such challenges across STEM. Three-level meta-analytic evidence shows that game-based learning has a positive overall effect on chemistry achievement and motivation across educational levels (Hu et al., 2022); systematic reviews of gamification confirm small-to-moderate but reliable effects on engagement, motivation and academic performance in science education (Kalogiannakis et al., 2021; Zainuddin et al., 2020); and reviews of probability and statistics education conclude that simulation-based learning environments are particularly well suited to building students' conceptual and modelling-oriented understanding of uncertainty (Pratt & Kazak, 2018). Within both chemistry and mathematics specifically, the open-access PhET Interactive Simulations developed at the University of Colorado Boulder have become a de facto international standard, with a substantial body of empirical work documenting gains in conceptual understanding, attitudes and self-efficacy when they are used as part of inquiry-oriented instruction (Perkins et al., 2006; Salame & Makki, 2021; Banda & Nzabahimana, 2023).

In Kazakhstan, however, much of the available evidence on PhET- and game-based learning is concentrated at the school level and is fragmented across subjects: chemistry studies and probability/statistics studies have largely developed in parallel rather than in dialogue. Higher education institutions, including those preparing future chemistry and mathematics teachers, have so far adopted such tools unevenly. Recent national studies emphasise that the professional competence of future chemistry teachers depends critically on their exposure to digital technologies during initial training (Karmanova et al., 2024); a parallel comparative study of secondary and higher education in Kazakhstan reports that gamification remains fragmented and lacks systemic policy support (Sardarova et al., 2026). Bridging these gaps requires evidence that is not only empirical but also cross-disciplinary demonstrating that the same digital-pedagogical principles can be translated into the methodology courses of multiple subject teacher programmes.

The evidence base on the digitalisation of Kazakhstani higher education, and on the digital-pedagogical preparation of future teachers in particular, has grown rapidly but remains thin. Beyond the two studies noted above, recent work points consistently to a gap between policy ambition and classroom-ready competence. Abiltayeva et al. (2025), surveying 240 pre-service biology teachers across three Kazakhstani universities, found high self-reported technological-pedagogical knowledge coexisting with markedly lower frequency of actual digital-tool use, and concluded that hands-on, subject-specific training is needed to close the gap between positive attitudes and practice. Yespenbetova et al. (2024) report that online and virtual laboratory work is becoming central to undergraduate chemistry but is adopted unevenly across institutions, while Sardarova et al. (2026) document an urban–regional digital divide and the absence of explicit institutional policies on gamification. Across these studies a common pattern emerges: national strategy (including the "Digital Kazakhstan" programme and Bologna-aligned reforms) endorses digital pedagogy, yet pre-service teachers graduate without structured, discipline-specific experience of designing and enacting technology-rich lessons. What is still missing is cross-disciplinary classroom evidence showing that a single set of digital-pedagogical principles can be translated into the methodology courses of more than one

subject.

The present article addresses that gap by reporting on two complementary case studies conducted by the authors. Case 1 examines the integration of the PhET simulation "Reactants, Products and Leftovers" into 8th-grade chemistry instruction across three Almaty schools. Case 2 examines the integration of the PhET simulation "Plinko Probability" into 10th-11th-grade mathematics instruction (probability theory and statistics) across two Almaty schools. The article pursues four objectives: 1) to evaluate the impact of structured PhET-based interventions on students' conceptual understanding, motivation and instructional time in two distinct STEM subjects; 2) to identify the design principles that made the interventions effective at the school level; 3) to test whether the same principles emerge across chemistry and mathematics; and 4) to translate the principles into a unified framework for embedding DGBL into university methodology courses for future chemistry and mathematics teachers in Kazakhstan.

In doing so, the article contributes to three focus areas, methodology of teaching in higher education, quality assurance, and digitalization of higher education, by showing how cross-disciplinary research evidence generated in schools can be systematically used to upgrade the digital-pedagogical preparation of university students who will themselves become subject teachers.

DGBL and educational simulations are most often grounded in three converging theoretical perspectives, all of which apply equally to the teaching of chemistry stoichiometry and to the teaching of probability theory. Constructivist learning theory holds that learners actively build mental models through interaction with their environment, and predicts that interactive simulations which allow manipulation of variables and immediate visual feedback should support deeper conceptual restructuring than passive instruction (Hammad et al., 2020). Cognitive load theory complements this view by arguing that well-designed simulations can reduce extraneous load (e.g., the symbolic complexity of formulas, or the abstractness of theoretical probabilities) by externalising representations, freeing working memory for schema construction; conversely, poorly designed games may add load and depress learning (Hawlitschek & Joeckel, 2017). Self-determination theory frames the motivational benefits of gamification: feedback, autonomy of pace, and graded challenge support intrinsic motivation, particularly when game elements such as points and leaderboards are balanced against opportunities for collaboration and meaningful choice (Zainuddin et al., 2020).

Together, these frameworks predict that digital simulations – whether of molecular reactions or of stochastic experiments – should be most effective when integrated into instruction that is conceptually focused, scaffolded by structured tasks, and accompanied by metacognitive reflection. They also predict that simply providing students with a simulation, without instructional guidance, will produce small or null effects – a prediction confirmed by experimental work on game design (Hawlitschek & Joeckel, 2017). The teacher's role in shaping the simulation-based learning environment emerges as a key finding in the probability literature as well (Pratt & Kazak, 2018), suggesting that the cross-subject convergence we report below is not coincidental.

PhET Interactive Simulations are research-based, openly licensed simulations covering most of the core topics in school and undergraduate chemistry and mathematics. In chemistry, Salame and Makki (2021), in a study of 158 General Chemistry II students at the City College of New York, reported that students perceived PhET simulations as significantly enhancing their conceptual grasp of abstract topics. Banda and Nzabahimana (2023), using a quasi-experimental design with 280 secondary students in Malawi, found large effects of PhET-based instruction on academic achievement (Cohen's d = 1.14) along with significant gains in self-efficacy and active learning strategies. In mathematics, the "Plinko Probability" simulation – a digital implementation of the Galton board – has been widely adopted to teach binomial and normal distributions, the law of large numbers, expected value and variance through dynamic visualisation: students drop balls through a peg array and observe how empirical histograms converge on theoretical distributions as the sample size grows. Pratt and Kazak's (2018) review of probability research highlights such simulation-based environments as one of the most promising routes to addressing the persistent intuitive misconceptions documented by Fischbein (1975), and the GAISE framework explicitly endorses simulation as a core method for K-12 statistics instruction (Franklin et al., 2007).

Beyond PhET specifically, meta-analytic evidence shows that game-based chemistry learning yields a positive overall effect on student outcomes (Hu et al., 2022); a recent systematic review of gamification in

primary and secondary education identified increased motivation and engagement as the most consistently reported outcomes (Vrcelj et al., 2023). At the higher education level, Montenegro-Rueda et al. (2023) report that gamified university courses are associated with stronger engagement and modest gains in achievement, while Park and Kim (2021) show that gamified online learning sustains motivation in distance settings. A broad review of computer-based technology and student engagement concludes that interactive technologies are among the most consistent predictors of behavioural and cognitive engagement when integrated thoughtfully (Schindler et al., 2017). Stohl (2005) makes a complementary argument specifically for probability teacher education: pre-service teachers who do not themselves experience probability as an experimental, simulation-rich subject tend to teach it as a purely formal topic, perpetuating their own misconceptions.

A more recent and still emerging strand of research focuses specifically on how gamification and DGBL should be taught to future teachers. Jiménez-Valverde et al. (2024), in a 14-week mixed-methods study of 65 pre-service primary teachers, demonstrated that structural gamification of a science methodology course significantly improved pre-service teachers' attitudes toward physics and chemistry and their motivation to teach these subjects. Lampropoulos and Kinshuk (2024), in a systematic review, argue that integrating gamification with virtual and immersive technologies is becoming a defining feature of next-generation teacher education. These findings suggest a dual mechanism: experiencing gamification as a learner enables future teachers to internalise its pedagogical logic, while subsequent design tasks consolidate the corresponding professional competence. Without this dual exposure, university graduates often default to the lecture-and-drill style that they themselves experienced in school, where new teachers "cannot conduct this subject in the same way as it was taught to us" because, in many cases, it was not taught to them at all.

In Kazakhstan, the integration of digital tools into chemistry and mathematics teacher preparation is officially encouraged by the Bologna-aligned reform of higher education and by the State Programme priorities. Karmanova et al. (2024), studying the development of professional competence of future chemistry teachers at O. Zhanibekov South Kazakhstan Pedagogical University, concluded that purposeful integration of electronic textbooks, virtual laboratories and interactive resources significantly improves professional competence indicators. Yespenbetova et al. (2024) similarly reports that online and virtual laboratory practices in physical chemistry are increasingly central to undergraduate chemistry programmes. For mathematics, Kaiyngbayeva et al. (2021) document the systemic difficulties of teaching probability theory in Kazakhstani schools – absent textbook tradition, limited methodological literature, and the lack of any university course on "methods of teaching probability theory and statistics in school" – and propose an applied, simulation-friendly elective course as part of the solution. Sardarova et al. (2026) provide the most recent comparative analysis of gamification in secondary and higher education in Kazakhstan, reporting that secondary school learners respond more strongly to competitive game elements (points, leaderboards, badges) while university students prefer simulation-based and project-based gamification, and that systemic implementation is hindered by uneven infrastructure, insufficient teacher training, and the absence of explicit institutional policies on gamification.

Three implications follow. First, the available Kazakhstani evidence converges across subjects in identifying digital simulations and gamification as promising methods. Second, there is a clear institutional need to translate this evidence into the chemistry and mathematics teacher preparation curricula in parallel, so that pre-service teachers across STEM acquire the technological-pedagogical knowledge required to implement DGBL in their future schools. Third, demonstrating that the same design principles work across two very different STEM subjects is itself an empirical contribution to the policy argument: a framework that generalises is far more defensible as a basis for university-level reform than one that has been validated only within a single discipline. In particular, while DGBL and PhET simulations are well established internationally, their systematic, curriculum-aligned use in Kazakhstani probability teaching and the demonstration that one framework can serve two STEM subjects at once is new to the national context and constitutes the study's principal contribution to local practice.

Methods and materials

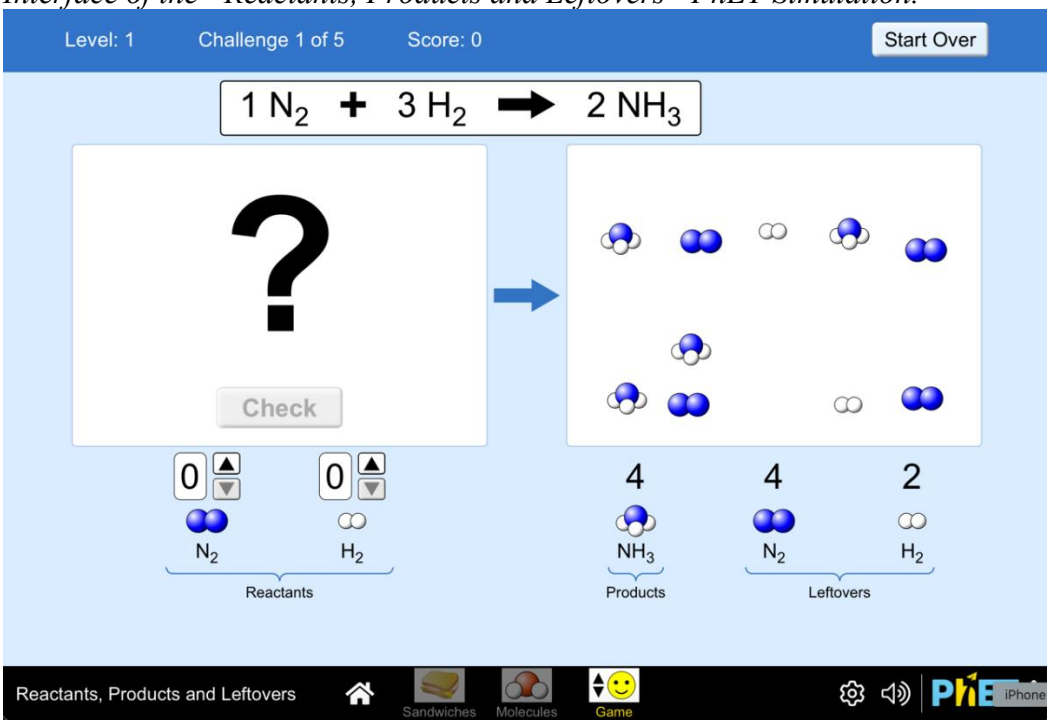
The study used a mixed-methods, multi-site, dual-case-study design conducted over multiple academic years. The two cases were chosen because they target topics that the international and Kazakhstani

literatures identify as among the most cognitively demanding in their respective subjects, because both topics are addressed by mature open-access PhET simulations, and because evidence drawn from two different STEM subjects under a common methodology offers a stronger basis for generalisable curricular recommendations than a single case would. The dual-case orientation was chosen because it allows a contextualised analysis of how digital tools function inside two different real curricula, and because it supports translation of findings into design principles for higher education a strategy aligned with prior qualitative work on gamification in Kazakhstani education (Sardarova et al., 2026) and on probability teaching in Kazakhstan (Kaiyngbayeva et al., 2021).

The study was guided by four research questions: (RQ1) Does structured use of the PhET simulations "Reactants, Products and Leftovers" and "Plinko Probability" improve students' conceptual understanding of stoichiometry and probability theory respectively, compared with traditional instruction? (RQ2) How does each intervention affect student engagement and the instructional time required to reach mastery? (RQ3) Do the same qualitative themes emerge across the two subjects? (RQ4) Which features of the interventions are transferable to higher education methodology courses for future chemistry and mathematics teachers?

Case 1 – Stoichiometry (chemistry). Case 1 examined the integration of the PhET simulation "Reactants, Products and Leftovers" (developed by PhET Interactive Simulations, University of Colorado Boulder) into 8th-grade chemistry instruction at three urban schools in Almaty, Kazakhstan. The intervention was conducted across four academic years. Approximately 380 students aged 13-14 took part, distributed across nine 8th-grade classes. The intervention occupied four lessons per cohort within the stoichiometry unit, structured as Predict-Observe-Explain cycles supported by a printed activity guide adapted from the PhET teacher resources (Lesson 1: "sandwich" analogy and atom conservation; Lesson 2: limiting reactants and leftovers; Lesson 3: stoichiometric ratios; Lesson 4: integrated game challenges).

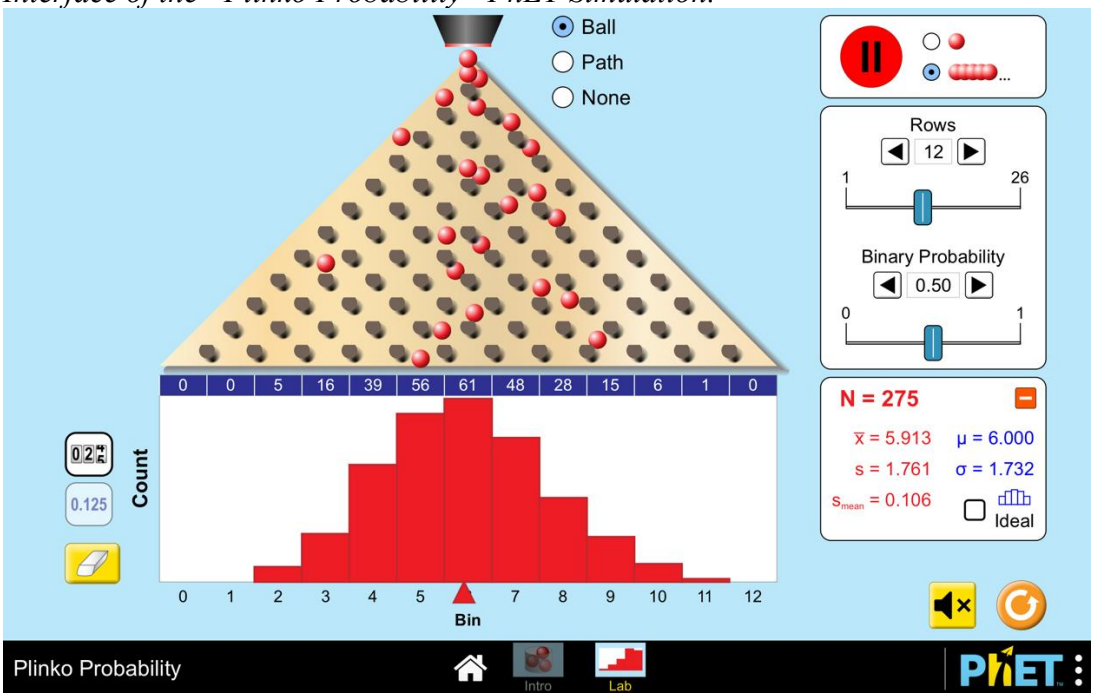
Figure 1.
Interface of the "Reactants, Products and Leftovers" PhET Simulation.



Case 2 – Probability and statistics (mathematics). Case 2 examined the integration of the PhET simulation "Plinko Probability" (also developed by PhET Interactive Simulations, University of Colorado Boulder) into 10th-11th-grade mathematics instruction at two urban institutions in Almaty. The intervention was conducted across two academic years within the regular probability theory and statistics unit defined by the national curriculum. Approximately 150 students aged 15-17 took part, distributed across six classes. The intervention occupied four lessons per cohort, structured as Predict-Observe-Explain cycles supported by a printed activity guide (Lesson 1: random events, relative frequency, and the empirical ↔ theoretical

probability distinction, using the simulation's Intro screen; Lesson 2: emergence of the binomial distribution as ball count and row count increase, using the Lab screen; Lesson 3: mathematical expectation, dispersion and standard deviation read directly from the simulation's statistics view; Lesson 4: the binomial → normal transition for large numbers of rows, with formative-assessment challenges in which students predict, observe and explain distribution shape and parameters). The choice of Plinko was motivated by its near-perfect alignment with the Kazakhstani 10th-11th-grade curriculum content, which explicitly includes Newton's binomial formula, relative frequency, random variables, mathematical expectation, dispersion, standard deviation, binomial distribution and normal distribution.

Figure 2.
Interface of the "Plinko Probability" PhET Simulation.



Across both cases, schools were selected purposively for diversity in size and infrastructure but homogeneity of national curriculum. In each case, teachers played a coaching rather than transmissive role, intervening primarily to scaffold prediction and reflection. Students worked in pairs at a single device, alternating roles between operator and recorder.

Quantitative data were collected through pre-tests and post-tests of subject reasoning, each comprising 15 items aligned with the relevant section of the school curriculum and reviewed by two experienced subject methodologists for content validity. For Case 1, the test items targeted (a) balancing of equations, (b) identification of the limiting reactant, (c) prediction of products and leftovers given starting amounts, and (d) translation between molecular and symbolic representations. For Case 2, parallel four-construct items targeted (a) calculation of simple and compound probabilities, (b) identification of independent vs dependent events and the law of large numbers, (c) prediction of distribution shape, mathematical expectation and standard deviation given experimental parameters, and (d) translation between empirical histograms and theoretical (binomial / normal) distributions. Instructional time required to achieve a class-level mastery criterion (≥ 70 % of students above the cut score) was logged by the teacher in a structured journal. Qualitative data were collected through (i) a structured student questionnaire administered after each intervention (closed Likert items on engagement, perceived clarity and enjoyment, plus three open-ended items), and (ii) field notes recording classroom interactions, peer talk and teacher coaching moves. Observations were guided by an observation sheet adapted from the qualitative case-study tradition (Miles, Huberman & Saldaña, 2018).

Pre- and post-test scores were compared using paired-sample t-tests at the class level, with Cohen's d as the effect size. Time-to-mastery was compared with averages from the same teachers' records of equivalent classes from prior years that had received traditional instruction only. Open-ended student

responses and field notes were thematically analysed using a hybrid deductive-inductive approach: deductive codes were derived from the gamification literature (engagement, motivation, conceptual clarity, frustration), and additional inductive codes were generated from recurring patterns in the data. Thematic analysis was conducted independently for each case and then jointly to identify cross-case themes – the central focus of RQ3. To support the credibility of qualitative findings, source triangulation across students, teachers and observers was used, together with member checking with the participating teachers. Following a convergent mixed-methods logic, the quantitative and qualitative strands were analysed separately and then deliberately integrated at the interpretation stage: for each case the magnitude and location of the test-score gains were mapped onto the qualitative themes and the time-to-mastery records, allowing convergence, divergence and complementarity between the two strands to be examined (cf. Miles, Huberman & Saldaña, 2018).

Use of generative AI tools. The authors disclose the limited use of generative AI tools during the preparation of this manuscript. The tool was used solely to assist with language polishing of the English-language draft and with bibliographic formatting. No data analysis, no interpretation of results and no generation of references were delegated to AI.

Results

Conceptual understanding (RQ1). In both cases, post-test scores were significantly higher than pre-test scores. In Case 1 (stoichiometry, $n \approx 380$), the aggregated mean pre-test score was 6.8 out of 15 ($SD \approx 2.1$) and the aggregated mean post-test score was 11.4 out of 15 ($SD \approx 1.8$); paired-sample t-tests at the class level were significant at $p < 0.001$ across all nine classes, with effect sizes ranging from $d = 0.92$ to $d = 1.31$ (median $d \approx 1.1$). In Case 2 (probability theory, $n \approx 150$), the aggregated mean pre-test score was 5.9 out of 15 ($SD \approx 2.0$) and the aggregated mean post-test score was 10.7 out of 15 ($SD \approx 1.9$); paired-sample t-tests at the class level were significant at $p < 0.001$ across all six classes, with effect sizes ranging from $d = 0.85$ to $d = 1.18$ (median $d \approx 1.0$). In Case 1, the largest gains were observed on items targeting limiting reactants and the prediction of leftovers – the sub-topics that the simulation visualises most directly. In Case 2, the largest gains were observed on items targeting the binomial-to-normal transition and the prediction of standard deviation, which are precisely the relationships that the Plinko simulation makes visible. In both cases, items requiring translation between visual and symbolic representations also improved substantially, suggesting that the simulations' linkage between dynamic visualisation and formal expression supported the cognitive integration of representations described by Salame and Makki (2021) for chemistry and by Pratt and Kazak (2018) for probability.

Engagement and instructional time (RQ2). On the post-intervention questionnaire, more than 85 % of students in Case 1 and more than 80 % of students in Case 2 reported that the simulation made the topic "more interesting" or "much more interesting" than typical lessons. Open-ended responses across both cases repeatedly emphasised three themes: the immediacy of feedback, the freedom to experiment without consequences, and the perceived game-like quality of the challenge mode. Teacher journals in both cases recorded a substantial reduction in the instructional time needed to reach the class-level mastery criterion: in Case 1, the criterion was reached on average in three to four lessons of simulation-supported instruction (vs five to seven in equivalent prior cohorts taught conventionally); in Case 2, the criterion was reached on average in five to six lessons (vs seven to nine in prior cohorts). While these comparisons are based on teacher records rather than randomised controls, the consistency of the trend across teachers and subjects lends it credibility.

Cross-case qualitative themes (RQ2 and RQ3). Joint thematic analysis across both cases yielded four cross-cutting themes that emerged in both subjects and that are summarised in Table 1: 1) visualisation of phenomena that students cannot otherwise see (sub-microscopic in chemistry, stochastic in mathematics); 2) productive failure under low-stakes simulation; 3) the limited appeal of competitive game elements when richer simulation play is available; and 4) the centrality of teacher coaching as the decisive factor in whether the simulation's pedagogical potential was realised. The convergence of these themes across two unrelated STEM subjects is the central qualitative finding of the study and the principal warrant for the generalisable framework proposed in the Discussion.

Table 1.

Cross-case themes from the school-level interventions in chemistry and mathematics, and their implications for higher education teacher preparation.

Theme	Description (across both cases)	Implication for higher education
Visualisation of the invisible	In chemistry, students articulated for the first time why some reactants are "left over", linking molecular pictures to the symbolic equation. In mathematics, students articulated why empirical histograms approach the theoretical distribution, linking dynamic ball drops to the binomial formula.	Future teachers must learn to link visual, particulate / experimental, and symbolic representations explicitly when designing lessons in both subjects.
Productive failure	In both cases, the simulation enabled risk-free trial and error, with students expressing willingness to attempt difficult problems they had previously avoided.	Methodology courses should model how to design tasks where failure is informative rather than punitive.
Game elements without forced competition	In both cases, students preferred individual challenges and self-set goals over leaderboards; only a minority valued public ranking. This converges with Sardarova et al. (2026) on Kazakhstani learner preferences.	Pre-service teachers should be taught to balance competitive and collaborative elements rather than default to leaderboard-based gamification.
Teacher coaching as the decisive factor	In both cases, the intervention worked when teachers shifted from explanation to questioning; when teachers reverted to lecturing over the simulation, gains shrank. This is consistent with the role of the teacher highlighted in Pratt and Kazak (2018) for probability.	Universities should embed structured micro-teaching with simulations into chemistry and mathematics methodology courses.

These cross-case themes are consistent with the wider STEM-education literature on PhET simulations (Salame & Makki, 2021; Banda & Nzabahimana, 2023) and on probability simulation environments (Pratt & Kazak, 2018), with meta-analytic findings on game-based chemistry learning (Hu et al., 2022), and with the Kazakhstani comparative evidence reported by Sardarova et al. (2026). They also extend the school-level Kazakhstani evidence on probability teaching by showing that simulation-supported probability instruction can produce conceptual gains comparable to those routinely reported for chemistry simulations.

Mixed-methods integration (RQ3 and RQ4). Bringing the two strands together clarifies why the interventions worked, not merely that they worked. In both cases the quantitative gains were largest on exactly the items that the qualitative "visualisation" theme identifies as the simulations' distinctive contribution: limiting reactants and leftovers in chemistry, and the binomial-to-normal transition and standard deviation in probability. The questionnaire and field-note evidence on "productive failure" – students repeatedly running low-stakes trials – maps directly onto the measured reduction in time-to-mastery, suggesting that fast, consequence-free iteration is the mechanism behind the efficiency gain. Where the strands diverge, they are informative rather than contradictory: students rated the competitive challenge mode highly on the questionnaire, yet the qualitative data show they abandoned it once richer free-exploration play was available, which helps explain why competition contributed little to the conceptual gains. Finally, both strands converge on the centrality of teacher coaching: across both cases the field notes most often associated students' movement from incorrect predictions to correct explanations with moments of teacher prediction-and-reflection prompting, echoing the quantitative finding that the largest gains appeared on the items the simulations make most directly visible. These strand-by-strand links are set out as a joint display in Table 2, which functions as a meta-inference across the quantitative and qualitative evidence rather than a purely thematic summary; together with the thematic summary in Table 1, they provide the basis for the transferable design principles carried forward into the framework (RQ4).

Table 2.

Joint display integrating the quantitative results and qualitative findings from the two cases, with the resulting cross-strand meta-inferences for higher education teacher preparation.

Cross-case theme	Quantitative result	Qualitative finding	Cross-strand meta-inference
Visualisation of the invisible	Largest post-test gains on the most visualisation-dependent items: limiting reactants and leftovers (up to d = 1.31); the binomial-to-normal transition and standard deviation (up to d = 1.18).	"Visualisation" was the dominant code; students and field notes repeatedly described "seeing" the otherwise-invisible sub-microscopic (chemistry) and stochastic (mathematics) processes.	Simulations add the most value precisely where a phenomenon cannot otherwise be observed; teacher training should prioritise such topics.
Productive failure under low-stakes simulation	Reduced time-to-mastery (Case 1: 3–4 vs 5–7 lessons; Case 2: 5–6 vs 7–9 lessons).	Over 80–85% rated the topic more interesting; open responses stressed the freedom to experiment without consequences and repeated low-stakes trials.	Consequence-free iteration, not content delivery, drives faster mastery; design tasks that reward trial-and-revision.
Limited appeal of competitive game elements	The competitive challenge mode added little measurable gain beyond structured free exploration.	Students rated the challenge mode highly at first but abandoned it once richer free-exploration play was available.	Competition (points and leaderboards) is not the active ingredient; future teachers should not equate gamification with competition.
Centrality of teacher coaching	Gains concentrated on the items the simulation makes visible, consistent with guided rather than unguided use (unguided simulations yield null effects in the literature).	Field notes identified prediction-and-reflection prompting as the recurring teacher behaviour accompanying conceptual breakthroughs.	The teacher, not the tool, realises the potential; make coaching and scaffolding the core competence of the practicum.

Discussion

The school-level findings reported above raise the question that motivates this article: how can such evidence be used to upgrade higher education? We argue that two distinct uses are warranted. The first is direct: PhET-style simulations are themselves valuable resources for teaching introductory chemistry and probability/statistics at the university level, especially for first- and second-year undergraduates whose conceptual foundations may be uneven. Universities in Kazakhstan can, and increasingly do, adopt these simulations in their own laboratory and theory courses (Yespenbetova et al., 2024). The second use is mediated and is, in our view, more strategically important: the school-level evidence should be used to redesign the methodology courses through which future chemistry and mathematics teachers are prepared. Crucially, the cross-case convergence we report the same four themes emerging in two unrelated STEM subjects – means that a single framework can be defensibly recommended for both teacher preparation programmes, rather than each subject developing its own.

Synthesising the empirical results, the international literature and the Kazakhstani context, we propose a four-component framework for embedding DGBL into chemistry and mathematics teacher preparation. The framework is summarised in Table 3.

Table 3.

A four-component framework for integrating digital game-based learning into chemistry and mathematics teacher preparation in Kazakhstani universities.

Component	Aim and content	Sample university activity (chemistry / mathematics)
1. Conceptual orientation	Develops pre-service teachers' own conceptual command of demanding school topics by having them re-solve school-level problems through simulations.	Chemistry: future teachers complete the "Reactants, Products and Leftovers" activity guide, then write a brief reflective note on their own misconceptions. Mathematics: future teachers run "Plinko Probability" experiments and reflect on the shift from intuitive to formal probability.
2. Simulation literacy	Builds the technical-pedagogical knowledge required to evaluate,	A laboratory session comparing simulations across STEM (PhET in chemistry, mathematics, physics) using criteria from the literature

	adapt and combine digital simulations with curriculum standards.	(Hu et al., 2022; Pratt & Kazak, 2018; Vrcelj et al., 2023).
3. Gamified lesson design	Engages students in designing and justifying gamified lesson sequences that balance competitive and collaborative elements.	Pairs of pre-service teachers design a four-lesson stoichiometry unit (chemistry strand) or probability/statistics unit (mathematics strand) using a Predict-Observe-Explain structure with PhET, including formative-assessment game challenges; designs are peer-reviewed using a rubric.
4. Reflective practicum	Provides supervised classroom enactment of digital game-based lessons in school practicum, with structured reflection.	During the school placement, future chemistry or mathematics teachers deliver one PhET-based lesson, video-record it, and analyse pupil engagement and conceptual gains in a written reflection aligned with the framework above.

The proposed framework is consistent with the most recent evidence on gamification in teacher preparation. Jiménez-Valverde et al. (2024) demonstrated that pre-service teachers who experienced structural gamification as learners showed measurable gains in motivation and attitudes toward science teaching. Lampropoulos and Kinshuk (2024) argue that combining gamification with virtual environments is becoming a defining feature of modern teacher preparation. Stohl (2005), specifically for probability, makes the same argument: pre-service mathematics teachers must experience probability as an experimental, simulation-rich subject before they can teach it that way themselves. Our four-component model operationalises these insights for both chemistry and mathematics teacher preparation: future teachers do not merely learn about gamification they are taught using DGBL, and they are then required to design and enact DGBL lessons themselves. This dual exposure addresses the gap that current Kazakh teachers "cannot conduct this subject in the same way as it was taught to us", and that the corresponding methodology course at the university level "simply did not exist and still does not exist".

Because the framework draws partly on evidence from outside Kazakhstan, a brief orientation helps international readers judge its transferability. Three local features shape it: a Bologna-aligned system whose state programmes (e.g. "Digital Kazakhstan") endorse digital pedagogy but leave subject-specific implementation to individual universities; the recent arrival of probability in the school curriculum with no dedicated methodology course, which the "simulation literacy" and "reflective practicum" components directly address; and an urban–regional infrastructure divide that makes open-access PhET simulations decisive for equity. The framework therefore has two layers: the core mechanisms – experiencing DGBL as a learner, then designing and enacting it rest on international evidence (Jiménez-Valverde et al., 2024; Lampropoulos & Kinshuk, 2024; Stohl, 2005) and are portable, whereas the sequencing, joint chemistry–mathematics delivery and reliance on free simulations are calibrated to Kazakhstani conditions. Readers elsewhere can adopt the mechanisms while re-tuning these contextual parameters to their own setting.

The framework also has implications at the level of curriculum and policy. First, programme designers in chemistry and mathematics teacher education should treat digital simulations not as supplementary aids but as one of the core tools through which methodology and content pedagogy are taught. Second, quality-assurance criteria for chemistry and mathematics teacher programmes should include explicit indicators of pre-service teachers' capacity to design and enact technology-enhanced lessons aligned with national curriculum standards. Third, the cross-subject generalisability we have demonstrated means that a single university-level methodology module on DGBL could be offered jointly to chemistry and mathematics teacher candidates, with subject-specific worked examples – a structure that would be more efficient than running parallel siloed modules. Fourth, the open-access status of PhET simulations means that the framework can be implemented even in resource-constrained universities, addressing some of the equity concerns raised by Sardarova et al. (2026) about the digital divide between urban and regional institutions.

The study has limitations that should temper its conclusions. First, both school-level cases are multi-site case studies without randomised control groups, which limits causal claims; comparison cohorts were drawn from prior-year records by the same teachers, an approach that controls for teacher effects but is vulnerable to year-on-year cohort differences. Second, the higher education framework proposed in Table 3 is conceptual and grounded in evidence from outside Kazakhstan; it must now be empirically tested with cohorts of pre-service chemistry and mathematics teachers at Kazakhstani universities, ideally through a quasi-experimental study comparing methodology courses with and without DGBL integration. Third,

although the present study covers two STEM subjects, it does not yet include physics, biology, or earth science; the four-component framework is in principle applicable to these as well but requires empirical validation before such claims can be made. Finally, longitudinal follow-up of graduates entering schools would clarify whether DGBL-trained teachers actually use such methods in their first years of teaching, addressing the persistent concern that university training does not translate into classroom practice.

Conclusion

This article reported on two complementary multi-year case studies of integrating PhET simulations "Reactants, Products and Leftovers" in 8th-grade chemistry and "Plinko Probability" in 10th-11th-grade mathematics, and used the converging evidence to derive a unified framework for embedding digital game-based learning into chemistry and mathematics teacher preparation in Kazakhstani higher education. Across both subjects, the interventions were associated with substantial gains in conceptual understanding (median Cohen's d ≈ 1.0-1.1), increased student engagement, and reduced time to mastery. Crucially, the same four cross-cutting themes emerged in both cases visualisation of the invisible, productive failure, the limited appeal of forced competition, and the centrality of teacher coaching – strengthening the case for a single, generalisable framework rather than a set of subject-specific recommendations. We argued that this evidence should be translated into a four-component framework conceptual orientation, simulation literacy, gamified lesson design and reflective practicum applicable equally to chemistry and mathematics teacher preparation. Such a framework aligns with the digitalization priorities of higher education in Kazakhstan, with the quality-assurance focus of the journal "Higher Education in Kazakhstan", and with international evidence on the most effective forms of teacher preparation in the digital age. Realising this potential will require coordinated action by universities, methodologists and policymakers, but the evidence and the tools for doing so are already available.

Conflict of Interest Statement

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Author Contributions

Tursyngozhayev K.: Conceptualization, Methodology, Investigation (chemistry case), Writing - original draft, validation, supervision, review and editing.

Kaiyngbayeva Zh.: Methodology and Investigation (mathematics case – design and delivery of the Plinko Probability intervention), Resources, Writing - review and editing of the mathematics-related sections.

Kavak N.: Scientific input and suggestions for the collection and analysis of data, approving final version.

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