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Artificial intelligence technologies as a means of improving the digital literacy of future teachers

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ABSTRACT

This study aimed to find out whether artificial intelligence (AI) technologies can improve digital mastery among in-training educators in Kazakhstan. It determines the rate of adoption of AI tools, evaluates their role in enhancing digital competencies, and examines the associated challenges and opportunities. Mixed-method approach was employed, which began with a quantitative phase (pre- and post-intervention tests) and concluded with a qualitative phase (interviews). The survey sample comprised 385 participants while 80 participants (40 each) made up the intervention consisting of traditional instruction and AI integrated instruction (ChatGPT and Google Cloud AI). The result showed that prior the intervention, all participants showed low digital literacy and did not adopt AI. However, a 100% AI adoption rate was observed after the intervention, with 75% having moderate to 25% high digital literacy. A paired t-test found significant improvements in digital literacy ($M = 25.34$ to 35.32, $t(19) = 2.12$, $p < 0.05$) and AI proficiency ($M = 19.89$ to 30.21, $t(19) = 1.03$, $p < 0.05$). Lack of institutional support, tool unfamiliarity, and skepticism were some of the problems people encountered. Conversely, the problems with digitally competent users were informed reflection and pedagogic balance. Despite these challenges, both groups recognized the possibilities of individual learning, better classroom result, and team development. Conclusively, targeted AI interventions in teachers training will greatly improve pre-service teacher's digital literacy. Therefore, when applied, close monitoring and ethical strategies should be put in place to enhance academic integrity.

Keywords: AI technologies, Chat GPT, Google Cloud AI, Digital literacy, Pre-service teachers

1. Introduction

The active development of digital technologies is also radically changing the world of education in the twentiet century [1]. Artificial intelligence (AI) has been employed to carry out both basic and technical tasks in numerous fields of human endeavor over the last 20 years [2]. This change has been embraced globally, whereby educational institutions are now actively integrating them into their learning process, to complement physical and one-on-one teaching, as well as streamline teaching and learning processes, particularly following the outbreak of COVID-19, which has resulted in the increased adoption of online educational tools [3, 4].

Pre-service teachers are in greater need of know-how and understanding of how to apply these AI tools in providing instructions to the classes. Leading in this revolution is the meaning of technological mastery, with capacity to access, analyze, produce, and exchange information through various digital mediums and channels [5, 6]. The digital literacy is a necessary condition to effective pedagogical practice and education in the twenty first century classrooms, especially future teachers (in-training educators) [7]. As education systems around the globe consider incorporating technology into pedagogical systems, the question of how digitally literate teacher candidates are trained has become a strategic point of focus [8]. Therefore, in the context of the

creation of digital competencies and change of the teacher education curriculum, AI technologies can be considered a powerful tool of new solutions [1].

Basic computer skills or knowledge of software applications do not come close to digital literacy. It is an integrated knowledge of how digital tools can be used to help in critical thinking, collaboration, creativity and so on [9]. In-training educators are able to create instructional content that are inclusive and exciting to learner and prepare them to adapt to the digitally inclined world with [10]. Lastly, teacher education has also welcomed AI technologies and field as a whole, has now started to develop and take advantage of the prospects that these technologies have never witnessed. Some of which include to customize the learning experience, automate manual administrative processes experienced in traditional learning processes, fast student information processing, and building smart tutoring systems [10]. These does not only make the teaching practices more efficient but also promoting adaptive learning and make future teacher ready to address the dynamic demands of the contemporary instruction and other AI-enhanced techniques learning in education [11], [12]. AI in education has been utilized in various applications, for instance Khan Academy's Khanmigo, Duolingo's Duolingo, iFlyTek's iFlyTek, Absorb LMS and Docebo's Absorb LMS, and SoftBank Robotics' Nao and Pepper robots [13], [14], [15].

These AI systems provide personalized learning support, intelligent feedback, and support teaching and learning activities [16]. In teacher education, AI might function as a virtual assistant that assists with classroom logistics, as an intelligent tutor providing real-time feedback on a teacher's teaching performance and as an evaluator for course designs to determine how assessments may be remodeled to draw out and reward higher-level conceptual knowledge in the area of computer science [17]. This is because AI helps teachers to rehearse, practice teaching strategies in non-combatant settings, and facilitative effective and efficient learning [18].

Despite all these potentials, there is an unequal uptake of machine learning technologies in developing parts of the world. The current situation with teacher preparation in Kazakhstan is slowly evolving, as there is an understanding that the digital tools have to be incorporated into their training to meet global standard [19]. Nevertheless, there are still a few issues that the country has to struggle with to see a complete digital literacy attainment among future teachers. The major obstacle is that advanced technological infrastructure can access only a small number of citizens, particularly in rural and underserved regions. Most teacher training institutions in digital learning environments do not support it sufficiently because of the lack of hardware, software, and internet connectivity [20]. Presence of such digital divide will widen the gaps that exist in education attainment, contradicting the initiative of producing a digitally proficient teaching force. According to research studies there are still noticeable gap in the professional development as too many teachers in teacher training programs are not adequately trained to use digital tools or AI applications to integrate them into students' training [20, 21].

The result is a dissonance between the digital competencies expected of pre-service teachers and the instructional practices they encounter during their preparation. Also, digital literacy is not systematically taught in the curricula of many Kazakhstani teacher education programs. Consequently, digital skills are frequently viewed as a minor or optional subject rather than as integrated into the learning content (pedagogical content knowledge) and instructional methodology. There is also the current state of attitudes towards technology among faculty and students [22]. There may be cultural and generational influences beyond timing that reflect the willingness to adopt new technologies, which serve as another barrier to the inclusion of machine learning in teacher training. Also, it does not have a national policy or strategic framework which creates a sense of uncertainty and inconsistency in its implementation in different institutions. Despite the initiatives to increase digital infrastructure, update educational standards, and advance information and communication technology (ICT) competencies by Kazakhstani government's the progress is somehow slow.

The addition of AI technologies training aligns perfectly with the digital transformation and the overall innovation proposed in the country, as its goals are national [23]. As an illustration, the development of e-learning platforms, smart classrooms, and the development of virtual resources will be used as lighthouses, as they represent the opportunities of AI in educating teachers. The next possibilities to find the knowledge, funds or advanced technologies are in the cooperation with such international organizations or providers of educational technology as [24]. As important as the availability of technological infrastructure in educational institutions to integrate new technologies such as AI. It is also important to organize training and skills for them to be able to design learning tasks that will use technology or new approach to teaching [25], [26], [27].

To exploit the power of AI to empower future teachers and equip them with the digital literacy skills, the challenge must be considered in its holistic form since it is a complex matter. To begin with, teacher education

curriculums should include digital literacy as a core requirement, learning outcomes, assessment standards, and learning strategies. AI applications can be used to facilitate the transformation by providing personalized learning paths, automating formative assessment, and engaging in learning. To take a specific example, AI-driven simulations can be used by pre-service teachers to simulate classroom management, differentiated instruction or engagement with students in virtual reality worlds.

Special training of teachers is necessary to become successful in making AI and digital tools part of their instruction. This training ought to be based on the pedagogical objectives and should be facilitated by peer mentoring, learning communities, and the online learning platforms. Inclusion of institutional support such as the commitment of the leadership and distribution of resources is important. Finally, developing digital literacy is not just the work with technology but an ethical practice that needs to focus on the well-being of students. Research and evaluation play a vital role in obtaining lessons learned and improving AI integration strategies of teacher education [28]. Evidence can guide policymakers and educators to base their decisions on the use of machine learning system tools on data, identify best practices by conducting a systematic study of its effects on teaching practice and professional development.

The lessons learned in such collaborative research between the universities, schools, technology providers and the government agencies can be used to generate innovation [29]. The implementation of AI technologies can be regarded as one of the possible ways of improving the digital literacy of the teacher in Kazakhstan in the future. However, the barriers are quite considerable, such as the unavailability of technologies, the inefficacy of the professional experience of the faculty, and the insufficiency of the teacher education curriculum [30]; and, also, the potential of reforming teacher education is quite large with the assistance of the strategic investments, policy reinforcement and transformational pedagogical practices.

Even better, as we attain a more complex and more connected world, we can have the next generation of teachers to become digital competent with the help of AI. Other than having digital literate teachers would mean effective teaching and learning, we need to prepare the school teachers to establish a robust and forward-thinking system of education that could assist the nation to grow and be a strong competitor in the global system. The research contributes to a great extent to the teacher preparation so as to offer an instructional curriculum that offers maximum technological advancement of student educators during this 21st century. Hence, future educators need to be furnished with technological competence. The AI focus of the research is that these tools can be effectively used to enhance the digital literacy of the future teacher, including intelligent teaching systems, personal learning platforms, and AI-based assessment tools, which can give aspiring teachers new opportunities to reach the students and tailor their learning.

The study adds to both global and local academic discourse other than by advancing teacher education. At the global level, given that the interest in AI in education is increasing, numerous studies articulate previous research centering on student achievements but not teacher preparation. This research discusses the possibility of AI to improve teachers' technological and professional advancement as part of UNESCO digital transformation agenda.

It offers context-specific ideas and viable solutions in integrating AI in the national teacher training programs. Moreover, the study interrelates education, technology, and ethics, and thereby, interdisciplinary discourse is strengthened. It empowers academic institutions and legislators, intellectual, ethical, addition to its technical application in teacher education. By doing this, it will help add to the current academic debate on curriculum development, education policy, and professional growth in the era of AI, particularly regarding the digital revolution in future areas.

1.1. Problem statement

Digitalization as the global necessity implies that most teacher preparation programs continue to be challenged in providing digital capability necessary to prepare future teachers in the digital capabilities required to be in their contemporary classrooms. This is particularly acute in Kazakhstan: the lack of digital mastery in-training educators makes them incompetent [31].

Also, research conducted by Bagdaulet [32] in primary schools indicates that new teachers usually take digital literacy as simple ICT skills, which are very poorly understood and implemented. In spite of the national campaign to modernize education by digital transformation, such as the Digital Kazakhstan, an institution of teacher education continues to be hindered, such as the use of outdated curricula, accessibility to sophisticated information technology devices, and less-skilled teacher education staff in adapting the information that is

technology-integrated in the teaching process [33]. All these restrictions continue to widen an existing gap in the teaching field (a digital divide), between cities and rural regions and ultimately denies students of the opportunity to access comprehensive and qualitative education.

AI can be used to provide personalized learning programs, smart tutoring technologies, and automated feedback to enable pre-service teachers to learn digital skills [34]. AI integration into teacher education of Kazakhstan is marginal, even though, and empirical studies concerning its operation in the country are not available. The current shortage of digital literacy in future teachers can further perpetuate the inequities in student achievement and the national capacity to sustain the standards of education in line with international standards in case it is not addressed [35].

Although AI-based teacher strategies are yet to be introduced to the pre-service training of teachers, they will likely continue to increase the competency disconnect between teachers and digitally fluent students that they must educate. Secondly, unless specific actions are undertaken, Kazakhstan is likely to lag behind the world trends, and therefore, a special focus on digital innovation in the construction of education systems adapted to the future is essential [36]. Due to this, it is highly significant to examine how AI technologies can be implemented in a more systematic way to enhance digital mastery in the education of in-training. It is not just a professional development problem of the future educators, but it has to be addressed to make the national education system viable and fit in this digital world.

1.2. Research objectives

The following objectives were aimed by the present research:

- to examine the level of digital literacy and AI adoption rate among pre-service teachers in Kazakhstan;
- to investigate how AI tools affect Kazakhstani pre-service teachers' digital literacy;
- to establish the effectiveness of using AI tools, such as a generative tool (ChatGPT) and Google Cloud AI, in designing and implementing classroom instruction;
- to investigate the experiences, issues and opportunities of pre-service teachers in relation to the introduction of AI and digital literacy skills among pre-service teachers in Kazakhstan.

Study adds to the body of knowledge on teacher education as a current issue being tackled by world educational institutions like UNESCO and OECD. It also information that can be used to address the needs of digitally naive students and enhance their capacity to deliver dynamic and responsive learning. It bridges a huge knowledge gap on teacher preparation program in Kazakhstan.

2. Literature review

2.1. Theoretical framework

TPACK framework extends the concept of Pedagogical Content Knowledge (PCK) presented by Shulman [37] to include technology as the third critical area of knowledge. TPACK, developed by Koehler and Mishra [38], helps to comprehend how technology can be used to enhance the instruction process by combining these areas of knowledge in synergy.

Chai et al. [39] further indicated that effective teaching of technology in TPACK depends on the knowledge of the three domains of knowledge which include technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). The effectiveness of education and learning is dependent on the efficiency, their efficiency with the e-learning tools and the subject matter. Subsequently, three areas led to TCK, TPK, PCK and TPACK that are instrumental in incorporating and facilitating effective, context-specific methods of teaching.

With reference to Kazakhstan, the Technological Pedagogical Content Knowledge (TPACK) model suggested by Mishra and Koehler [40] is best suited to offer the background of this research on digital literacy and the role of AI in teacher education. In the work by Chai et al., the authors focus on the use of TPACK in the context of teacher education in Asia [39]. Similar frameworks were also used by Temirkhanova et al. [41] to support the importance of interrelated areas of knowledge in Kazakhstan.

The measurement tool aligned with the domains of measurement of the TPACK where the competencies among teachers were to be measured in the seven domains. Questions such as how familiar teachers are with the digital tools are associated with Technological Knowledge (TK) and questions associated with instructional strategies

are associated with Pedagogical Knowledge (PK). Questions that were to be used in its subject specific applications of technology were also created to measure TCK and TPK respectively. By doing so, each component of the tool operationalizes a particular construct of TPACK, which gives theoretical coherence to the framework, along with the measurement process.

2.2. Conceptual review

Digital literacy or mastery are skills to access, utilize digital tools and platforms, assess the information that is available online and integrate technical skills into teaching. Akayoglu et al. note that digital literacy practices of pre-service teachers will entail not only the use of digital technology, but also critical evaluation of the digital technology to ensure that they are used safely and productively in the teaching and learning process to achieve desired learning outcomes [41].

Likewise, Niyazova et al. describe it as the digital skills needed to use AI in the form of chatbots, adaptive learning systems, and analytics which great influence on employment, education, and social relations [43]. These artificial intelligence applications enhance student involvement; better the teaching learning process; personalized learning; and eventually learning outcomes.

The application of AI in school is a section of a worldwide trend to utilize technology in meeting diverse needs of the students. Haseski briefly states that the use of AI in education will not replace teachers but will make learning more individual, provide practical learning experiences, enable students to discover their talents, improve their creativity and reduce teachers' workload [44].

2.3. Empirical review

2.3.1. Global trends in AI adoption and digital literacy in teacher education

The study of the digitalization process and transition between the traditional and virtual learning environments has grown at an extremely high rate, especially after the COVID-19 pandemic. According to Georgieva [2], this change has led to increased attention to the potential transformative nature of AI in teacher education.

Likewise, Zawacki-Richter et al. [45] and Zhang and Zhang [1] present extensive evidence that, on the one hand, AI helps with inclusive teaching, efficiency, and the acquisition of digital skills; on the other hand, it does not. However, these studies tend to include a mix of student, teacher, and administrative data, which limits information on pre-service teacher preparation.

Regarding the introduction of AI in teacher education, Holmes and Tuomi [46] state that there are different levels of inequality in the implementation of the solution, with significant differences across the developing world.

Another fact presented by Baker and Smith [47] is that, despite AI tools' ability to assist with personalized learning, pre-service teachers are not always provided with organized training on how to use them pedagogically. Therefore, the reason for choosing and targeting this study is pre-service teachers in Kazakhstan, whose needs and competencies in AI have not yet been well studied.

2.3.2. The digital literacy and attitudes of pre-service teachers towards AI

Research studies have found that digital literacy significantly influences pre-teachers' attitudes towards AI adoption and integration [5], [48]. Nonetheless, the results cannot be easily generalized to Kazakhstan due to variations in infrastructure, levels of digital preparedness, and pedagogical methods.

Ng et al. [49] found that levels of digital literacy vary widely across developed and developing countries, underscoring the need for contextual research. Also, it was stated that digital competence may not necessarily be accepted as AI literacy, which means that teacher training should include specialized AI training courses.

2.3.3. Artificial intelligence literacy and teacher pedagogical readiness

Sperling et al. [17] show wide gaps in teachers' AI literacy and suggest that teachers be educated based on professional knowledge. Although broad, their overview of the world does not consider the specific problems of Central Asia, where AI infrastructure and teacher-training reforms are underway.

According to Traga Philippakos & Rocconi [50], the AI literacy level of teachers is not only a matter of skills but also of ethical awareness and regulation (contextual), which is a poorly developed field in post-Soviet education. Another critical area that Han [51] pointed out is the balance of pedagogical and technical competence, along with AI literacy, among pre-service teachers worldwide.

2.3.4. Studies on teacher education and digitalization in Kazakhstan

Locally relevant studies are necessary, but they reveal significant gaps in their themes and methodologies. Yelubayeva et al. [19] note a structural problem in teacher training but do not address digital literacy or AI preparedness. Karmanova et al. [20] focus on the use of digital tools by chemistry teachers but ignore AI technologies and generalization due to the specificity of the subject.

Kerimbayeva et al. [52] offer a human-centered approach to digital literacy but pay little attention to AI and do not make cross-country comparisons. It was stated that there are general barriers to digitalization but fail to analyse post-COVID changes or the use of AI. According to Nazyrova et al. [53], institutional inertia predisposes Kazakh pre-service teachers to rely on obsolete ICT competencies, implying a poor foundation for implementing AI in education. Yermekova et al. [54] found that the digital divide between urban and rural teacher-training institutions in Kazakhstan exacerbates disparities in AI-related abilities.

2.3.5. AI and digital literacy research methodologies

The analyzed literature demonstrates the application of a wide range of methodological approaches to research digital literacy and AI integration in education. Quantitative research, including that by Zhang and Zhang [1] and Lim [5], will be effective in establishing trends and relationships but will not effectively reflect the subjective teachers.

Alternatively, qualitative research, such as that by Yelubayeva et al. [19], provides more information about the sociocultural and systemic limitations in Kazakhstan's education system. They however, are relatively poor at prediction and limited to a particular field. The new materialism also speaks in favor of this argument. As Sharma et al. [55] point out, mixed-methods methods have become a significant element of developing a more in-depth perception of not only quantifiable dynamics of AI tools.

2.4. Research gap

Review studies on pre-service teachers is usually low, and the TPACK-related AI competencies are not integrated into the teacher education programs. This research will fill these gaps by analyzing digital literacy and AI competencies among pre-service teachers, discussing how AI can contribute to academic and professional growth, and revealing the barriers and opportunities to AI implementation in Kazakhstan's teacher education system.

These objectives are consistent with international and domestic priorities, as UNESCO demands AI capacity-building in Central Asia, and the digital strategy in Kazakhstan emphasizes teachers' digital competence but does not include robust evaluation systems. The research then utilizes experimental methods that are imperative for advancing critical expertise, such as information assessment [56], ethical data use, problem-solving, and pedagogical assimilation, by defining setting-specific elements that affect AI projects, and by furnishing vital information to inform other policies, curriculum development, and successful AI integration in teacher education.

3. Research method

3.1. Research design

The design used in this research is a sequential explanatory mixed-methods experimental design, which combines quantitative (experimental) and qualitative (phenomenological) methodologies [57]. It was the right design, as it allowed the researcher to initially study the quantifiable impacts of an AI-based model of instruction on digital literacy and TPACK-based competencies, and subsequently analyze the participants' lived experiences to interpret the quantitative findings.

The design was developed in three consecutive steps, as depicted in Figure 1. This integrative and sequential process enhances the credibility, validity, and explanatory power of the results by combining quantitative results with intensive experiential information [58].

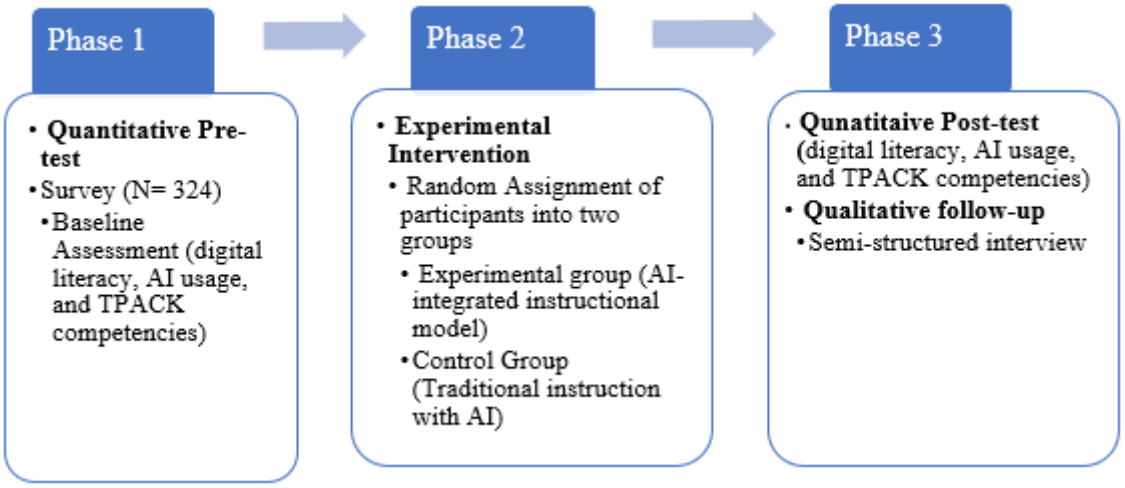

Figure 1. Three study sequential phases

3.2. Participants and sampling

The respondents were teachers who are students of the Faculty of Pedagogy at M. Utemisov West Kazakhstan University, Uralsk, Republic of Kazakhstan. For the first phase of the baseline assessment, the convenience sampling method was employed, resulting in the identification of 384 pre-service teachers. This method was deemed most appropriate, as the overall population was large and distributed across several departments.

The participants were selected based on the availability of their classes and the consent of the lecturers. As such, only students who were at school and willing to participate in the data collection process were included. To sample the 384 student participants, 80 students were chosen to represent phase 2. The inclusion criteria will be: pedagogical specialization, having at least one introductory course in ICT or educational technology, and consent to participate.

These subjects were randomly assigned to the two conditions: Experimental Group (40 students) and Control group (40 students), using a computer-generated randomization list with equal probability of assignment to either condition to control for systematic differences at baseline and minimize selection bias.

Phase 3 had 12 participants (6 students in each group (experimental and control group) who were sampled to be interviewed on a one-on-one basis through purposive sampling. The selection was made to ensure diversity across gender, performance level, prior AI experience, and consent to participate.

3.3. Procedures

The research involved a pre-test/post-test randomized control group experimental study done over three weeks of intervention (a total of 9 sessions). The pre-test used structured questionnaires (i) digital literacy scale gauged the level of digital literacy, frequency and purpose of using AI, and (ii) TPACK framework (Technological, Pedagogical, and Technological-Pedagogical Knowledge). Demographics were also captured by the tools: age, gender, prior use of AI, and knowledge of tools such as ChatGPT and Google Cloud AI.

The intervention had a total of nine sessions, each lasting 90 minutes and completed over three weeks (three sessions per week). The instructional model with AI entailed direct teaching of generative AI, demonstrations using ChatGPT and Google Cloud AI, practice in generating lesson notes, collaborative teaching of AI-supported feature instructional materials, and reflective debates on ethics, pedagogy, and technical details by the experimental group.

Participants in the control group, in turn, resort to traditional instruction and lesson preparation tools and are not exposed to AI tools. Both conditions were tested with the same post-test instrument as in Phase 1, which assessed the effects of growth and treatment administered (40 minutes). Semi-structured interviews were audio-recorded, transcribed word-for-word, and analyzed using thematic analysis.

3.4. Materials

The study used two questionnaires (the digital literacy scale and the TPACK competencies scale) to gather primary data. The digital literacy scale was a modified version of the DigCompEdu Check-In. The scale consisted of two parts: Section A contained demographic information about the participants, such as age, gender,

previous experience with AI tools, whether AI tools were used to create lessons, and whether students were aware of ChatGPT, Google Cloud AI, and other websites. Section B will comprise 12 questions that will scale the six dimensions of digital competence.

The second tool was the TPACK competencies scale, which measured three aspects of teachers' competencies (Technological, Pedagogical, and Technological-Pedagogical Knowledge). There were also 12 items in the scale (TK: 1-4, PK: 5-8 and TPK: 9-12). Moreover, seven semi-structured questions focused on the experience of using or not using AI tools, perceived changes in digital literacy, challenges faced, and opinions on how AI use in teaching would evolve in the future to obtain qualitative data. Two educational technology experts have reviewed both qualitative and quantitative data instruments.

Factor analysis was used to establish construct validity, yielding a KMO value of 0.82. Also, a pilot test of the quantitative tools was conducted with 30 students who were not part of the sample to assess the tools' caliber and simplicity prior to the actual administration. Their answers were used to conduct the reliability test, which was used to derive the internal consistency of the items based on the Cronbach alpha coefficient (adapted digital literacy scale = 0.83, TPACK competencies scale = 0.91), indicating that the instruments were suitable for use. Moreover, a thematic analysis of future teachers' experience was conducted by two independent coders, and Cohen's kappa value was 0.78.

3.5. Data collection

The data collection was in four phases. Stage 1 was linked to the development of the AI-based and traditional Moodle spaces and to the building of the structured AI-based learning model. Stage 2 entailed administering pre-test instruments (DigCompEdu Check-In, AI Literacy Scale, and EdTech Self-Efficacy Questionnaire) to the two groups. In stage 3, the 12-week blended e-learning intervention was delivered by two instructors with equal qualifications, a master's degree in educational technology, who were trained and given standard training to minimize the effect of the instructors.

The post-test was conducted in stage 4, where the two groups underwent the re-test using the same instruments as in the pre-test, and the potential instruments to be used in the studies were also considered. During the qualitative section, participants were interviewed (semi-structured, 40 minutes each) to discuss the application of AI, confidence, and challenges. The interviews were recorded on audio tape and transcribed word-for-word, and the thematic analysis was conducted using a deductive approach to identify structured themes.

Data analysis was conducted using SPSS and NVivo 12. A normality check was performed on the data, and the results were summarized and described. Independent-samples t-tests were applied to test intra-group variation and Cohen's d for effect size. The deductive thematic approach was use to analysis data from interview responses. These reactions were coded and combined into themes.

3.6. Ethical consideration

The department's research ethics committee was obtained. The study ensured voluntary consent from all participants. Students were given comprehensive knowledge about the study's goals, phases, possible risks, and advantages.

4. Results and discussion

4.1. First phase: survey and pre-test baseline assessment (descriptive statistics of participants)

4.1.1. Artificial intelligence technology awareness of pre-service teachers

The adoption rate of AI technologies, the level technological mastery, and the frequency of AI use were first established to determine the general trend, based on a survey of 324 participants selected prior to the pre-test baseline assessment.

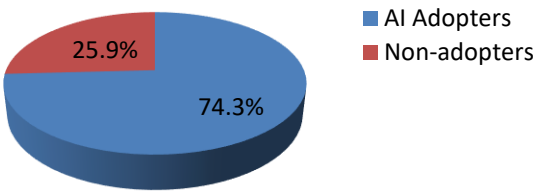

Figure 2. AI technology adoption among pre-service teachers

Figure 2 shows the level of AI technology adoption among in-training educators. From the results in-training educators (74.03%) have heard of AI, while 25.97% have not indicating that majority of the respondents were technologically prepared and are ready to use AI tools.

4.1.2. Level of digital literacy among pre-service teachers

Based on survey results from 324 participants, pre-service teachers were categorized into three levels (high, moderate, and low) of digital literacy, with a criterion score of 3.0.

Pre-service teachers whose scores are above the overall mean score are categorized as having a high level of digital literacy; scores around the mean are considered moderate; and scores below the overall mean are categorized as low. The level of digital literacy among pre-service teachers is shown in Figure 3.

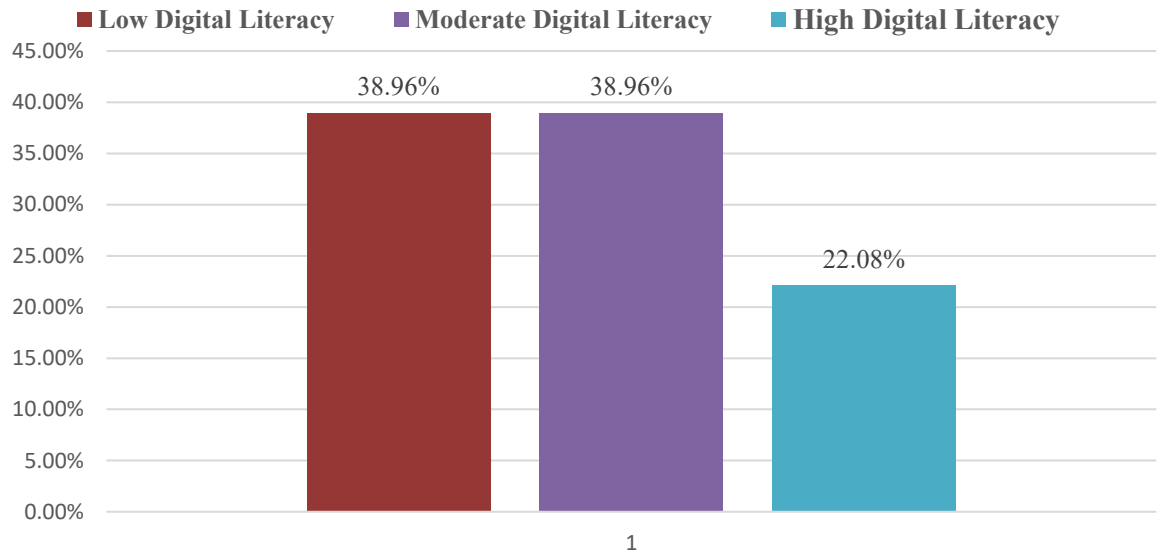

Figure 3. Level of digital literacy among pre-service teachers

Both low and moderate have 38.96% each while only 22.08% of them possess high digital literacy indicating that digital literacy remains a challenge among in-training educators, potentially affecting their integration and efficient use of AI tools.

4.1.3. Frequency of AI tool usage among pre-service teachers

The frequency of AI tool usage (ChatGPT, Google Cloud AI, video gen, and others) among 385 pre-service teachers is illustrated in Figure 4.

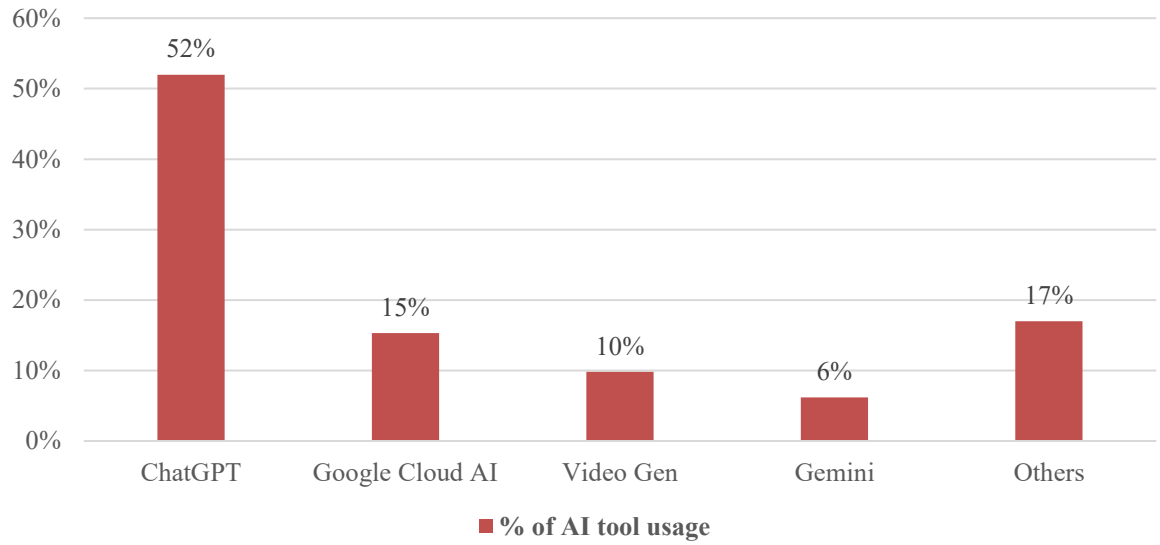

Figure 4. Percentage of AI tool usage among pre-service teachers

An average of participants (52%) used ChatGPT, indicating its popularity. Reporting: 15% of participants reported using Google Cloud AI. The low adoption rates of Gemini (6%) and Video Gen (10%) may be due to their limited availability, low awareness, or lack of relevance to pre-service teachers' needs. 17% reported using other undefined AI technologies.

4.1.4. Pre-test baseline assessment (80 participants)

To examine the impact of AI-based educational tools on the digital literacy skills of future teachers in Kazakhstan.

80 future teachers' baseline levels of digital literacy skills were assessed using the digital literacy scale and the TPACK competences scale before the intervention with the AI-Integrated model for both the control and experimental groups, as presented in Table 1.

Table 1. Descriptive analysis of Pre-Test digital literacy skills

Digital Literacy Skills	Experimental Group (n=40) (n=40) Mean (SD)	Control Group (n=40) Mean (SD)
Digital Literacy	3.12 (0.48)	3.15 (0.51)
Technological Knowledge (TK)	2.74 (0.56)	2.68 (0.59)
Pedagogical Knowledge (PK)	3.45 (0.44)	3.42 (0.47)
Technological Pedagogical Knowledge (TPK)	2.89 (0.49)	2.84 (0.52)
Grand Mean (SD)	3.05 (0.49)	3.02 (0.52)
Digital Literacy	3.12 (0.48)	3.15 (0.51)

The control and experimental conditions yielded similar baseline results across all competencies, and the level of digital literacy was moderate (Experimental: M = 3.12, SD = 0.48; Control: M = 3.08, SD = 0.51).

In both groups, Technological Knowledge (TK) was also very poor, with a mean score below 3.0, indicating low technical expertise. Pedagogical Knowledge (PK) and Technological Pedagogical Knowledge (TPK), on the other hand, had the highest and moderate levels of competence, respectively. In general, the groups were similar before the introduction of the AI-based teaching model.

4.2. Second phase: intervention (post-test)

4.2.1. Intervention phase

To establish the effectiveness of using AI tools, such as a generative tool (ChatGPT) and Google Cloud AI, in designing and implementing classroom instruction. The pre-test was compared to the post-test illustratively in Table 2.

Table 2. Descriptive analysis of pre-test and post-test

Digital Literacy Skills	Group	Pre-Test	Digital Literacy Skills
Digital Literacy (Overall)	Experimental	3.12 (0.48)	4.18 (0.41)
	Control	3.15 (0.51)	3.34 (0.49)
Technological Knowledge (TK)	Experimental	2.74 (0.56)	4.09 (0.45)
	Control	2.68 (0.59)	2.89 (0.54)
Pedagogical Knowledge (PK)	Experimental	3.45 (0.44)	4.22 (0.39)
	Control	3.42 (0.47)	3.55 (0.45)
Technological Pedagogical Knowledge (TPK)	Experimental	2.89 (0.49)	4.12 (0.42)
	Control	2.84 (0.52)	3.10 (0.50)
Grand Mean (SD)	Experimental	3.05 (0.49)	4.15 (0.42)
	Control	3.02 (0.52)	3.22 (0.49)

The baseline showed that both groups were equally digitally literate (Experimental: M = 3.12; Control: M = 3.15). Following the intervention, the experimental group showed a significant increase in digital literacy (M = 4.18), whereas the control group showed a relatively small increase (M = 3.34).

The results indicate that ChatGPT and Google Cloud AI significantly improved in-training educators' digital literacy which include the processing of digital information, and the capacities to navigate the digital environment. For technological knowledge score increases from mean value of 2.74 to 4.09, while the groups showed reasonably good pedagogical knowledge at baseline.

The experimental group, however, noted a significantly greater improvement (3.45 to 4.22) compared to the control group (3.42 to 3.55). TPK of the experimental group significantly increase in mean score from 2.89 to 4.12, demonstrating their improved ability to integrate technology and pedagogy effectively.

The grand mean of experimental group increases significantly to 4.15 indicating the impact of the intervention. Furthermore, observed difference between the two groups was carried out by t-test presented in Table 3.

Table 3. Independent T-test comparing experimental and control groups (Post-Test)

Group	N	Mean	SD	Df	t	p	Cohen's
Experimental	105	4.15	0.42	78	9.11	0.001	0.58
Control	105	3.22	0.49				

Note: N = No of observation, SD = Standard Deviation, df = Degree of Freedom, t = t-test value, p = significant value

Results showed that the difference in mean scores between the experimental group (M = 4.15, SD = 0.42) and the control group (M = 3.22, SD = 0.49) is statistically significant ($P < 0.05$).

Moreover, Cohen's (d) value of 0.58 indicates a moderate effect size, implying that the AI-integrated model intervention had a noticeable positive impact on students' overall digital literacy skills.

4.2.2. Perceptions and experiences of Pre-Service teachers regarding the use of AI tools

Ten items were used to assess the levels of perceptions and experiences among pre-service teachers.

These items were scored on a 5-point response scale ranging from strongly agree = 5, agree = 4, neutral = 3, disagree = 2, and strongly disagree = 1.

The rating yielded a criterion mean value of 3.5, which was used as the benchmark (Table 4).

Table 4. Mean and standard deviation of the perceptions and experiences of Pre-Service teachers

S/N	Statements	SA	A	N	D	SD	Mean	Std. Dev
			Frequency = 384					
			Perceptions					
1	I believe AI tools should be integrated into teacher training programs	150	130	40	45	19	4.07	0.89
2	AI tools provide personalized feedback that enhances my learning	148	128	50	42	16	4.04	0.88
3	Using AI tools has improved my ability to complete academic tasks more efficiently	140	120	60	50	14	3.97	0.92
4	I am concerned about the ethical implications of using AI in education	38	98	64	110	74	3.68	1.21
5	Using AI tools in my training has increased my interest in digital technologies	135	120	62	53	14	3.92	0.97
			Grand Mean				3.93	0.85
			Experiences					
6	I feel confident in my ability to use AI tools for educational purposes	38	64	98	110	74	3.18	1.21

S/N	Statements	SA	A	N	D	SD	Mean	Std. Dev
			Frequency = 384					
			Perceptions					
7	AI tools have helped me better understand the subject matter I am studying	40	58	102	112	72	3.14	1.18
8	My instructors have adequately supported me in learning how to use AI tools effectively	36	55	106	110	77	3.08	1.19
9	AI tools help me prepare better teaching materials and lesson plans	34	52	110	110	78	3.04	1.17
10	Overall, my experience with AI tools in my teacher training has been positive	40	60	96	108	80	3.10	1.22
	Grand Mean						3.11	1.19

Note: strongly agree = SA, agree = A, neutral= N, disagree = D, strongly disagree=SA

The frequency of the response options, mean, and standard deviation for all the items are shown in Table 4. Results showed that all mean perception scores are above the criterion mean of 3.5. Also, the grand mean of pre-service teachers' perception scores is 3.93, indicating positive attitudes and strong agreement among participants. Conversely, with a relatively low level of expertise (grand mean = 3.11) among many participants, this suggests that, while AI technologies are viewed positively, actual use and support remain limited, exposing a disconnect between perception and experience.

4.3. Third phase: qualitative results

The qualitative stage investigated the experiences, issues and opportunities of pre-service teachers in relation to the introduction of AI, digital literacy skills, and integration of instruction.

The data were structured around the research questions and then thematically analyzed. Results are provided together with the quotes and significance of the number of respondents who supported each theme.

4.3.1. RQ1: what are the problems encountered by pre-service teachers in their integration of AI technologies in teaching?

Theme 1: Low Digital literacy as an impediment to adoption of AI: The lowly digital literate participants reported that the incorporation of AI felt overwhelming and intimidating. 7 out of 12 participants reported that they were not able to navigate learning management systems, understand AI-generated feedback, and use more than one digital tool at a time.

''Occasionally, the feedback provided by ChatGPT is not easy to understand, and I do not even know how to implement it in my lesson'' (Participant 4)

''When the number of digital tools presented simultaneously is too large, I simply lose my temper and quit'' (Participant 2)

The participants also mentioned fear and distrust of AI:

''I am also afraid that someday the AI will take over some of our work''.

4.3.2. RQ2: what are the opportunities that pre-service teachers see in the utilization of AI tools in teaching and learning?

Theme 2: Improvement of Skills and Effective Instruction: Nevertheless, most respondents have admitted that AI applications will make learning faster and enhance the teaching process once basic digital literacy is achieved.

''Planning of the lesson is made quicker with the help of AI as well, in particular, when I can create examples and questions that I have in the quiz right away''. (Participant 8)

''The use of AI makes me feel better about myself since I can verify my ideas of teaching prior to presenting them''. (Participant 10)

4.3.3. RQ3: how do digital literacy levels influence the moral concerns and professional judgment of pre-service teachers in the use of AI?

Theme 3: Pedagogical and Ethical Concerns among Digital Users: Individuals of moderate to high digital literacy talked about more subtle issues. Instead of technical challenges, 6 of 12 participants reported concern about ethics, academic integrity, and data privacy.

''I am concerned that students will be excessively dependent on AI and ignore the thinking stage'' (Participant 9)

''The sensation is sometimes that AI is delivering the response and not me. It causes me to doubt my judgment as well'' (Participant 11)

Theme 4: Innovative, Collaboration and Peer Support: 8 out of 12 participants reported this. Respondents with moderate-to-high digital literacy underscored that AI expanded their instructional creativity and collaboration.

''AI provides me with alternative forms of delivery of content, and in particular, interactivity'' (Participant 6)

''I usually assist my classmates who are failing to use AI tools. It is nice to have each other on our side'' (Participant 1)

Theme 6: Need for Balanced Integration: Participants with moderate to high literacy levels emphasized the importance of monitoring AI use to prevent over-reliance that could compromise pedagogical integrity.

4.4. Discussion of findings

The findings indicate that there is a very large gap between the rate of adoption of AI technology and digital mastery of in-training educators. Although the majority of respondents' report having regular use of AI tools, not all of them are very digital, and a large proportion of individuals are middle or low-rank digital.

The presence of such a paradoxical combination of a high rate of adoption and low rates of digital literacy implies that the pre-service teachers are using AI tools and are not necessarily using them competently and pedagogically.

This difference is in line with the past research by Turabay et al. [27] who underscored the fact that teachers might have access to digital tools but fail to apply them as learning resources. It is also indicated in the international literature, e.g., Zhang and Zhang [1] in China and Sperling et al. [17] in Europe expressed that AI-based educational platforms have become a massive trend, but the digital literacy levels are not high.

Findings from the study shows that some contextual factors also influence the differences observed among teachers in Kazakhstan as reported in previous studies [19], digital competence is lower in rural institutions where infrastructure, training, and technology are often unstable. The findings at hand indicate a minor increase in digital literacy levels compared with previous national surveys, which probably results in: the development of a digital framework in Kazakhstan; wider access to online learning platforms; and Federal programs that facilitate digitalization in education. However, implementing without proper skills risks a less profound use of AI than deep pedagogical practices.

The findings also indicate that AI technologies, especially generative technologies such as ChatGPT, and analysis tools such as Google Cloud AI, have helped enhance digital literacy when taught purposefully during training. A higher quality of problem-solving, customized learning support, automatic feedback on assignments, and more convenient navigation of online platforms were identified by the participants

These findings show that AI could be used as an instrument and as a scaffolding to scaffold the acquisition of digital literacy and take the cognitive load off and support students in doing complex tasks. This conforms to the views across the world [36] that focus on AI as a source of encouraging critical thinking, teamwork, and innovation. However, qualitative data reveal that the level of experience did not grow by an insignificant margin even though there were positive perceptions. Pre-service teachers stated that they were willing to work with AI but that practical work is not that significant of an interest yet as compared to interest, and therefore practice comes second after interest. This is unlike findings of other nations, including the United States, where Lim [5] established that teachers confident in AI also use it most frequently. conversely, the positive attitudes of the Kazakhstani in-training educators are not supported by the confidence towards using AI, probably because the use of AI is not highly institutionalized in the teacher education program.

The intervention stage provided statistically significant positive differences in technological mastery level, AI level, specifically in technological knowledge, pedagogical integration, of the intervention group. The participants were more confident in developing lesson plans, had better ability to individualize learning, better use of AI-generated discussion, and better in managing their instructional efforts.

These findings substantiate the notion that the intentioned, methodical treatment to exposure to AI devices is efficient in attaining the instructional competencies. Even a brief, carefully designed AI training program can bring about considerable benefits in case the in-training educators are improved in terms of their willingness to work in digital classrooms.

This validates the argument that AI training must be incorporated in teacher education course work as opposed to discovery learning. The systematic implementation of AI in pedagogy can reduce current digital disparities, offer everyone equal opportunities to access high-quality digital practices, and improve the quality of teaching across institutions. The intervention stage showed statistically significant positive changes in the digital literacy levels, AI level, and technological knowledge, as well as in the pedagogical integration level, of the experimental group. The participants showed greater confidence in creating lesson plans, enhanced their capacity to personalize learning, applied AI-generated insights more effectively, and were more effective at controlling their instructional activities.

These findings support the idea that the purposeful, systematic approach to exposure to AI tools is effective in achieving instructional competencies. The improvements of in-training educators' readiness in digital classrooms may produce significant benefits even in case of a short, properly designed AI training program.

This supports the claim that AI training should be integrated into teacher education programs rather than used for discovery learning. The systematic implementation of AI in pedagogy can reduce current digital disparities, offer everyone equal opportunities to access high-quality digital practices, and improve the quality of teaching across institutions.

Respondents found many advantages of AI integration, including improved personalization of learning, greater efficiency in lesson creation, higher levels of technological confidence and technology competency, and the facilitation of collaborative and adaptive learning. These opportunities can align with global trends, in which AI exemplifies the development of key 21st-century skills [36], such as creativity and critical thinking.

In addition to the positive results, pre-service teachers also noted the existence of significant challenges, the learners had difficulties with sophisticated digital functions, the skills gap was observed despite the high adoption rate, and participants expressed concerns regarding the issue of data safety, the credibility of AI-generated content, and academic dishonesty, overreliance on AI, and limited training opportunities and insufficient curriculum reform were regarded as barriers. These issues underscore the need for AI ethics education, responsible use of technology, critical evaluation of AI results, humanistic education, and the reasonable use of automated tools. Pre-service teachers without this moral background are susceptible to developing superficial dependence rather than a purposeful, reflective use of AI.

5. Conclusions

This study examines the perceptions and experiences of in-training educators on the use of AI-based tools to enhance their digital literacy in Kazakhstan along with the pros and cons associated with the use of the tools. Digital literacy is still low in those who are already pre-service teachers. It also demonstrated that systematic interventions boosted digital literacy and the use of AI.

Despite the identified ethical concerns, data privacy and integrity threats, and overreliance on AI, these findings have a substantial implication on the teacher education policy, and curriculum development in Kazakhstan.

Confident and competent teachers who know how to use AI technologies will be more inclined to substantially implement them in teaching and thus have a positive impact on the long-term student learning outcomes. Faculty development programs are also required to provide training to teachers who can be the role models towards ethical and successful applications of AI in the classroom. It is recommended that teachers should start to incorporate AI tools in their lesson plans, schools should create AI courses and, policymakers need to build a national roadmap on integrating AI.

Further study should explore AI-based interventions' long-term effects on teaching efficacy, student outcomes, and ethical decision-making among pre-service teachers, involving larger, diverse samples.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

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