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Model of Formation of Digital Competences of Future Teachers in the Conditions of Integration of E-Learning and Artificial Intelligence Technologies

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ABSTRACT

The effect of an artificial intelligence (AI) integrated instructional model in developing the digital competencies of future teachers at Ualikhanov University, Kazakhstan, is investigated in the paper. A mixed-methods approach (experimental and qualitative) was employed in the study. The study included a sample of 210 students in their 3rd and 4th years of pedagogical specialties. To evaluate an AI-integrated e-learning model with the use of tools such as DigCompEdu, an AI Literacy Scale a 12-week pre-test/post-test control group design was implemented in the study as well as an EdTech Self-Efficacy Questionnaire. Data were analysed using t-tests, ANCOVA, effect size measures, correlation analyses, and regression models. The results demonstrated that the difference in mean scores between the experimental group ($M = 4.14$, $SD = 0.40$) and the control group ($M = 3.08$, $SD = 0.44$) was statistically significant ($P< 0.05$), indicating that the AI-integrated model intervention had a substantial positive impact on students' overall digital competencies. Thus, AI literacy is the strongest predictor of digital competence ($\beta = 0.43$, $p < .01$). The qualitative data resulted in six themes: autonomy, critical thinking, ethics, and creativity, which confirmed that competence development extended beyond technical skill. The study concluded that an AI-integrated e-learning model significantly improved students' (future teachers) digital competence. Policymakers and institutions should incorporate AI literacy, given its strong predictive power, into teacher education and training programs.

KEYWORDS

AI-integrated model; digital competence development; digital innovation; future teacher; higher education.

INTRODUCTION

The digitalization of education has become a defining feature of modern teaching and learning. The rapid integration of information and communication technologies (ICT) into educational institutions has transformed traditional pedagogical methods, increasing the demand for teachers to develop advanced digital skills (Cabezas-González et al., 2024; Makeleni et al., 2023; Moore et al., 2020). Beyond conventional e-learning tools, artificial intelligence (AI) technologies such as ChatGPT, Copilot, and other generative AI systems have introduced new dimensions in teaching and learning, including personalized instruction, assessment, and feedback (Chung et al., 2024; Crompton & Burke, 2024; Ogurlu & Mossholder, 2023; Zhang & Tur, 2023). Now that AI has been integrated into pedagogy, teachers and future educators need to be prepared, trained, and equipped with the necessary skills for effective implementation (Chiu et al., 2024; Long & Magerko, 2020). UNESCO (2023) and Lucas et al. (2024) as well state that teachers' provision with adequate training on AI innovations has a strong influence in its successful adoption. However, the recent international shift toward AI-based learning environments has created an urgent need for teacher education programs to offer systematic, research-based training. In Kazakhstan and other developing countries, the gap between digital transformation policy goals and the actual preparation of future educators continues to widen. Teacher candidates often enter the classroom with limited digital skills, minimal knowledge of AI ethics, and little experience applying AI tools to real instructional situations. This disconnect threatens the quality of future classroom practice and poses a broader challenge to the country's digital modernization efforts.

These challenges are further highlighted by empirical studies conducted in Kazakhstan. Namely, according to the national reports and educational policy studies, despite the growth of the digital learning infrastructure in universities, teacher education programs do not offer systematic training in advanced digital skills and AI-assisted pedagogy (Navas Sabater, 2023; OECD, 2023). Polls of pre-service teachers in Central Asian educational organizations also indicate that a significant number of students have access to the basic ICTs but do not receive planned training concerning the use of digital technologies and AI services in making pedagogical decisions and ethical classroom practices. The results indicate that the concept of integrated digital competence frameworks in teacher education has yet to be developed evenly and in ways that are adequately aligned to the new AI-based educational setups.

Despite a growing body of research, few studies explicitly connect AI literacy with established frameworks such as DigCompEdu and TPACK (Carretero Gomez et al., 2017; Chung & Wei, 2022; Mohamed Sapawi & Nik Yusoff, 2025; Sierra et al., 2023). Prior research has studied these digital competencies separately. This fact limits teachers' readiness for AI-driven learning environments, revealing the need for studies that include theory with practical application in the classroom (López-Nuñez et al., 2024; Ussainova et al., 2025). This division constrains the formation of holistic competency portraits, and the future teachers will not be able to apply the theoretical digital competencies to the real classification tasks in the classroom (López-Nuñez et al., 2024; Maksymchuk et al., 2019).

This leads to the primary research problem where future teachers often lack a structured, integrated approach in the development of a full spectrum of digital competencies required for AI-enhanced education. Navas Sabater (2023) states that in Kazakhstan, numerous efforts have been accomplished in order to equip teachers with AI-based classrooms. Prior models, however, were not highly geared towards artificial intelligence and did not adequately incorporate AI literacy in pedagogical and ethical instruction. This weakness highlights the importance of a more detailed framework that can help covering the gaps between digital proficiency, ethical implications, as well as technology usage in teacher education, specifically in Kazakhstan background (Yang et al., 2025). This gap is important to address in order to ensure that graduates of teacher education programs are competent, self-assured, and morally conscious users of AI technologies. Hence, the study aims to examine the effectiveness of an e-learning and artificial intelligence (AI) integrated instructional model in developing the digital competencies of future teachers at Ualikhanov University, Kazakhstan.

Based on an experimental design, empirical evidence of the effectiveness of the educational model in the context of Kazakhstan was provided, showing that AI literacy was the strongest predictor of overall digital competence. The combination of quantitative and qualitative data also demonstrated how AI-supported learning enhanced digital autonomy, pedagogical creativity, critical thinking, and ethical awareness of future teachers in countries undergoing digital transformation.

LITERATURE REVIEW

DigCompEdu, TRACK, and SAMR Model

Several theoretical frameworks have been developed to describe how teachers acquire and apply digital competence in education. The most popular include the Digital Competence Framework for Educators (DigCompEdu), Technological Pedagogical Content Knowledge (TPACK) model, and the Substitution-Augmentation-Modification-Redefinition (SAMR) model. The frameworks offer valuable conceptualizations of the digital technologies incorporation into teaching practice as they cover various aspects of competence, such as technological knowledge, pedagogical integration, and the levels of technology use in the instructional design. Collectively, they have influenced the modern trends in digital pedagogy and teacher education in universities (Morudu, 2025; Mosia & Matabane, 2022; Özyer, 2024).

The DigCompEdu model is one of the most impactful models in teacher digital competence conceptualisation, which includes six areas that facilitate professional engagement, resource use, digital pedagogy, assessment, and learner empowerment (Carretero Gomez et al., 2017; García et al., 2021). It offers the advantage of providing a quantifiable and systematic model for evaluating the digital preparedness of educators (UNESCO, 2023). However, major objections include that until recently, DigCompEdu had not been designed with

AI-assisted learning in view, and thus offers minimal advice on such matters as data ethics, algorithmic transparency, and responsible use of AI, which are emerging as important competencies in higher education (Navas Sabater, 2021; OECD, 2023).

Although DigCompEdu lays more stress on the domains of digital competence, other models are more concerned with the combination of technology and pedagogical and disciplinary knowledge. The Technological Pedagogical Content Knowledge (TPACK), thus, model is one of the most powerful frameworks. The Technological Pedagogical Content Knowledge (TPACK) model offered by Mishra and Koehler (2006) offers some useful information concerning the dynamic relationship between technological knowledge, pedagogical knowledge, and subject content knowledge. It assists in designing blended and technology-enhanced learning spaces by noting the significance of the combination of these three knowledge areas (Imankulova et al., 2025; Magocha et al., 2025; Schmid et al., 2020; Sierra et al., 2023). Nevertheless, researchers emphasise that the TPACK framework fails to consider the new issues related to AI technologies, such as AI-based personalization, generative AI ethics, and automated decision-making processes in education, that is the reason of non-application of the model in modern teaching situations (Crompton and Burke, 2024; Kravchuk et al., 2023; Lee et al., 2022).

Besides competence and knowledge integration frameworks like DigCompEdu and TPACK, models have also been put forward to lead the practical levels of technology integration in classroom activities. The SAMR model is one of the model that has been introduced. Substitution- Augmentation- Modification- Redefinement (SAMR) model is an effective and thought-provoking instrument that assessed the level of technology integration in instruction by Puentedura (2010). The model offers teachers to advance beyond simple technology replacement to more radical applications that redesign learning activities (Hodges et al., 2020; Son, 2024). Although SAMR is helpful in terms of technology integration, it lacks specific examples concerning the methods of teaching or learning AI literacy, the pedagogical risks of automation, and the ethical risks of AI-aided decision-making. It makes it less applicable in AI-implemented learning settings (Hess et al., 2025; Laupichler et al., 2022).

AI Literacy Frameworks and Digital Competence

AI literacy is increasingly recognized as crucial for teachers' preparation. Long and Magerko (2020) define it as the ability to understand, evaluate, and co-create with AI systems. More recent work expands this to ethical awareness, data reasoning, and human–AI collaboration (Chiu et al., 2024). Global organizations such as UNESCO (2023) and the OECD (2023) identify AI literacy as a foundation for sustainable digital transformation.

Nonetheless, as the study of teacher education in Kazakhstan shows, the willingness of teachers to adopt new technologies is not sufficiently covered, and the morality of AI and the application of algorithms in decision-making is not a topic of education (Navas Sabater, 2023).

Teacher digital competence has evolved from technical skills to include investigative, imaginative, and moral applications of technology (Basilotta Gomez-Pablos et al., 2022). DigCompEdu provides a validated structure, while more recent frameworks such as Higher

Education Digital Competence (HEDiCom) emphasise ethical responsibility and pedagogical adaptability for higher education (Ikwuka et al., 2024; Tondeur et al., 2023).

International findings show that pre-service teachers adopt new technologies more flexibly than in-service teachers but require structured support to develop deeper competence (Lan et al., 2024; Masoumi & Noroozi, 2025; Turebayeva et al., 2020). In developing contexts, infrastructural limitations remain a central barrier (Ogunbodede et al., 2023). This is also the case with Kazakhstan, where the national policy is oriented towards digital transformation, yet the preparedness of teachers, especially in terms of AI ethics and data literacy, is not at par (OECD, 2023; Shcherban & Khoma, 2024).

Artificial Intelligence in Higher Education: Implementation, Ethics, and Pedagogical Impact

Artificial intelligence (AI) is one of the major tools of change in higher education, reforming institutional management. AI technologies are reshaping higher education through adaptive learning, analytics, and generative content creation (Castillo-Martínez et al., 2024; Zawacki-Richter et al., 2019). Intelligent tutoring systems and learning analytics support personalization and evidence-based teaching (Crompton & Burke, 2023; Son, 2024). Generative AI, such as ChatGPT, enhances idea generation and writing support but introduces challenges related to dependency, academic integrity, and cognitive overload (Schepman, 2023; Hess et al., 2025).

Although it is rapidly adopted, studies show a significant gap between the ethical preparedness of teachers and institutional policies that help regulate the responsible use of AI, especially in higher education settings with limited regulatory structures (Adamakis & Rachiotis, 2025; Buele & Llerena-Aguirre, 2025).

Traditional e-learning environments provide flexibility but often result in limited learner engagement and less interactive feedback (Hodges et al., 2020; Zhang & Tur, 2023). AI-enhanced learning addresses these gaps through automation, adaptive support, and more dynamic interaction (Ogunleye et al., 2024). Nevertheless, the universities of Kazakhstan still focus on the acquisition of basic ICT skills over sophisticated digital or AI literacy, which causes the disparity in institutional preparedness (Karimi & Khawaja, 2025; Lucas et al., 2024).

National strategies such as Digital Kazakhstan and the Resilient Digital Kazakhstan Program emphasize digital transformation. However, gaps between policy and practice persist due to the lack of teacher training and the lack of principles of ethically sound AI integration (Navas Sabater, 2021; OECD, 2023). Hence, there is a need for a combined AI-integrated instructional model.

Identified Research Gaps and Analytical Synthesis

Even though DigCompEdu, TPACK, and SAMR offer useful theoretical and practical knowledge of digital pedagogy, each model addresses only a part of the broader competencies required for AI-enhanced education. None of them incorporates the AI competence, ethical thinking, and contextual adaptation in full, especially in non-European educational frameworks like Kazakhstan. This gap shows the necessity of more complex models that will relate the development of digital competence to AI literacy and ethical awareness in teacher education.

Throughout the reviewed literature, there is a recurring limitation of the digital competence fragmented treatment, pedagogical design, and ethical integration. While frameworks such as DigCompEdu and TPACK provide valuable pedagogical and technological guidance (Carretero Gomez et al., 2017; Sierra et al., 2023), they usually do not analyse the ethical and socio-emotional aspects of AI-mediated learning (Hess et al., 2025). AI literacy research also highlights the need for educators to combine technical and critical understanding of AI tools, but rarely connect these competencies to broader pedagogical frameworks (Chiu et al., 2024; Duri Long & Magerko, 2020). This reveals a lack of comprehensive framework uniting competence, ethics, and pedagogy in AI-supported higher education (Adamakis & Rachiotis, 2025; Yang et al., 2025).

Another major gap lies in the limited longitudinal and cross-cultural validation of digital competence models, particularly in emerging contexts such as Kazakhstan (Masoumi & Noroozi, 2025; Shcherban & Khoma, 2024). Although policies emphasise digital transformation (Navas Sabater, 2023; OECD, 2023), practical evidence of sustained teacher development remains rare. Moreover, studies rarely concern AI literacy training and sustainable competence assessment methods that reflect real classroom adaptation (Lucas et al., 2024).

Most of the existing research offers limited guidance that is both comprehensive and context-sensitive for supporting ethical and pedagogical AI integration in teacher education. These findings reveal the need for an empirically grounded framework that connects pedagogical competence, that connects AI literacy, and ethical awareness for higher education in Kazakhstan and beyond.

State Hypotheses and Their Correspondence to Research Design

This paper aim is to examine the effectiveness of an integrated e-learning and artificial intelligence (AI) learning model in developing digital competencies of future teachers at Ualikhanov University, Kazakhstan. Therefore, the following important questions and hypotheses were raised in the study:

Q1: What is the level of digital competence of future teachers at Ualikhanov University, Kazakhstan?

Q2: What is the impact of the e-learning model using AI on the level of digital competence of future teachers?

Q3: What are the students’ experiences and perceptions of using AI technologies in the learning process?

H1: There is a significant difference in the digital competence of future teachers who received integrated AI learning and traditional learning.

H2: AI literacy, AI teaching skills, and assessment methods will significantly and positively predict the overall digital competence of future teachers.

As noted by Hess et al. (2025) and Miao et al. (2021), the study developed an AI-integrated model based on existing frameworks such as DigCompEdu and TPACK, addresses the gap in digital training for future teachers, strengthening their digital competencies for effective implementation and adoption of AI-based educational technologies.

METHOD

Research design

A mixed-method (experiment and qualitative) approach was employed in the study. The method was considered suitable because it incorporates a survey-based approach (quantitative) and interview (qualitative) designs as well as data. Particularly, the research adopted a sequential and explanatory combined approach, where quantitative data were gathered and interpreted initially, and then qualitative data were used to elaborate on the quantitative results. The design was selected as it allowed the researcher to initially determine the patterns and relationships using primary data statistically and then investigate the experiences of the participants to comprehend the reasons behind the patterns in a better way, with reference to the AI instructional model. This sequential and integrative process increased the credibility and richness of the study findings (Creswell & Creswell, 2018).

Participants and Sampling

The study comprised 210 participants undergraduate students of pedagogical specialities (students of the 3rd and 4th year of higher education) of Ualikhanov University, Kazakhstan. A systematic random sampling technique was employed in participants selection from departmental enrolment lists. The inclusion criteria included pedagogical specialization, 3rd or 4th-year standing, at least one introductory course in ICT or in educational technology, and an involvement consent. While the exclusion criteria included students on academic leave, students who have not yet responded to the pre-test, and students who did not provide consent to be involved. Out of the total number of 228 students contacted, 92% volunteered to take part in the study, 12 students (8%) refused, and a total of 210 students were left eligible to participate. For the interview, 20 students (10 3rd year and 10 4th year) were selected using purposive sampling, such as experiences regarding the AI-integrated model.

The results in Table 1 showed that females dominated the sample with approximately 63 % compared with males comprising roughly 37%. The majority are 3rd-year students (56 %), followed by 4th-year students (44 %). Primary education students constituted the largest subgroup (57%), followed by small but sizable groups in Inclusive/Correctional Pedagogy and Early Childhood Education (both 17%). An overwhelming majority (82%) already possessed prior ICT training, leaving 18 % without such experience.

The simple randomization, in the form of a computer-generated random number sequence, was used in order to randomly assign the participants to groups (105 students per group). This process was used to guarantee that an equal number of students had the chance to be in either the experimental group (EG), which were students who received an AI-integrated instructional model, or the control group (CG), which were students who continued with traditional e-learning with no AI.

A sample size of 200-250 students was chosen on the basis of a priori power calculations (power =0.80, 2 =0.05, expected medium effect size f =0.25) that indicated that the used sample had to have at least 128 students to monitor any significant group differences. The final sample contained 210 students, which was greater than the necessary sample and enhanced the precision of estimates. The participants were divided into two equal groups of 105 per group. The equal group sizes were not eliminated since there was no dropout in the 12-week intervention. The final sample was not different from the greater population of teacher education students.

Table 1.

Participants' Demographic Data (N=210)

Variable	Category	Frequency	%
Gender	Female	133	63.3
	Male	77	36.7
Study Year	3rd Year	118	56.2
	4th Year	92	43.8
Specialization	Special Education	25	11.9
	Primary Education	120	57.1
	Inclusive/Correctional Pedagogy	35	16.7
	Early Childhood Education	35	16.7
Prior ICT Training	Yes	172	81.9
	No	38	18.1
Group Assignment	Experimental (AI Model)	105	50.0
	Control (Traditional E-learning)	105	50.0

Instruments

The chosen quantitative measures were DigCompEdu Check-In (EU, 2019), which included six dimensions of digital competence, and the AI Literacy Scale (Nong et al., 2024). The DigCompEdu Check-In tool, designed by the European Commission (EU, 2019), included 22 items in six dimensions of professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating digital competence in learners. Nong et al. (2024) created the AI Literacy Scale as an instrument in order to determine the knowledge and skills of students regarding artificial intelligence. The tool had 15 Likert-scale items in four subscales: AI application ability, AI morality and ethics, AI-related critical thinking, and AI cognitive understanding. Nong et al. (2024) created the AI Literacy Scale as an instrument to determine the knowledge and skills of students regarding artificial intelligence. The tool had 12 Likert-scale items in four subscales: AI application ability, AI morality and ethics, AI-related critical thinking, and AI cognitive understanding. Qualitative measures included the portfolio assessment, microteaching performance rating scale, and reflective diaries. Covariates for the study included prior ICT training, year of study, digital competence baseline score, and prior use of AI-based tools.

The instruments for both qualitative and quantitative data were reviewed by experts to ensure their suitability and adaptation to the Kazakhstan context. In the case of the DigCompEdu Check-In scale, the six-factor model was supported using Confirmatory factor analysis (CFA), which showed that the model had a decent fit (χ^2/df = 2.31, CFI = 0.93, TLI = 0.92, RMSEA = 0.056, SRMR = 0.048). The standardized factor loadings were 0.61-0.84, which meant that the items were obtained as a good reflection of the underlying constructs. In the case of the AI Literacy Scale, CFA verified that the 4-factor model has good model fit (χ^2/df = 2.18, CFI = 0.94, TLI = 0.93, RMSEA = 0.052, SRMR = 0.045). The average factor loadings scored between 0.64 and 0.87, and this corroborated the construct validity of the scale. In the same way, CFA results of the Self-Efficacy in Educational Technology Questionnaire showed that the model fitted the data (χ^2/df 2 /df = 2.27, CFI = 0.92, TLI = 0.91, RMSEA = 0.054, SRMR = 0.049) with a standardized factor loading of between 0.60 and 0.85, which affirmed the validity of the measurement model. Additionally, a pilot test of the quantitative instruments was conducted amid 35 students that were not part of the sample in order to test clarity and ease of use before the actual administration. The reliability test was conducted using their responses to obtain the internal consistency of the items, using the Cronbach alpha coefficient (DigCompEdu Check-In = 0.93, AI Literacy Scale = 0.84, adapted Self-Efficacy in Educational Technology scale: 0.89), indicating the appropriateness of the instruments to be fully used (Taber, 2018).

Procedure and Interventions

A pre-test/post-test control group experimental design was employed, with a period of 12 weeks. The 12-week intervention was based on a systematic e-learning and AI-based instructional design in the form of Moodle, which was divided into five developmental blocks of digital and AI competence. Namely, it was the Block 1: motivational and value (awareness of the importance of digital education); Block 2: cognitive (knowledge of e-learning tools and AI); Block 3. operational and technological (application of tools in educational cases); Block 4: reflective and analytical (self-assessment, ethics, academic integrity); Block 5. communicative and professional (collaboration in digital environments) (Appendix I). The participants in the experimental group received all five blocks during the intervention in the form of structured activities, exercises, and AI-based learning modules. The control group, in its turn, did not receive the AI-enhanced Moodle program and proceeded with the regular curriculum. In order to determine the acquisition of digital and AI competencies so that the results of the intervention could be compared with the results of the control condition, the two groups also received the pre- and post-assessment.

Data collection

The collection of data was accomplished in four phases. The stage 1 was associated with the creation of AI-supported and traditional Moodle spaces as well as the construction of the organized AI-based learning model. The stage 2 involved the administration of pre-test tools (DigCompEdu Check-In, AI Literacy Scale, and EdTech Self-Efficacy Questionnaire) to the two groups. The 12-week blended e-learning intervention in the stage 3 was provided by two instructors with equal qualifications in terms of the master’s degree in educational technology, who were trained and received standard training to reduce the influence of instructors. The stage 4 was used to deal with the post-test, where both groups took the re-test with instruments provided in the pre-test, where the possible instruments to be used in the studies were taken, the portfolio test, the microteaching test, and the reflective diary were administered. The entire population of 105 students of the Experimental Group created digital portfolios with documentation of weekly assignments, AI applications, learning artefacts, and micro-teaching resources. In the qualitative part, to discuss the use of AI, confidence, application, and challenges, the participants were interviewed (semi-structured interviews, 45 minutes each). The audio-recorded interviews were transcribed word-for-word, and the thematic analysis was performed in the form of deductive analysis to come up with structured themes.

Dana Analysis

The analysis of quantitative and qualitative data was conducted in SPSS and NVivo 14. Before the analysis, a stringent data-cleaning process was effectuated. The completeness was checked by screening the responses, and the results were summarized in terms of mean and standard deviation of the pre-test and post-test results. To test intra-group variation, independent-samples t-tests were used. To provide the key effect of the intervention, ANCOVA was conducted, with pre-test scores and other extraneous variables as covariates. Independent-samples t-tests were used to determine homogeneity of variance by applying the Levene test, which yielded a value of 0.396 above 0.05, which implies that the homogeneity of variance assumption is met. Cohen’s d (t-tests) and partial eta squared (eta η^2) were used to compute the effect sizes. Pearson correlation coefficients were calculated to understand the relationship between the components of digital competence. In addition, the Variance Inflation Factor (VIF) was as well used in order to determine the level of multi-collinearity, with a value of 2.6, which is not as high as the level of multi-collinearity is 5. Moreover, a multiple regression analysis was conducted to show the value AI literacy and EdTech self-efficacy have in predicting the increase in digital competence. In the case of qualitative data, deductive thematic analysis was applied to reflective journals, portfolios, and interviews. Two independent coders' ratings were used to establish reliability with a Cohen's Kappa value of 0.84. Also, out of the considerable data based on the structured questions provided by the respondents, the codes were created and combined into final themes according to the research questions of the study.

Ethical considerations

The study ensured a voluntary consent from all participants. Students were given comprehensive, easily comprehensible information about the study's goals, phases, possible risks, and advantages. Research ethical procedures were followed as it uses human subjects.

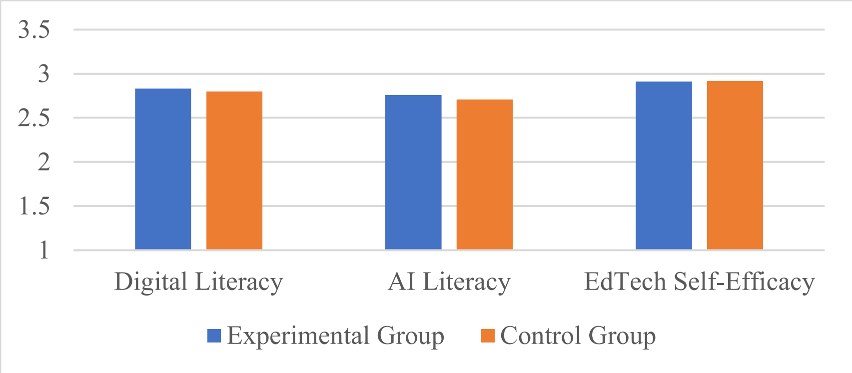
RESULTS

Quantitative Findings

Students’ level of digital competencies was assessed using the Digital Competence Questionnaire, AI Literacy Scale, and Self-Efficacy in EdTech Questionnaire before the intervention of the e-learning and AI-Integrated model for both the control and experimental groups, as shown in Figure 1.

Figure 1.

Level of Digital Competencies of Future Teachers Before the Intervention



The results from Figure 1 demonstrate the mean and standard deviation scores for both the control and experimental group across digital literacy, AI literacy, and self-efficacy in educational technology before the intervention. For digital competence, the experimental group had a mean = 2.83 (SD 0.42), while the control group had a mean = 2.80 (SD 0.45). In terms of AI literacy, the experimental group had a mean = 2.74 (SD 0.51), while the control group had a mean = 2.71 (SD 0.48). For self-efficacy, the experimental group has a mean = 2.91 (SD 0.47), while the control group had a mean = 2.92 (SD 0.46). These results indicate that the mean scores across all three variables were relatively close between groups, suggesting both groups had the same level of digital competencies, which is a baseline for comparing the effects of the intervention.

Table 2.

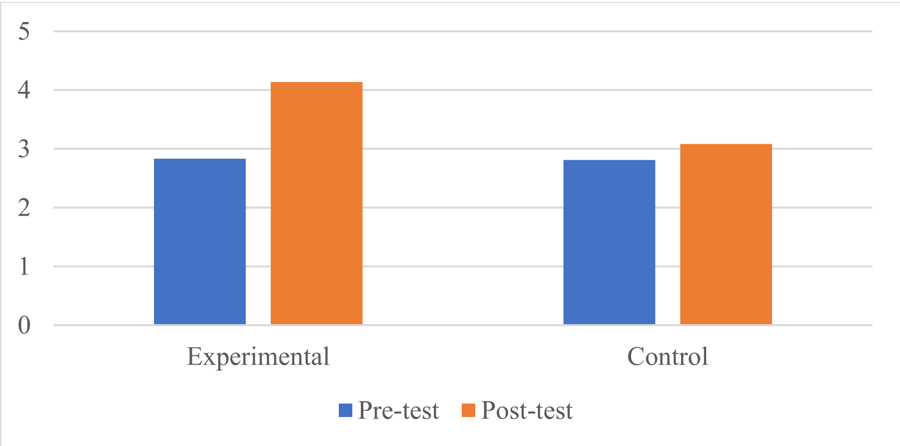
Pre-Test and Post-Test Descriptive Statistics for Digital Competence Levels of Future Teachers (N = 210)

Aspect	Group	Pre-Test		Post-Test	
		Mean	SD	Mean	SD
Digital Competence	Experimental	2.83	0.42	4.12	0.39
	Control	2.80	0.45	3.05	0.44
AI Literacy	Experimental	2.76	0.51	4.08	0.42
	Control	2.71	0.48	3.02	0.46
EdTech Self-Efficacy	Experimental	2.91	0.47	4.21	0.40
	Control	2.92	0.46	3.18	0.43

The data in Table 2 demonstrated that pre-test scores for both experimental and control groups showed comparable levels of digital competencies (digital literacy, AI literacy, and EdTech self-efficacy). Before the intervention, there was no noticeable difference between the experimental and control groups, as the experimental group's mean scores were 2.83, 2.76, and 2.91, respectively, while the control group’s scores were 2.80, 2.71, and 2.92. However, after the intervention of e-learning and an AI-integrated model, all three variables showed a significant improvement in the experimental group after the intervention. The post-test means for the experimental group rose to 4.12 (digital literacy), 4.08 (AI literacy), and 4.21 (EdTech self-efficacy), demonstrating a significant improvement in their comprehension of AI principles, ability to use educational technologies with confidence, and overall digital proficiency. These results indicate that the intervention of e-learning and an AI-integrated model significantly influences the level of digital competencies of future teachers. The overall mean score of the level of digital competencies of future teachers before and after intervention is shown in Figure 2.

Figure 2.

Level of Digital Competencies of Future Teachers Before and After the Intervention



As shown in Figure 2, digital competency levels were almost equal in both groups (Experimental Group: M = 2.83, Control Group: M = 2.80). Nevertheless, following the intervention, the experimental group's digital competency significantly improved (Post-test M = 4.12), while the control group's increased only slightly (Post-test M = 3.05).

The H1: There will be a significant difference in the digital competence levels of future teachers who participate in the AI-integrated e-learning intervention compared with those who receive traditional instruction.

The independent t-test statistics were used to examine whether the observed difference between experimental and control groups was statistically significant. The result of this test is presented in Table 3.

Table 3.

Independent Samples t-test Comparing Experimental and Control Groups (Post-Test) in the Digital Competence Levels

Group	N	Mean	SD	Df	t	p	Cohen's d
Experimental	105	4.14	0.40	208	18.28	0.001	0.52
Control	105	3.08	0.44				

The results showed that the difference in mean scores between the experimental group (M = 4.14, SD = 0.40) and control group (M = 3.08, SD = 0.44) was statistically significant (P< 0.05). Moreover, Cohen's (d) value of 0.52 indicated a moderate effect size, implying that the AI-integrated model intervention had a noticeable positive impact on students' overall digital competencies. Furthermore, ANCOVA analysis was used to examine whether there was a significant difference in students' post-test digital competence scores between the experimental and control groups after controlling for their pre-test scores, prior ICT training, year of study, and prior AI use, as presented in Table 4.

Table 4.

Analysis of Covariance of the effect of AI-integrated Model Intervention on the Level of Digital Competencies

Source	SS	Df	MS	F	p	Partial η^2
Corrected Model	160.50	9	17.83	20.12	0.000	0.47
Intercept	70.25	1	70.25	79.00	0.000	0.28
Pre-test	12.50	1	12.50	14.05	0.000	0.06
Group (Experimental vs Control)	44.10	1	44.10	49.50	0.000	0.19
Prior ICT Training	5.25	1	5.25	5.90	0.016	0.03
Group –Prior ICT Training	1.10	1	1.10	1.23	0.269	0.006
Year of Study	2.50	1	2.50	2.80	0.096	0.014
Group – Year of Study	0.80	1	0.80	0.90	0.343	0.004
Prior AI Use	3.00	1	3.00	3.37	0.068	0.016
Group – Prior AI Use	0.50	1	0.50	0.56	0.454	0.003
Error	185.00	200	0.925			
Total	345.50	209				
Corrected Total	345.50	209				

The ANCOVA results indicated that, when the pre-test results, previous ICT training, year of study, and previous AI use were taken into consideration, the overall model significantly predicted the post-test performance, $F(9, 200) = 20.12$, $p < 0.001$, $\eta^2 = 0.47$. The group had a significant main effect, $F(1, 200) = 49.50$, $p < 0.001$, Partial $\eta^2 = 0.19$, meaning that the experimental group performed better than the control group, which was in line with the t-test results ($t(208) = 18.28$, $p < 0.05$). The pre-test scores and past ICT training were also the predictive elements that had a significant impact on the post-test results ($p< 0.05$), but the other factors were insignificant: year of study, previous AI use, and all interaction terms.

The H2: AI literacy, e-learning instructional skills, and assessment practices will significantly and positively predict the overall digital competence of future teachers.

The results indicated that the three variables of digital competence (e-learning instruction, AI literacy, and digital literacy) were positively related and statistically significant, which implied that the enhancement of these variables could substantially enhance digital competence. The close correlation was noted between the AI literacy and assessment practices, with a correlation coefficient of 0.67, in that those students with higher knowledge of AI principles felt more confident in practices of digital innovative teaching and reflective assessment. There was also an intermediate relationship between e-learning teaching and AI literacy (r=0.62) and the practices of assessment (r=0.55). In addition, the impact of each of the components on the development of digital competence was investigated through the regression analysis. Moreover, the regression analysis was used to examine the relative influence of each of the components on digital competence development.

Table 5.

Pearson Correlation Coefficient among the Components of Digital Competencies

Correlations				
Components of Digital Competence		**E-learning instruction**	**AI Literacy**	**Assessment**
E-learning instruction	Pearson Correlation	1	0.62**	0.55**
	Sig. (2-tailed)		0.001	0.001
AI Literacy	Pearson Correlation	0.62**	1	0.67**
	Sig. (2-tailed)	0.001		0.001
Assessment Practices	Pearson Correlation	0.55**	0.67**	1
	Sig. (2-tailed)	0.001	0.001	
	N	210	210	210

**correlations are significant at $p < 0.05$ (two-tailed)

Table 6.

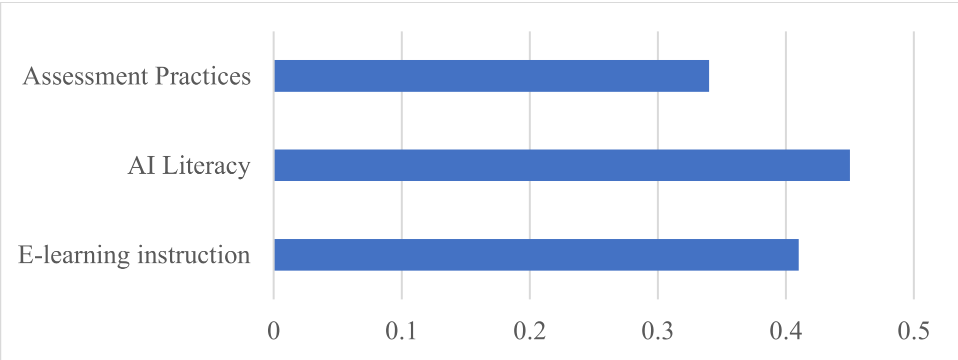
Regression Analysis of the Relative Influence of Digital Literacy, AI Literacy, and EdTech Self-Efficacy on Digital Competencies

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta (β)**		
(Constant)	1.842	0.312	—	5.90	0.000
E-learning instruction	0.328	0.071	0.41	4.62	0.001
AI Literacy	0.301	0.067	0.45	4.49	0.001
Assessment Practices	0.224	0.058	0.34	3.86	0.001
Model	**R**	**R^2**	**Adjusted R^2**	**Std. Error of the Estimate**	
1	0.812	0.659	0.652	0.438	

The regression results showed that all three components (e-learning instruction, AI literacy, and assessment practices) jointly predicted the variance observed in digital competence (R^2 = 0.659), indicating that approximately 66% of the total variation in digital competence development could be explained jointly by the combined effect of the three components. Furthermore, improvements in these domains significantly increased overall digital competence, as evidenced by the statistically significant positive effects of all three components on digital competence ($p < 0.05$). The result showed that the greatest contribution was made by AI literacy ($\beta = 0.45$, $p < 0.05$), indicating that AI literacy is the highest predictor of digital competence, followed by e-learning instruction ($\beta = 0.41$) and assessment practices ($\beta = 0.34$) as the least predictor of digital competence. Figure 3 displays standardized regression coefficients (β) of each of the components.

Figure 3.

Standardized Regression Coefficients (β) for Digital Competence Components

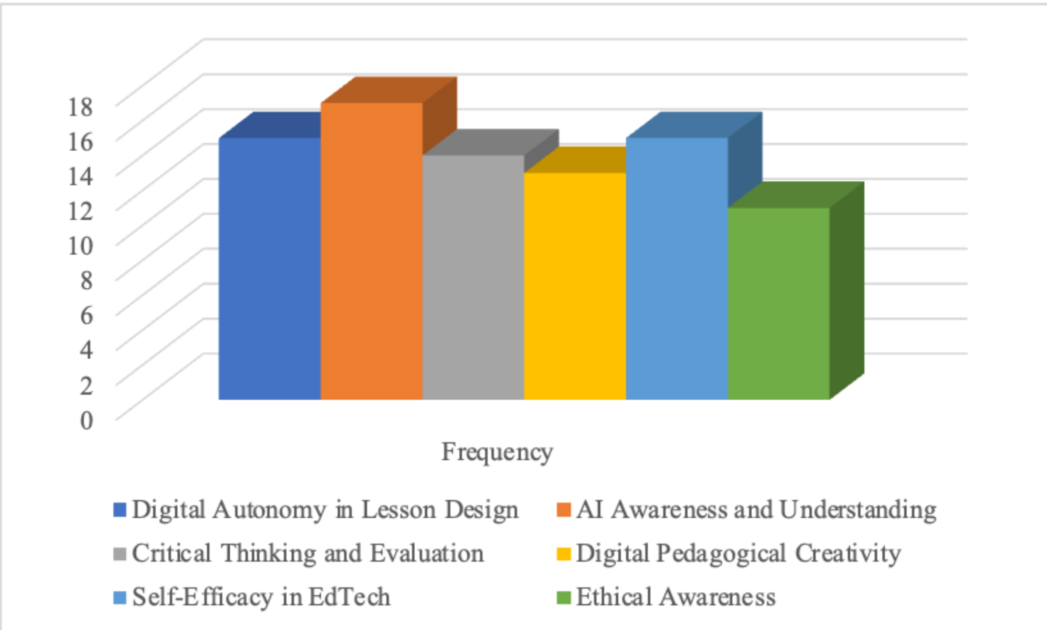


Qualitative Findings

After the intervention of e-learning and an AI-integrated model, students' reflective diaries were coded and categorized, which resulted in 6 major themes (Figure 4). The themes were discussed in detail, and students' specific quotes were randomly selected and highlighted.

Figure 4.

Themes Generated from Students' Reflective Diaries



Theme 1: Digital Autonomy in Lesson Design: This was explained in terms of students being able to design and select the right digital platforms or AI tools for specific learning, without constant assistance. Students also explained it as being comfortable to use AI-enhanced techniques to organize and arrange lessons after the intervention. A student shared her experience of moving from a passive user to an active user of AI tools.

> *"Initially, I used AI randomly, but the training helped me to understand its potential better. I now consciously apply it to form assignments, assess materials, and develop pedagogical concepts which I have.''*

Theme 2: AI Awareness and Understanding: In this theme, students shared how they demonstrated an improvement in the application and comprehension of concepts and practices of e-learning platforms and AI tools in teaching and learning processes.

> *''I have learned the distinction between AI-assisted tools and conventional digital tools after the training.''*

Theme 3: Growth in Critical Thinking and Evaluation: This theme explained that student experienced an improvement in their ability to think and evaluate both digital resources and AI information. After the intervention, students can now compare information from multiple sources, check for accuracy, bias, and authenticity of AI-generated materials.

> *"It is not sufficient to accept AI recommendations; I must verify whether they are correct and genuine.''*

Theme 4: Enhanced Digital Pedagogical Creativity: Following the intervention, students explored new methods of incorporating AI into classroom activities and created interactive tasks, quizzes, and content using various AI tools. A male student shared how he was able to try different tools and understand new ways to make lessons more interactive after the intervention.

Theme 5: Improvement of Self-Efficacy in EdTech: Students expressed higher belief, comfort, and confidence in using AI tools as well as implementing EdTech in real classrooms. In some of the students' diaries, they had early anxiety, but after having a training and microteaching experience, they have more confidence. A 4th-year student was actually impressed after the training sessions.

> *"I can actually operate these tools independently, as I have just shown during the micro-teaching session."*

Theme 6: Ethical Awareness: They showed their awareness towards upholding academic integrity, plagiarism, and the importance of securing learners' personal data.

> *"I learned how to check whether the AI-generated content is factual, does not violate any laws, and has no plagiarized content."*

In summary, the quantitative and qualitative outcomes demonstrated significant positive changes in the digital competence of future teachers following the intervention based on AI integration. This contributed to an increase in digital autonomy, AI awareness, critique, and creativity, as well as self-efficacy in EdTech and ethical awareness, which are all important elements of developing digital competence.

DISCUSSION

The impact of AI-based e-learning model on the digital competence of the future teacher in Ualikhanov University, Kazakhstan was investigated in the study. Overall, both the quantitative and qualitative strands of findings were strongly convergent to demonstrate a consistent and significant progress of the three main indicators of digital competence, which were digital literacy, AI literacy, and educational technology self-efficacy. The level of baseline competence between the experimental and control groups was similar before the intervention, which validated their similarity before the intervention, as also reported by Ogunleye et al. (2024).

There were moderate levels of competence in the three constructs at the baseline, as prior research findings showed that Sanusi et al. (2022) and Santos (2023) found similar levels of mid-range digital readiness in pre-service teachers working in developing settings. Based on the qualitative reflections, a great number of students became participants of the program as passive or uncritical users of technology, and systematic pedagogical assistance was required. This is in line with UNESCO (2023) and Lameras and Arnab (2021), which emphasize that digital competence cannot be achieved without a specific design of instructions.

The data collected after the intervention indicated significant improvements in all indicators, which proves the success of the AI model. These results are consistent with the research conducted by Shcherban and Khoma (2024) and Serik et al. (2022), who also indicated that there were huge competence improvements after teacher trainees took structured AI courses. The enhanced pedagogical creativity and EdTech self-efficacy are similar to Zawacki-Richter et al. (2019), who claimed that AI supplemented teachers' ability but did not replace it. Moreover, the critical assessment of AI-generated outputs can be associated with suggestions provided by Holmes et al. (2022) and Zeng et al. (2025). The reflective process incorporated in the model seems to have had an especially strong impact and helped educators to design lessons in which technology was operated not as a groundbreaking innovation.

The experimental group recorded much higher gains on all indicators after twelve weeks on the AI-integrated model, and this confirmed the H1, which argued that students who underwent exposure to the integrated AI model would experience greater gains than students who underwent conventional learning. The regression findings that were made in comparison also showed that AI literacy, e-learning teaching practices, and assessment methods had a significant impact on overall digital competence. This result supports the H2, which posited that technological and pedagogical skills are not independent, but interdependent in the development of overall competence. This gap proves the rationale of emerging models that combine pedagogical, technological, and ethical competencies to prepare educators for AI-integrated e-learning settings (Concepción Tenorio-Sepúlveda et al., 2025; Maksymchuk et al., 2018; Zasiekina et al., 2025). Conversely, the year of study, previous AI use, and all the interaction terms were insignificant, which meant that the efficacy of the intervention was strong irrespective of the level of study of students and their previous experience with AI. This proved that a well-organized AI-driven learning could have a positive influence on digital competence among students of various backgrounds.

Qualitative findings of students' reflective diaries resulted in six important themes, such as students' improvement from passive users of technology to active users of AI-enhanced instructional activities, as well as AI tools, which were the benefits of meaningful digital engagement. Enhanced skill in discerning the correctness and being able to discern bias was also reported by the students, which is a critical ethical skill in contemporary AI ecosystems (Bilytska et al., 2022; Hess et al., 2025; Kurakbayeva & Xembayeva, 2025; Tsekhmister, 2023). Although the engagement and efficiency are promising, the students were worried about responsible usage and the larger ethical aspects of AI implementation, with the international under-research on the pedagogic, human, and ethical aspects of AI implementation (Slimi, 2023). This observation justifies the existence of models that would harmonize the field of technological innovation with moral consciousness to ensure that digital learning processes are fair instead of increasing the gap between the rich and the poor.

The observed improvements align with international frameworks such as DigCompEdu, UNESCO ICT-CFT, and TPACK, emphasizing integration of technology, pedagogy, and ethics (Redecker, 2017). These supports incorporating AI literacy and competence-based assessment in teacher training. Limitations include self-reported bias, single-institution sampling, and focus on senior students. Future studies should expand samples across countries, institutions, disciplines, and year levels to improve generalizability overall.

CONCLUSIONS

The research demonstrates that an AI-based e-learning framework is highly effective in enhancing the digital competence of future teachers. It significantly improves digital literacy, AI literacy, pedagogical innovation, assessment practices, and EdTech self-efficacy. The model promotes learner autonomy, strengthens the ability to critically evaluate AI-generated content, and fosters ethical awareness, main competencies in modern digital education environments.

The study theoretically contributes to the expanding field of AI-enhanced teacher education by emphasizing the integration of technological, pedagogical, and ethical dimensions of digital competence. This integrated approach aligns with global frameworks such as TPACK, DigCompEdu, and UNESCO ICT-CFT.

Practically, the model offers a structured approach for teacher education institutions to modernize instructional practices and strengthen digital teaching capabilities. By emphasizing reflective practice, intentional AI use, authentic assessment, and ethical judgment, it equips future educators with essential skills for the classroom. Additionally, the model supports national digital transformation initiatives in Kazakhstan and offers adaptable solutions for similar contexts across Central Asia.

Despite the significance of the study, some limitations are acknowledged, such as student bias that may arise due to the use of a self-reported questionnaire for data collection. Also, the sample of students was selected from one institution, which may hinder the generalization of the findings for the total population of students in Kazakhstan. Finally, the AI-integrated model consists of blocks that address the 3rd and 4th year students, which may limit its effectiveness in educational settings.

Future research should increase sample size to include students from both private and public institutions in Kazakhstan as well as Ukraine to increase the training model's generalizability and adaptability to other educational contexts. To ascertain the universality of the created model, it is also critical to investigate how AI technologies affect various student classes from 1st to 4th year students and in other educational domains such as Arts, languages, sciences, and humanities differently.

REFERENCES

Adamakis, M., & Rachiotis, T. (2025). Artificial intelligence in higher education: A state-of-the-art overview of pedagogical integrity, artificial intelligence literacy, and policy integration. *Encyclopedia, 5*(4), 180. https://doi.org/10.3390/encyclopedia5040180

Bhandari, N. B. (2021). Diaspora and cultural identity: A conceptual review. *Journal of Political Science, 21*, 100–108. https://doi.org/10.3126/jps.v21i0.35268

Basilotta Gómez-Pablos, V., Casado-Aranda, L.-A., Matarranz, M., & Otto, A. (2022). Teachers' digital competencies in higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education, 19*(1), 8. https://doi.org/10.1186/s41239-021-00312-8

Bilytska, V. M., Andriiashyk, O. R., Tsekhmister, Y. V., Pavlenko, O. V., & Savka, I. V. (2022). Multimodal interaction in a foreign language class at higher education institutions of Ukraine. *Journal of Curriculum and Teaching, 11*(1), 218–234. https://doi.org/10.5430/jct.v11n1p218

Buele, J., & Llerena-Aguirre, L. (2025). Transformations in academic work and faculty perceptions of artificial intelligence in higher education. *Frontiers in Education, 10*, 1603763. https://doi.org/10.3389/feduc.2025.1603763

Cabezas-González, M., Casillas-Martín, S., & García-Valcárcel Muñoz-Repiso, A. (2024). Evaluating DigiCraft for the development of digital competence: A qualitative Approach. *Journal of Social Studies Education Research*, *15*(2), 231-250. https://jsser.org/index.php/jsser/article/view/5646

Carretero Gómez, S., Vuorikari, R., & Punie, Y. (2017). DigComp 2.1: The digital competence framework for citizens with eight proficiency levels and examples of use (EUR 28558 EN). *Publications Office of the European Union.* https://doi.org/10.2760/38842

Castillo-Martínez, I., Flores Bueno, D., Gómez Puente, S. M., & Vite-León, V. (2024). AI in higher education: A systematic literature review. *Frontiers in Education, 9,* 1391485. https://doi.org/10.3389/feduc.2024.1391485

Chiu, T. K. F., Ahmad, Z., Sanusi, T., Sanusi, I., & Ismailov, M. (2024). What are artificial intelligence literacy and competency? A comprehensive framework to support them. *Computers and Education Open, 6*, 100171. https://doi.org/10.1016/j.caeo.2024.100171

Chung Kwan Lo, Hew, K. F., & Jong, M. S.-y. (2024). The influence of ChatGPT on student engagement: A systematic review and future research agenda. *Computers & Education*, 219, 105100. https://doi.org/10.1016/j.compedu.2024.105100

Concepción Tenorio-Sepúlveda, G., Del Pilar Muñoz-Ortiz, K., & Soledad Ramírez-Montoya, M. (2025). Open Educational Resources for Computational Thinking: Digital Escape Room. *Journal of Social Studies Education Research*, *16*(2). https://jsser.org/index.php/jsser/article/view/5640

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Crompton, H., & Burke, D. (2023). Artificial intelligence in higher education: The state of the field. *International Journal of Educational Technology in Higher Education, 20*(1), 22. https://doi.org/10.1186/s41239-023-00392-8

Crompton, H., & Burke, D. (2024). The educational affordances and challenges of ChatGPT: State of the field. *TechTrends,* 68(3), 380–392. https://doi.org/10.1007/s11528-024-00939-0

European Union. (2019). DigCompEdu check-in. *Joint Research Centre.* https://joint-research-centre.ec.europa.eu/digcompedu/digcompedu-self-reflection-tools_en

García, J., García Carmona, M., Torres, J. M., & Moya-Fernández, P. J. (2021). Analysis of digital competence of educators (DigCompEdu) in teacher trainees: The context of Melilla, Spain. *Technology, Knowledge and Learning, 28*(1), 1–28. https://doi.org/10.1007/s10758-021-09546-x

Hess, Š., Flores-Asenjo, M. P., & Parra-Merono, M. C. (2025). The dual edge of generative AI in e-learning: Supporting decision-making under uncertainty while confronting ethical challenges in higher education. *Education and Learning Innovations Journal, 5*(3), Article 04. https://doi.org/10.57125/ELIJ.2025.03.25.04

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The difference between emergency remote teaching and online learning. *EDUCAUSE Review.* https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning

Holmes, W., & Tuomi, I. (2022). State of the art and practice in AI in education. *European Journal of Education, 57*(4), 542–568. https://doi.org/10.1111/ejed.12533

Ikwuka, O. I., Eleje, L. I., Iheanacho, E. C., & Onyebuchi, A. C. (2024). Teacher's attitude towards the use of digital technologies for capturing students' data in secondary schools in Imo State, Nigeria. *Futurity of Social Sciences, 2(4).* https://doi.org/10.57125/FS.2024.12.20.03

Imankulova, M., Nurgaziyev, T. & Moldagali, B. (2025). Effectiveness of Language Education in Kazakhstan: Integration of the Kazakh Language with Technology, Pedagogy, and Content (KFL-TPACK). *Journal of Social Studies Education Research, 16*(3), 332-348. https://jsser.org/index.php/jsser/article/view/6857/751

Karimi, H., & Khawaja, S. (2025). Exploring digital competence among higher education teachers: A systematic review. *International Journal of Learning, Teaching and Educational Research, 24*(1), 298–314. https://doi.org/10.26803/ijlter.24.1.15

Kravchuk, O., Kit, H., Yemelianova, O., Tolchieva, H., & Beseganich, I. (2023). With regard to the means and priorities for the development of the professional education system (the experience of the EU countries for Ukraine). *Journal of Curriculum and Teaching, 12*(5), 123–133. https://doi.org/10.5430/jct.v12n5p123

Kurakbayeva, A., & Xembayeva, S. (2025). Enhancing professional abilities of university students through digital educational interventions: A study in Kazakhstani universities. *Frontiers in Education, 9,* 1478622. https://doi.org/10.3389/feduc.2024.1478622

Lan, H., Bailey, R., & Tan, W. H. (2024). Assessing the digital competence of in-service university educators in China: A systematic literature review. *Heliyon*, 10(15), e35675. https://doi.org/10.1016/j.heliyon.2024.e35675

Lameras, P., & Arnab, S. (2021). Power to the teachers: An exploratory review on artificial intelligence in education. *Information*, 13(1), 14. https://doi.org/10.3390/info13010014

Laupichler, M., Aster, A., Schirch, J., & Raupach, T. (2022). Artificial intelligence literacy in higher and adult education: A scoping literature review*. Computers and Education: Artificial Intelligence, 3*, 100101. https://doi.org/10.1016/j.caeai.2022.100101

Lee, H.-Y., Chung, C.-Y., & Wei, G. (2022). Research on technological pedagogical and content knowledge: A bibliometric analysis from 2011 to 2020. *Frontiers in Education, 7*, 765233. https://doi.org/10.3389/feduc.2022.765233

Long, D., & Magerko, B. (2020). What is AI literacy? Competencies and design considerations. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (pp. 1–16). *Association for Computing Machinery.* https://doi.org/10.1145/3313831.3376727

Lucas, M., Zhang, Y., Bem-haja, P., & Vicente, P. (2024). The interplay between teachers' trust in artificial intelligence and digital competence. *Education and Information Technologies*, 29(14), 22991–23010. https://doi.org/10.1007/s10639-024-12772-2

Magocha, M., Munyaradzi, J., & Babalola, S. S. (2025). The Impact of the Pandemic on Digital Literacy Skills for Online Teaching in Zimbabwean Schools: A Mixed-Methods Research

Approach. *Research in Social Sciences and Technology, 10*(1), 310-331. https://doi.org/10.46303/ressat.2025.17

Makeleni, S., Mutongoza, B., & Linake, M. (2023). Language Education and Artificial Intelligence: An Exploration of Challenges Confronting Academics in Global South Universities. *Journal of Culture and Values in Education, 6*(2), 158-171. https://doi.org/10.46303/jcve.2023.14

Maksymchuk, B., Maksymchuk, I., Frytsiuk, V., Matviichuk, T., Demchenko, I., Babii, I., & Savchuk, I. (2018). Developing pedagogical mastery of future physical education teachers in higher education institutions. *Journal of Physical Education and Sport, 18*(2), 810–815. https://doi.org/10.7752/jpes.2018.02119

Maksymchuk, B., Sitovskyi, A., Kuzmenko, V., Nosko, Y., Korytko, Z., Bahinska, O., & Maksymchuk, I. (2019). Differentiated approach to physical education of adolescents with different speeds of biological development. *Journal of Physical Education and Sport, 19*(3), 1532–1543. https://doi.org/10.7752/jpes.2019.s4192

Masoumi, D., & Noroozi, O. (2025). Developing early career teachers' professional digital competence: A systematic literature review. *European Journal of Teacher Education, 48*(3), 644–666. https://doi.org/10.1080/02619768.2023.2229006

Miao, F., Holmes, W., Huang, R., & Zhang, H. (2021). *AI and education: Guidance for policy-makers.* UNESCO. https://doi.org/10.54675/PCSP7350

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record: The Voice of Scholarship in Education, 108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Mohamed Sapawi, M. S., & Nik Yusoff, N. M. R. (2025). Artificial Intelligence in Curriculum Development: A Global Systematic Review of Trends, Challenges, and Strategic Directions. *Journal of Curriculum Studies Research, 7*(2), 466-497. https://doi.org/10.46303/jcsr.2025.30

Morudu, K. (2025). Investigating Teachers' Integration of Technology in Automotive: A Case in Technical Schools. Research in Social Sciences and Technology, 10(1), 426-441. https://doi.org/10.46303/ressat.2025.23

Mosia, M., & Matabane, M. (2022). Exploring Factors that Serve as Predictors for Mathematics and Sciences Pre-Service Teachers to Use ICT in Teaching. *Research in Educational Policy and Management, 4*(1), 80-91. https://doi.org/10.46303/repam.2022.10

Navas Sabater, J. F. (2021). Concept stage program information document (PID) – Resilient Digital Kazakhstan Program – P176295. World Bank Group. http://documents.worldbank.org/curated/en/400941617469177523

Nong, Y., Cui, J., He, Y., Zhang, P., & Zhang, T. (2024). Development and validation of an AI literacy scale. *Journal of Artificial Intelligence Research, 1*(1), 17–26. https://doi.org/10.70891/JAIR.2024.100029

OECD. (2023). *Improving framework conditions for the digital transformation of businesses in Kazakhstan*. OECD Publishing. https://doi.org/10.1787/368d4d01-en

Ogunbodede, K. F., Ewata, T. O., Kumar, A., & Okediji, O. G. (2023). Digital competencies and the 21st-century skills of university teachers in Nigeria. *European Journal of Interactive Multimedia and Education, 4*(2), e02305. https://doi.org/10.3093/ejimed/13966

Ogunleye, B., Zakariyyah, K., Ajao, O., Olayinka, O., & Sharma, H. (2024). A systematic review of generative AI for teaching and learning practice. *Education Sciences, 14*(6), 636. https://doi.org/10.3390/educsci14060636

Ogurlu, U., & Mossholder, J. (2023). The Perception of ChatGPT among Educators: Preliminary Findings. *Research in Social Sciences and Technology, 8*(4), 196-215. https://doi.org/10.46303/ressat.2023.39

Özyer, K.K. (2024). Online Assessment in Turkish Universities: Challenges, Strategies, and Self-Efficacy Dynamics, *Journal of Social Studies Education Research, 15(*1), 1-37. https://jsser.org/index.php/jsser/article/view/5573/655

Puentedura, R. (2010). SAMR and TPCK: Intro to advanced practice. http://hippasus.com/resources/sweden2010/SAMR_TPCK_IntroToAdvancedPractice.pdf

Santos, A., Chinkes, E., Carvalho, M., Solórzano, C., & Marroni, L. (2023). The digital competence of academics in higher education: Is the glass half empty or half full? *International Journal of Educational Technology in Higher Education, 20*(1), 9. https://doi.org/10.1186/s41239-022-00376-0

Schmid, M., Brianza, E., & Petko, D. (2020). Developing a short assessment instrument for Technological Pedagogical Content Knowledge (TPACK.xs). *Computers & Education, 157,* 103967. https://doi.org/10.1016/j.compedu.2020.103967

Serik, M., Zhumagulova, S. K., Kazimova, D. A., & Abildaeva, G. B. (2022). Formation of competencies in parallel computing in databases by future information specialists. *World Transactions on Engineering and Technology Education, 20*(4), 263–268. https://wiete.com.au/journals/WTE&TE/Pages/Vol.%2020,%20No.4%20(2002)/10-Abildayeva-G.pdf

Shcherban, T., & Khoma, P. (2024). Formation of digital competence of future primary school teachers by using artificial intelligence. *Humanities Studios: Pedagogy, Psychology, Philosophy, 12*(3), 36–55. https://doi.org/10.31548/hspedagog/3.2024.36

Sierra, Á. A., Ortega Iglesias, J., Almenara, J., & Palacios-Rodríguez, A. (2023). Development of the teacher's technological pedagogical content knowledge (TPACK) from the lesson study: A systematic review. *Frontiers in Education, 8,* 1078913. https://doi.org/10.3389/feduc.2023.1078913

Slimi, Z. (2023). The impact of artificial intelligence on higher education: An empirical study. *European Journal of Educational Sciences, 10*(1), 17. https://doi.org/10.19044/ejes.v10n1a17

Son, T. (2024). Intelligent tutoring systems in mathematics education: A systematic literature review using the SAMR model. *Computers*, 13(10), 270. https://doi.org/10.3390/computers13100270

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education, 48*, 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Tsekhmister, Y. (2023). Effectiveness of blended learning in biomedical engineering: A meta-analysis*. Journal of Higher Education Theory and Practice, 2*3(5). https://doi.org/10.33423/jhetp.v23i5.5976

Turebayeva, K., Seitenova, S., Yessengulova, M., Togaibayeva, A., & Turebayeva, S. (2020). Nurture of multiculturalism of future teachers in the process of foreign language teaching. *Journal of Research in Applied Linguistics, 11(Proceedings),* 39–48. https://doi.org/10.22055/rals.2020.16272

UNESCO. (2023). *AI competency framework for teachers.* https://www.unesco.org/en/digital-education/artificial-intelligence

Ussainova, G., Seitmuratov, A., Issayeva, G., Shamsudinova, G., & Zhanseitova, L. (2025). Redesigning Instructional Design with an AI-Incorporated ADDIE Model for 21st Century Education. *Journal of Curriculum Studies Research, 7*(2), 498-521. https://doi.org/10.46303/jcsr.2025.31

Yang, Y., Zhang, Y., Sun, D., He, W., & Wei, Y. (2025). Navigating the landscape of AI literacy education: Insights from a decade of research (2014–2024). *Humanities and Social Sciences Communications, 12*(1). https://doi.org/10.1057/s41599-025-04583-8

Zasiekina, T., Vasylieva, D., Korshunova, O., Sipii, V., & Vashulenko, O. (2025). Electronic textbooks and their impact on learning in Ukrainian schools. *Periodicals of Engineering and Natural Sciences, 13*(3), 681–694. https://doi.org/10.21533/pen.v13.i3.459

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education—Where are the educators? *International Journal of Educational Technology in Higher Education, 16*(1), 39. https://doi.org/10.1186/s41239-019-0171-0

Zeng, M., Abdullah, Z., & Cheah, K. S. L. (2025). Pre-service teachers' digital competence: A systematic review of factors, frameworks, and global patterns. *International Journal of Learning, Teaching and Educational Research, 24*(8). https://doi.org/10.26803/ijlter.24.8.10

Zhang, P., & Tur, G. (2023). A systematic review of ChatGPT use in K-12 education. *European Journal of Education, 59*(1), 1–22. https://doi.org/10.1111/ejed.12599