Effects of Digital Tools and Innovative Teaching Methods on Innovative Competence, Digital Literacy, and Critical Thinking among Prospective Primary Teachers

Zhazira Stambekova* and Aziya Zhumabayeva

Department of Primary Education, Abai Kazakh National Pedagogical University, Almaty, Kazakhstan
Email: sanianurgalieva77@gmail.com (Z.S.); aziya_e@mail.ru (A.Z.)
*Corresponding author

Manuscript received October 14, 2025; revised December 11, 2025; accepted January 12, 2026; published June 18, 2026

***Abstract*—With the ongoing digital transformation of education systems, the need to foster innovative competence among prospective primary teachers has become increasingly evident. Traditional teacher training approaches do not always provide the competencies required for the effective implementation of innovations or the meaningful integration of digital technologies into educational practice. The purpose of this study was to investigate the effect of digital tools and innovative teaching methods on the development of innovative competence, digital literacy, and critical thinking among prospective primary school teachers. The study involved 60 undergraduate students from Abai Kazakh National Pedagogical University enrolled in a primary education program and was conducted using a quasi-experimental mixed-methods design. Over the course of one academic semester (16 weeks), the experimental group participated in learning activities supported by digital platforms, project-based tasks, and interactive teaching methods, while the control group followed a traditional instructional program. The results demonstrated that the integration of digital tools and innovative teaching methods had a statistically significant positive impact on the development of innovative competence. Compared to the control group, students in the experimental group showed substantial improvements in innovative competence, digital literacy, and critical thinking. The mean score increases were 0.84 for innovative competence, 0.67 for digital literacy, and 0.76 for critical thinking, thereby confirming the effectiveness of the intervention. These findings suggest that the systematic integration of digital tools and innovative teaching methods can enhance the preparation of innovation-competent teachers and inform the improvement of teacher education curricula.**

***Keywords*—competence development, digital transformation in education, digital tools, innovation, project-based learning**

I. Introduction

The professional requirements for teachers are continuously evolving, extending beyond technical proficiency in digital tools to include a fundamental rethinking of pedagogical practices. In response, teacher education programs increasingly focus on equipping Prospective Primary Teachers (PPTs) with the competencies needed to work effectively in digitally enriched and innovation-oriented educational environments [1]. The professional requirements for teachers are continuously evolving, extending beyond technical proficiency in digital tools to include a fundamental rethinking of pedagogical practices. In response, teacher education programs increasingly focus on equipping Prospective Primary Teachers (PPTs) with the competencies needed to work effectively in digitally enriched and innovation-oriented educational environments [1].

Within this context, Innovative Competence (IC) emerges as a key component of professional teacher competence. IC is understood as the ability to generate and implement new pedagogical ideas, apply innovative teaching methods, and integrate digital technologies meaningfully into teaching practice [2, 3]. For PPT, the development of IC is particularly important, as it underpins their capacity to design engaging learning experiences, foster Critical Thinking (CT), and adapt teaching strategies to the needs of a digitally oriented generation of learners [4, 5]. However, traditional approaches to teacher education often remain insufficient for the systematic development of IC, limiting students' readiness to integrate digital technologies and innovative methods into their future teaching practice [6].

Recent research emphasizes the importance of integrating digital tools into the educational process to enhance students' creativity, initiative, and project-based skills [7–9]. Digital Technologies (DT), including online learning platforms, interactive educational applications, collaborative design tools, and virtual laboratories, promote active student engagement and support learner-centered pedagogical approaches [10, 11]. These tools support not only engagement but also the development of Digital Literacy (DL) and CT, which are essential components of innovative competence.

Previous studies demonstrate that the use of such tools increases students' motivation and their ability to independently solve pedagogical problems [12, 13]. Nevertheless, many existing studies focus on individual digital tools or short-term interventions, which limit the understanding of their comprehensive and sustained impact on competence development [14]. Therefore, systematic experimental research is required to evaluate the effectiveness of integrating digital tools in combination with Innovative Teaching Methods (ITM).

The integration of ITM into the educational process involves the use of Project-Based Learning (PBL), interactive discussions, collaborative group work, and problem-oriented tasks supported by DT [15, 16]. These methods contribute to the development of CT, collaboration, and independent decision-making skills, which are considered essential components of IC [17, 18]. Thus, the integration of DT and ITM together forms a coherent framework for enhancing IC, DL, and CT. In educational practice, it is important not only to implement digital tools but also to systematically evaluate their impact on the development of students' innovative competence. In this regard, students' perceptions of digital tools and ITM play an

doi: 10.18178/ijiet.2026.16.6.2625

important role, as positive attitudes toward technology-enhanced learning environments are associated with higher engagement and learning effectiveness [19, 20]. Thus, IC is closely related to DL and CT, which together form the foundation for effective pedagogical innovation.

From a theoretical perspective, the integration of DT in teacher education is grounded in contemporary pedagogical frameworks that emphasize the interconnection between technology, pedagogy, and content knowledge. In this study, the integration of digital tools and ITM is conceptually informed by the Technological Pedagogical Content Knowledge (TPACK) framework, which integrates Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK) [21]. Based on these frameworks, the present study examines how systematically integrating DT and ITM can develop IC, DL, and CT in PPT.

According to this framework, effective teacher preparation requires the balanced development of technological, pedagogical, and content-related competencies, enabling future teachers to meaningfully and contextually integrate DT into the educational process [22]. In addition, the study draws on constructivist learning theory [23], which conceptualizes learning as an active, student-centered process supported by collaboration, reflection, and problem-based activities. Within this theoretical perspective, digital tools function not merely as instructional aids, but as mediators of active learning that foster critical thinking, creativity, and innovative competence.

This theoretical grounding also informs practical strategies for integrating DT and ITM into teacher education programs. Specifically, TK enables teachers to use digital tools effectively; PK supports the design of student-centered, problem-based learning activities; and CK ensures meaningful integration of subject matter. Constructivist learning theory further informs this study by emphasizing active, collaborative, and problem-based learning processes, in which students construct knowledge through engagement, reflection, and application. Within this framework, DT and ITM are not merely instructional aids, but mediators of learning that foster IC, DL, and CT. Based on this theoretical framework, it is hypothesized that the integration of DT and ITM will significantly enhance IC, DL, and CT among PPT.

Kazakhstan's education system is currently undergoing an active process of digital transformation, reflected in national strategies such as "Digital Kazakhstan" and the "Education Development Concept to 2030" [24]. These initiatives impose new professional and methodological requirements on teachers, including the ability to effectively use DT and implement innovative teaching methods [25]. As a result, PPT in Kazakhstan are expected to possess not only foundational pedagogical knowledge but also IC, including creativity, initiative, and digital proficiency. However, traditional teacher education programs in Kazakhstan often emphasize theoretical instruction and provide limited opportunities for the systematic use of DT, which reduces students' readiness to apply innovative approaches in real teaching contexts [26–28]. This gap between the demands of a digitally transforming education system and existing teacher preparation practices negatively affects the quality of the educational process and the implementation of educational innovations [29]. This gap highlights the need for empirical research to assess the effectiveness of DT and ITM integration in teacher education programs in Kazakhstan.

Although existing studies in Kazakhstan confirm the potential of individual digital tools and innovative methods, most are limited to local initiatives or short-term experiments [30–32]. There remains a lack of systematic experimental research examining the comprehensive impact of integrating digital tools and ITM on the development of innovative competence among PPT, taking into account the national educational context [33]. Addressing this gap is essential for improving teacher education curricula and supporting the digital transformation of pedagogical universities.

Therefore, a pressing issue is to determine how the integration of digital tools and ITM contributes to the development of IC among PPT in Kazakhstan, as well as to identify effective approaches for embedding these methods into teacher education curricula. Addressing this issue will contribute to improving the quality of teacher training in the country, enhancing prospective teachers' readiness for innovation, and increasing the overall level of DL within Kazakhstan's educational system. Accordingly, the purpose of this study was to investigate the effect of digital tools and ITM on the development of IC, DL, and CT among PPT. The key research question guiding this study is: How does the implementation of digital tools and ITM in teacher education influence the development of IC, DL, and CT among PPT?

II. Literature Review

Contemporary research in pedagogy emphasizes the importance of developing IC in PPT as a key component of their professional competence [34]. IC is defined as the ability to generate new ideas, apply modern teaching methods, and integrate DT into the EP [35]. Several studies analyzing the integration of digital technologies in teacher education are grounded in the TPACK framework and constructivist learning theory, highlighting the importance of aligning technological tools with pedagogical goals and content knowledge [36]. Research demonstrates that when digital tools are integrated within project-based and collaborative learning environments, they contribute to the development of innovative competence, critical thinking, and professional autonomy [37]. The digital transformation of educational systems is being actively implemented in many countries, including Kazakhstan, where the national programs "Digital Kazakhstan" and "Education Development Concept until 2030" emphasizes the need to develop teachers' innovative skills and DL. These initiatives are aimed at improving the quality of teaching and integrating modern technologies into the EP. Research shows that the use of digital tools such as online platforms, interactive applications, virtual laboratories, and collaborative design tools helps increase student engagement and develop their creativity [38–40]. DT enable the creation of conditions for Project-Based Learning (PBL), where students independently develop and implement educational projects, thereby developing IC. One is the integration of DT with PBL, which fosters CT, initiative, and independent decision-making [41]. Another approach emphasizes gamification of the EP and the use of interactive applications to enhance student motivation [42].

In Kazakhstan, some studies have focused on the integration of digital platforms into teacher training [43]. For

example, studies show that the use of Moodle, Google Classroom, and other platforms contributes to students' DL and improves their project-based skills [44]. However, most of these studies are limited to observing individual tools and short-term experiments, without a systematic approach to assessing the impact of the comprehensive implementation of ITM [45, 46]. There is evidence of the importance of students' perceptions of ITM. A positive attitude toward digital tools directly impacts their motivation and success in mastering educational programs [47, 48]. At the same time, inadequate teacher training in the use of DT reduces the effectiveness of implementing innovative methods [45]. International experience shows that the comprehensive implementation of digital tools and ITM promotes the development of IC, improves CT, and enhances collaboration in students [49]. However, in Kazakhstan, there are no systematic studies that would comprehensively assess the impact of such interventions on the development of innovative activity among PPT, taking into account the specifics of the national education system. Therefore, the literature review [50, 51] confirms the relevance of the study: a systematic experimental study is needed to assess the impact of the implementation of digital tools and ITM on the development of IC among students in pedagogical faculties in Kazakhstan. The results of such a study can serve as a basis for modernizing curricula and improving the effectiveness of teacher training in the context of digital transformation.

Despite the theoretical relevance of these models, existing studies in Kazakhstan rarely apply the TPACK framework and constructivist learning theory as an integrated conceptual framework within experimental research, which limits systematic understanding and the generalizability of their impact on the development of IC among PPT. To address this gap, Fig. 1 presents the theoretical framework of the study, illustrating how the TPACK framework and constructivist learning theory guide the integration of digital tools and innovative teaching methods aimed at fostering the development of IC among PPT.

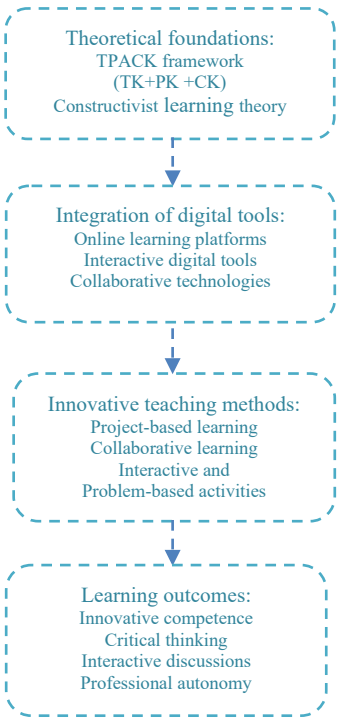

Fig. 1. Theoretical framework of the study.

III. Materials and Methods

This study utilized a quasi-experimental mixed-methods approach [52]. The blended approach allows for a comprehensive understanding of the impact of digital tools and ITM on the development of IC in PPT. Quantitative data provides a measurable assessment of changes in competencies, while qualitative data allows for the consideration of student perceptions and the identification of factors that contribute to the successful implementation of innovative practices.

A. Collection of Research Samples

Students enrolled in the primary education program at Abai Kazakh National Pedagogical University were selected for the study, ensuring a representative sample for the context of teacher training in Kazakhstan. A total of 60 second- and third-year students participated in the study, including 30 in the Experimental Group (EG) and 30 in the Control Group (CG). Participants were randomly assigned to groups based on their basic level of DL and academic performance to ensure comparability between the groups. All participants provided informed consent to participate in the study and to use the data obtained for scientific purposes (see Table 1).

Table 1. Participant characteristics

Characteristic	EG (n = 30)	CG (n = 30)	p-value
Age (years, Mean ± SD)	20.8 ± 1.1	21.0 ± 1.2	0.42
Gender (Male / Female)	12 / 18	11 / 19	0.79
Academic Year	2nd year: 16 (53%) 3rd year: 14 (47%)	2nd year: 15 (50%) 3rd year: 15 (50%)	0.83
Average Academic Grade	3.8 ± 0.4	3.7 ± 0.5	0.47
Previous Digital Training (%)	40%	37%	0.68
Level of DL (%):	Medium: 70 High: 30	Medium: 73 High: 27	0.75

B. Sample Selection for Qualitative Data

For the qualitative component of the study, purposive sampling was employed to select participants from the experimental EG learning intervention. A total of 12 students were selected for semi-structured interviews, and 18 students participated in focus group discussions, which were organized into three groups of six participants each.

The selection criteria included regular attendance, active engagement in project-based learning activities, consistent use of digital tools, and willingness to reflect on learning experiences. This criterion-based approach ensured the collection of rich and relevant qualitative data aligned with the objectives of the study (see Table 2).

Table 2. Qualitative sample characteristics

Data source	Number of participants	Selection method
Semi-structured interviews	12	Purposive sampling
Focus group discussions	3 groups (6 participants each)	Criterion-based sampling

C. Procedure

The study was conducted at Abai University during the 2024–2025 academic years (September 2024–January 2025). The intervention lasted one academic semester (16 weeks). Both the EG and CG completed pre-tests and post-tests,

while the EG participated in a structured digital learning program consisting of four modules integrating innovative pedagogical methods. The overall design and sequence of the study are presented in Fig. 2.

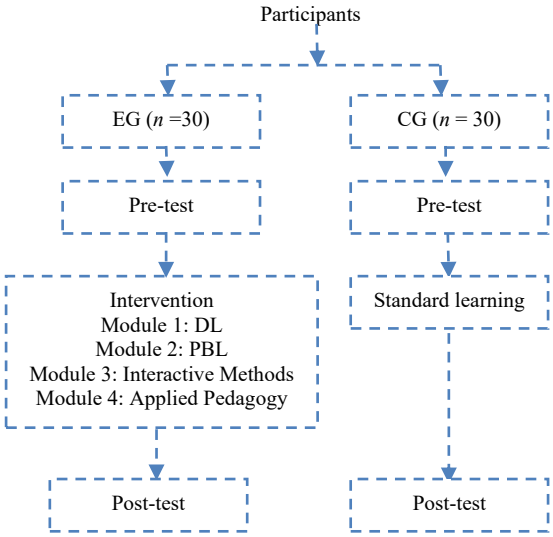

Fig. 2. Experimental design and procedure of the study.

D. Teacher Training Program

As part of an experiment implementing digital tools and ITM, a special training course was organized for teachers to work with an EG of students. The primary goal of the training was to ensure the consistent and methodologically sound implementation of the digital and ITM in the EG. The program was developed taking into account modern approaches to the pedagogical implementation of innovations and included three key components: digital teacher literacy, PBL methods, and the integration of interactive tools into the EP. Teachers completed training modules that provided gradual mastery of digital platforms, project planning skills, and technology-enabled feedback methods. This approach not only improved the teachers' skills but also ensured uniform implementation of the intervention across the EG (see Table 3).

Table 3. Teacher training program

Module	Topics	Format of sessions	Duration
1. Teacher DL	Basics of Moodle and Google Classroom, use of interactive applications, virtual labs	Practical sessions + seminar	4 weeks, 2 hours/week
2. PBL	Planning and implementing project assignments, assessing student projects, group work	Seminar + workshop	3 weeks, 2 hours/week
3. Integration of innovative methods	Using digital tools for feedback, interactive lectures and discussions, gamification	Practicum + training	3 weeks, 2 hours/week
4. Preparation and testing of learning materials	Creating electronic assignments, developing project cases, testing interactive elements	Practicum + consultation	2 weeks, 2 hours/week

E. Intervention

The intervention was designed as a structured, multi-phase digital learning program based on project-based and interactive teaching approaches. All activities were supervised by trained instructors to ensure consistency and fidelity of implementation. The main components of the intervention are presented in Fig. 3.

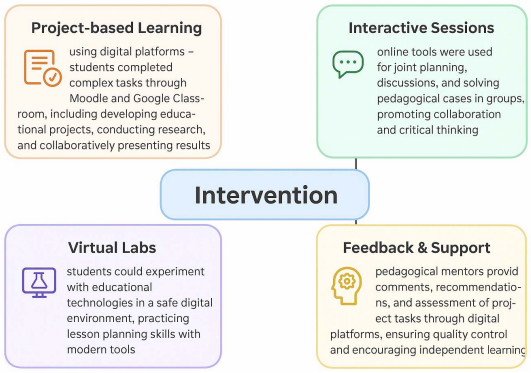

Fig. 3. Main components of the intervention.

The intervention was implemented in stages: first, students mastered digital tools and platforms, then completed individual and group projects, and then participated in interactive discussions and workshops. This phased approach ensured the gradual development of IC skills, minimized stress, and increased student engagement (see Table 4).

Table 4. Structure of the intervention program

Phase	Student Activities	Digital Tools
1. Orientation	Introduction to Moodle and Google Classroom; initial training	Moodle, Google Classroom
2. Individual work	Completing digital projects and self-directed learning tasks	Virtual labs, e-resources
3. Group projects	Designing collaborative projects and case discussions	Google Docs, Zoom, whiteboards
4. Interactive practicums	Participation in simulation-based sessions	Virtual simulators, apps
5. Feedback and Revision	Receiving instructor feedback and revising projects	Moodle, Google Classroom
6. Final presentation	Project defense and peer/self-assessment	Zoom, e-portfolios

F. Instruments, Reliability, and Validity

The study employed both quantitative and qualitative instruments to assess the impact of the intervention on students' IC, DL, and CT. All instruments were adapted to the context of Kazakhstan. Participation was voluntary, with informed consent obtained from all participants and full data anonymization ensured. Reliability and validity were established through pilot testing, standardized administration procedures, double coding of qualitative data, and triangulation across instruments (see Table 5).

Table 5. Summary of research instruments

Instrument	Type	Reliability and Validity
Student IC Questionnaire (Table A1).	Quantitative	Cronbach's $\alpha = 0.87$; based on international and national pedagogical standards
DL Test (Table A2).	Quantitative	Test–retest $r = 0.82$; standardized tasks reflecting key digital competencies
CT and Problem-Solving Test (Table A3).	Quantitative	Test–retest $r = 0.82$; standardized case-based tasks
Focus Groups (Table A4).	Qualitative	Double coding (Cohen's Kappa = 0.81); member checking
Semi-Structured Interviews (Table A5).	Qualitative	Standardized questions; expert evaluation; triangulation with other data

For the qualitative component, purposive sampling was used to select participants from the EG. A total of 12 students participated in semi-structured interviews, and 18 students took part in focus group discussions, organized into three groups of six participants each. Selection criteria included regular attendance, active engagement in project-based learning activities, consistent use of digital tools, and willingness to reflect on learning experiences.

All questionnaire-based instruments employed a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Composite scores for IC, DL, and CT were calculated by averaging item responses within each scale. Higher scores indicated higher levels of the measured constructs.

G. Data Analysis

Table 6 summarizes the data analysis methods. Quantitative data were analyzed using descriptive statistics (mean ± SD) and inferential tests. Within-group pre–post differences were assessed with paired-sample t-tests, and post-test scores between the EG and CG were compared using independent-sample t-tests. Pearson correlation analysis examined relationships among IC, DL, and CT in line with the study's aim of assessing how DT and ITM influence these competencies. Assumptions of normality (Shapiro–Wilk) and homogeneity of variance (Levene's test) were satisfied ($p > 0.05$). Qualitative data from focus groups and semi-structured interviews were analyzed using content and thematic analysis in NVivo. Reliability was ensured through double coding (Cohen's Kappa = 0.81), triangulation, and expert review. All quantitative instruments demonstrated acceptable internal consistency (Cronbach's $\alpha \geq 0.80$) and stability (test–retest $r = 0.82$).

Table 6. Data analysis methods

Data Type	Analysis Method
Quantitative	Descriptive statistics (mean, SD)
Quantitative	Paired-sample t-test (within-group pre–post comparison)
Quantitative	Independent-sample t-test (between-group post-test comparison)
Quantitative	Pearson correlation analysis
Qualitative	Content analysis (focus groups)
Qualitative	Thematic analysis (semi-structured interviews)
Mixed	Data triangulation

IV. Result

Table 7 presents within-group differences in IC between pre- and post-test measurements for the EG and the CG.

Table 7. Within-group comparison of pre- and post-test IC scores (paired-sample t-test)

Group	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Difference	*t*	*p*
EG	3.21 ± 0.42	4.05 ± 0.35	0.84	9.12	<0.001
CG	3.19 ± 0.41	3.28 ± 0.39	0.09	1.02	0.314

The results indicate that the implementation of digital tools and project-based learning methods was associated with a significant increase in IC among students in the EG (mean increase, $\Delta = 0.84$, $p < 0.001$). In contrast, the CG, which did not receive the intervention, showed no statistically significant change ($\Delta = 0.09$, $p = 0.314$), suggesting that the intervention contributed to the improvement in IC.

Table 8 presents within-group changes in DL between pre- and post-test measurements for the EG and the CG.

Students in the EG demonstrated a statistically significant improvement in their ability to use educational platforms, interactive applications, and virtual laboratories ($\Delta = 0.67$, $p < 0.001$), whereas the CG showed only minor, non-significant changes ($\Delta = 0.09$, $p = 0.281$). These findings provide further evidence of the effectiveness of integrating digital technologies within a project-based instructional framework.

Table 8. Within-group comparison of pre- and post-test DL scores (paired-sample t-test)

Group	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Difference	*t*	*p*
EG	3.45 ± 0.38	4.12 ± 0.30	0.67	7.85	<0.001
CG	3.42 ± 0.36	3.51 ± 0.34	0.09	1.10	0.281

Table 9 presents within-group changes in CT between pre- and post-test measurements for the EG and the CG.

Table 9. Within-group comparison of pre- and post-test CT scores (paired-sample t-test)

Group	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Difference	*t*	*p*
EG	3.12 ± 0.40	3.88 ± 0.37	0.76	8.34	<0.001
CG	3.10 ± 0.39	3.17 ± 0.38	0.07	0.92	0.364

The EG demonstrated significant growth in their ability to analyze pedagogical cases, formulate solutions, and justify decisions ($\Delta = 0.76$, $p < 0.001$), while the CG remained at approximately the baseline level ($\Delta = 0.07$, $p = 0.364$). These results indicate that the applied digital and project-based instructional approach contributed to the development of students' CT skills. To further examine the relationships among IC, DL, and CT, a Pearson correlation analysis was conducted using post-test scores.

Table 10 presents the Pearson correlation matrix.

Table 10. Pearson correlation matrix for IC, DL, and CT (post-test scores)

Variables	1	2	3
1. IC	1.00		
2. DL	0.62**	1.00	
3. CT	0.58**	0.55**	1.00

Note: ** Correlation is significant at the 0.01 level (two-tailed); Pearson's *r*, $n = 60$. Squared correlation coefficients (r^2) indicate that the proportion of shared variance among the variables ranges from approximately 30% to 38%.

As shown in Table 10, DL was significantly and positively correlated with IC ($r = 0.62$, $p < 0.01$) and CT ($r = 0.55$, $p < 0.01$). In addition, IC showed a moderate positive association with CT ($r = 0.58$, $p < 0.01$). These results indicate that higher levels of DL are associated with stronger IC and more advanced CT skills; however, these relationships reflect associations rather than causal effects.

Table 11 presents post-test comparisons between the EG and the CG based on independent-sample t-tests.

Table 11. Post-test comparison between the EG and the CG (independent-sample t-test)

Competence	EG (Post-test) Mean ± SD	CG (Post-test) Mean ± SD	*t*	*p*
IC	4.05 ± 0.35	3.28 ± 0.39	7.48	< 0.001
DL	4.12 ± 0.30	3.51 ± 0.34	7.12	< 0.001
CT	3.88 ± 0.37	3.17 ± 0.38	6.95	< 0.001

The post-test results show that students in the EG achieved significantly higher levels of IC, DL, and CT than those in the CG ($p < 0.001$). Taken together with the within-group analyses, these findings confirm the effectiveness of the intervention in enhancing students' IC, DL, and CT.

Fig. 4 illustrates the pre- and post-test scores for IC, DL, and CT in both groups.

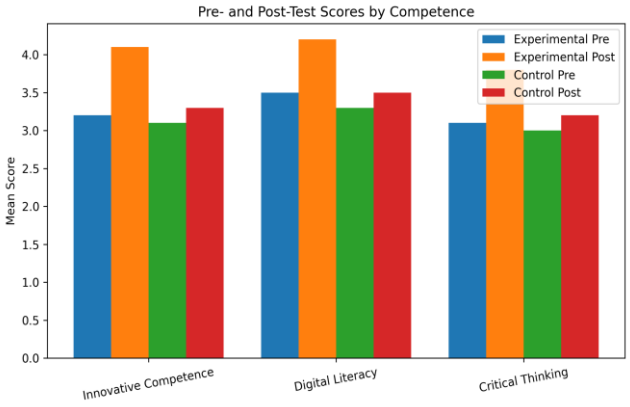

Fig. 4. Pre- and post-test scores for IC, DL, and CT in the EG and the CG.

As shown in Fig. 4, students in the EG demonstrated substantial improvements across all three competencies following the intervention, whereas the CG exhibited only minimal changes. To further explain the quantitative results, qualitative data from focus group discussions and semi-structured interviews conducted with EG participants were analyzed. Table 12 summarizes the key qualitative findings.

Table 12. Summary of qualitative findings from focus groups and interviews (EG)

Theme	EG Feedback
Use of digital tools	Students found Moodle, Google Classroom, and virtual labs highly useful; increased engagement and ease of project management
PBL	Encouraged creativity, collaboration, and problem-solving; students reported higher motivation
Creativity and initiative	Students reported increased confidence in generating ideas and proposing solutions
Perception of intervention	Positive overall; students suggested more collaborative tools and gamification

Qualitative findings indicate that students in the EG actively used digital platforms, demonstrated greater initiative, and enhanced creativity while completing project-based tasks. The integration of quantitative and qualitative results suggests that the implementation of digital tools and innovative teaching methods is associated with improvements in IC, DL, and CT.

To triangulate the findings, selected excerpts from student interviews and focus group discussions are presented below. These quotes illustrate participants' perceptions of the intervention and support the identified themes. One participant noted:

"I became more confident using digital platforms, especially Moodle and Google Classroom. Working on projects helped me generate new ideas and collaborate more effectively with my peers".

Another student emphasized the role of project-based learning:

"Project tasks motivated me to think creatively and take initiative. We were not just completing assignments, but solving real educational problems together".

V. Discussion

The findings of this study demonstrate that the integration of digital tools and innovative teaching methods has a significant impact on the development of IC among prospective primary teachers. The EG showed statistically significant improvements in IC, DL, and CT compared to the CG, which received traditional instruction. These findings confirm the effectiveness of the proposed intervention and are consistent with previous research emphasizing the role of digital transformation in enhancing teacher competencies [53–56]. For instance, Tang *et al.* [57] reported that the integration of digital tools into instruction promotes students' creativity and initiative, while Saad and Zainudin [58] demonstrated that project-based learning methods significantly enhance critical thinking and problem-solving skills.

The findings should be interpreted within the context of Kazakhstan, where the integration of digital platforms and innovative pedagogical approaches in teacher education is still at an early stage. Participants in the EG expressed positive attitudes toward the use of Moodle, Google Classroom, virtual laboratories, and interactive applications, which aligns with previous studies highlighting the need to strengthen digital competencies among prospective teachers [59].

The qualitative data obtained from focus groups and semi-structured interviews further support the quantitative results. Students reported that project-based assignments and interactive teaching methods fostered independence, initiative, and creativity. Similar outcomes have been reported in studies conducted in Malaysia and Singapore, where innovative teaching methods have shown a significant impact on student competencies [60, 61].

As shown in Table 10, the Pearson correlation analysis revealed a moderate and statistically significant positive relationship between DL and IC ($r = 0.62$, $p < 0.01$), supporting the hypothesis that proficiency in digital tools contributes to the development of innovation-related skills. This finding is consistent with previous research highlighting the interdependence of digital and innovative competencies in teacher education [62]. Moreover, qualitative analysis indicated that students in the EG positively evaluated not only the effectiveness of digital tools but also interactive learning formats, such as collaborative design and gamified assignments, which enhanced motivation and engagement. These observations are in line with research on active learning approaches [62].

Overall, the findings confirm that the integration of digital tools and innovative teaching methods represents an effective strategy for fostering IC among PPT by enhancing creativity, initiative, and problem-solving abilities. These results have important implications for the modernization of teacher education in Kazakhstan and for the development of teacher training programs in the context of the global digital transformation of education.

A. Limitations of the Study

This study has several limitations that should be considered. First, the sample was limited to 60 prospective primary teachers (30 per group), which may restrict the generalizability of the findings. Future research should involve larger and more diverse samples from multiple pedagogical universities in Kazakhstan. Second, the

intervention lasted a single semester (16 weeks), limiting the assessment of long-term effects; longitudinal studies are recommended to evaluate sustainability over time. Third, the controlled educational setting may not fully capture the complexity of authentic teaching practice. Further research could explore the effectiveness of these approaches during teaching internships or in real school environments. Fourth, although qualitative data from focus groups and interviews provided valuable insights, such data may reflect subjective perceptions. Incorporating classroom observations or independent evaluations could strengthen objectivity. Future research directions include expanding sample sizes, investigating innovative teaching methods in authentic teaching contexts, and developing adaptive programs tailored to students' initial digital literacy levels. Despite these limitations, the study offers valuable insights into the role of digital tools and innovative teaching methods in developing prospective teachers' competencies. The findings advance understanding of the relationship between DL and IC and provide a foundation for further research and practical implementation in pedagogical universities.

VI. Conclusion and Recommendations

This study confirms that the integration of digital tools and innovative teaching methods has a significant positive impact on the development of IC among prospective primary teachers. Students in the EG demonstrated substantial improvements in IC, DL, and CT compared to those in the CG, which followed traditional instructional approaches. The use of Moodle and Google Classroom platforms, virtual laboratories, and interactive applications contributed to the development of student independence, creativity, and initiative. The implementation of project-based learning and innovative teaching methods further enhanced student engagement, motivation, and the ability to collaboratively address pedagogical problems. Moreover, the identified positive correlation between DL and IC underscores the importance of systematic digitalization in teacher education programs. Qualitative findings provide additional support for these results, indicating positive student perceptions of innovative practices; however, their effective implementation requires adequate methodological support from instructors and targeted preparatory training. Based on the findings, several practical recommendations are proposed. These include integrating courses focused on DL and innovative teaching methods into the curricula of pedagogical universities; actively implementing project-based assignments, gamification elements, virtual laboratories, and collaborative instructional design; establishing mentoring and feedback systems to support students in mastering digital tools and applying innovative pedagogical approaches; organizing pilot programs and professional development training for instructors to enhance their readiness to implement innovative teaching practices; and developing adaptive learning modules that account for students' varying levels of digital proficiency to ensure equitable access to modern instructional methods.

In conclusion, the findings demonstrate that the systematic integration of digital tools and innovative teaching methods represents an effective mechanism for fostering IC among prospective primary teachers. This approach provides a solid foundation for the modernization of teacher education in Kazakhstan and in countries with similar educational development contexts.

Appendix

Table A1. Student IC questionnaire

Block	Sample Questions
Creativity	1. I am able to find unconventional solutions to pedagogical problems. 2. I easily generate new ideas for lessons.
Initiative	1. I actively propose my ideas in the study group. 2. I strive to independently improve the learning process.
Project-Based Skills	1. I can plan and implement a learning project from start to finish. 2. I can work in a group on a collaborative project.
Use of DT	1. I am confident in using educational platforms (Moodle, Google Classroom). 2. I can effectively apply interactive applications for teaching.

Note. All items were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Composite IC scores were calculated as the mean of responses across all items.

Table A2. DL test

Section	Sample Questions/Tasks
Platform usage	1. Create an assignment in Moodle and assign it to a student group. 2. Add a resource in Google Classroom and attach a document.
Use of interactive applications	1. Create a 5-question quiz in Kahoot. 2. Set up online voting in Mentimeter for class discussion.
Virtual labs	1. Conduct a lesson simulation using a virtual lab tool. 2. Document the results of the experiment.

Note. Each task was scored on a five-point scale (1 = not completed, 5 = fully and correctly completed). The overall digital literacy score was calculated as the mean score across all tasks.

Table A3. CT and problem-solving test

Section	Sample Questions/Tasks
Case analysis	1. Read a pedagogical case and identify the main problems. 2. Suggest three possible solutions.
Decision making	1. In a classroom conflict, choose the optimal course of action and justify your choice.
Argumentation	1. Explain why your chosen solution is the best.

Note. Responses were evaluated using a standardized rubric on a five-point scale (1 = low level of analysis, 5 = high level of critical reasoning). The total CT score represents the mean value across all assessed components.

Table A4. Focus group questions

Block	Sample Questions
Perception of digital tools	1. How do you evaluate the ease of use of Moodle/Google Classroom? 2. Which platform features were most useful for completing projects?
Perception of innovative methods	1. How do you assess the project-based assignments? 2. Which aspects of group work were most valuable for you?
Motivation and engagement	1. What motivated you to actively participate in project activities? 2. What difficulties did you encounter when using digital tools?
General feedback	1. Which skills do you consider most developed after the intervention? 2. What improvements would you suggest for the course?

Note. Focus group discussions were audio-recorded, transcribed verbatim, and analyzed using thematic analysis.

Table A5. Semi-structured interview questions

Block	Sample Questions
Experience using digital tools	1. Describe how you used the platforms to complete assignments. 2. Which features were the most difficult to

	master?
Impact of innovative methods on learning	1. How did project-based assignments affect your understanding of the material? 2. What skills did you develop through group work?
Personal development and creativity	1. Do you feel you have become more creative or proactive? 2. Give examples of when you applied new ideas in practice.
Recommendations	1. What changes would you suggest to improve the course? 2. What digital tools would you recommend adding?

Note. Semi-structured interviews were audio-recorded with participants' consent, transcribed verbatim, and analyzed using thematic analysis. Coding was conducted independently by two researchers, and inter-coder reliability was established using Cohen's Kappa coefficient.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, ZS and AZ; methodology, ZS; software, AZ; validation, ZS; formal analysis, AZ; investigation, ZS; resources, AZ; data curation, ZS; writing—original draft preparation, AZ; writing—review and editing, ZS; visualization, AZ; supervision, ZS; project administration, AZ; funding acquisition, ZS. All authors have read and agreed to the published version of the manuscript.

FUNDING

This research has been/was/is funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AP22685979).

REFERENCES

[1] M. Belousova, V. Belousov, and L. Narkevich, "Digital transformation of the educational process in university in the context of globalization," *Socio-Economic Systems: Paradigms for the Future,* Cham: Springer International Publishing, pp. 1267–1277, 2021. doi: 10.1007/978-3-030-56433-9_133

[2] Z. Zhumabayeva *et al.,* "Enhancing teaching skills through digital feedback in microteaching: A study with prospective primary teachers," *International Journal of Information and Education Technology,* vol. 15, no. 9, pp. 1820–1828, 2025. doi: 10.18178/ijiet.2025.15.9.2383

[3] S. Nurgaliyeva *et al.,* "Evaluating student satisfaction of terminological apparatus with natural and mathematical textbooks in Kazakhstani schools," *Cogent Education*, vol. 12, no. 1, 2468563, 2025. doi: 10.1080/2331186X

[4] G. Kurebayeva *et al.,* "From tradition to innovation: Pre-service teachers' perceptions of digital transformation in language learning," *Forum for Linguistic Studies*, vol. 7, no. 3, pp. 351–361, 2025. doi: 10.30564/fls.v7i3.8768

[5] T. Yerezhepov *et al.,* "Exploring burnout and resilience in physical education teachers: A case study from Kazakhstan," *Retos*, vol. 68, p. 66, 2025. doi: 10.47197/retos.v68.113620 (in Spanish)

[6] T. Kulgildinova *et al.,* "The influence of an adaptive non-formal education model on student learning activity and engagement," *International Journal of Modern Education and Computer Science*, vol. 17, no. 5, 2025. doi: 10.5815/ijmecs.2025.05.06

[7] T. S. Chang *et al.,* "Enhancing student creativity through an interdisciplinary, project-oriented problem-based learning undergraduate curriculum," *Thinking Skills and Creativity*, vol. 46, 101173, 2022. doi: 10.1016/j.tsc.2022.101173

[8] B. Wang and P. P. Li, "Digital creativity in STEM education: the impact of digital tools and pedagogical learning models on the students' creative thinking skills development," *Interactive Learning Environments*, vol. 32, no. 6 pp. 2633–2646, 2024. doi: 10.1080/10494820.2022.2155839

[9] Z. Karibaev *et al.,* "Subjective well-being of students with disabilities in Kazakhstan: An exploration of practice," *Journal of Curriculum Studies Research*, vol. 6, no. 2, pp. 88–103, 2024. doi: 10.46303/jcsr.2024.12

[10] A. Clark-Wilson, O. Robutti, and M. Thomas, "Teaching with digital technology," *ZDM—Mathematics Education,* pp. 1–20, 2020. doi: 10.1007/s11858-020-01196-0

[11] Z. Koukopoulos, and D. Koukopoulos, "Integrating educational theories into a feasible digital environment," *Applied Computing and Informatics,* vol. 15, no. 1, pp. 19–26, 2019. doi: 10.1016/j.aci.2017.09.004

[12] M. Beardsley *et al.,* "Emergency education effects on teacher abilities and motivation to use digital technologies," *British Journal of Educational Technology,* vol. 52, no. 4, pp. 1455–1477, 2021. doi: 10.1111/bjet.13101

[13] S. Timotheou *et al.,* "Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review," *Education and Information Technologies,* vol. 28, no.6, pp. 6695–6726, 2023. doi: 10.1007/s10639-022-11431-8

[14] D. Hamilton *et al.,* "Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design," *Journal of Computers in Education,* vol. 8, no. 1, pp. 1–32, 2021. doi: 10.1007/s40692-020-00169-2

[15] D. Baser, M. Y. Ozden, and H. Karaarslan, "Collaborative project-based learning: An integrative science and technological education project," *Research in Science & Technological Education,* vol. 35, no. 2, pp. 131–148, 2017. doi: 10.1080/02635143.2016.1274723

[16] M. Fitrah *et al.,* "The impact of integrated project-based learning and flipped classroom on students' computational thinking skills: Embedded mixed methods," *Education Sciences,* vol. 15, no. 4, p. 448, 2025. doi: 10.3390/educsci15040448

[17] E. Xu, W. Wang, and Q. Wang, "The effectiveness of collaborative problem solving in promoting students' critical thinking: A meta-analysis based on empirical literature," *Humanities and Social Sciences Communications,* vol. 10, no. 1, pp. 1–11, 2023. doi: 10.1057/s41599-023-01508-1

[18] K. V. Reddy and G. S. Lakshmi, "ICT and critical thinking," *Critical Thinking for Professional and Language Education: A Machine-Generated Literature Overview,* Cham: Springer Nature Switzerland, pp. 141–168*,* 2024. doi: 10.1007/978-3-031-37951-2_6

[19] R. Panigrahi, P. R. Srivastava, and P. K. Panigrahi, "Effectiveness of e-learning: the mediating role of student engagement on perceived learning effectiveness," *Information Technology & People*, vol. 34, no. 7, pp. 1840–1862, 2021. doi: 10.1108/ITP-07-2019-0380

[20] S. Getenet *et al.,* "Students' digital technology attitude, literacy and self-efficacy and their effect on online learning engagement," *International Journal of Educational Technology in Higher Education*, vol. 21, no.1, p. 3, 2024. doi: 10.1186/s41239-023-00437-y

[21] P. Shao *et al.,* "Revealing pre-service teachers' reflections regarding online practicum through the lens of TPACK," *Education and Information Technologies*, vol. 30, no.6, pp. 7009–7043, 2025. doi: 10.1007/s10639-024-13053-8

[22] H. Wen and V. H. Shinas, "Using a multidimensional approach to examine TPACK among teacher candidates," *Journal of Digital Learning in Teacher Education*, vol. 37, no.1, pp. 30–47, 2020. doi: 10.1080/21532974.2020.1804493

[23] S. Chuang, "The applications of constructivist learning theory and social learning theory on adult continuous development," *Performance Improvement,* vol. 60, no.3, pp. 6–14, 2021. doi: 10.1002/pfi.21963

[24] S. Issabayeva and A. Katyetova, "Deep learning of AI: Kazakhstan's case," in *Proc. Future of Information and Communication Conference,* Cham: Springer Nature Switzerland, 2025. doi: 10.1007/978-3-031-84460-7

[25] H. D. Osorio Vanegas *et al.,* "Educational technology in teacher training: A systematic review of competencies, skills, models, and methods," *Education Sciences,* vol. 15, no. 8, 1036, 2025. doi: 10.3390/educsci15081036

[26] S. Abildina *et al.,* "Enhancing reading literacy among elementary school learners in Kazakhstan: The application and effectiveness of modern teaching techniques," *Journal of Infrastructure Policy and Development,* vol. 8, no. 8, 5905, 2024. doi: 10.24294/jipd.v8i8.590

[27] S. Nurgaliyeva *et al.,* "Kazakhstan's universities: Global challenges and local duties improving education quality," *International Journal of Evaluation and Research in Education,* vol. 14, no. 1, pp. 768–776, 2025. doi: 10.11591/ijere.v14i1.31852

[28] Y. Ospankulov *et al.,* "Using physical education lessons to develop the autonomy of primary school children," *Cypriot Journal of Educational Sciences,* vol. 17, no. 2, pp. 601–614, 2022. doi: 10.35940/ijitee.A9152.119119

[29] K. Shalgimbekova *et al.,* "Innovative teaching technologies in higher

education: efficiency and student motivation," *Cogent Education*, vol. 11, no.1, 2425205, 2024. doi: 10.1080/2331186X.2024.2425205
[30] Z. Jumakulov *et al.,* "Internationalizing research in Kazakhstan higher education: A case study of Kazakhstan's state program of industrial innovative development 2015 to 2019," *Journal of Studies in International Education,* vol. 23, no. 2, pp. 234–247, 2019. doi: 10.1080/2331186X.2019.1611052
[31] L. Zheng, *et al.,* "The effectiveness of technology-facilitated personalized learning on learning achievements and learning perceptions: A meta-analysis," *Education and Information Technologies*, vol. 27, no. 8, pp. 11807–11830, 2022. doi: 10.1007/s10639-022-11092-7
[32] N. Durrani *et al.,* "Achieving SDG 4, equitable quality education after COVID-19: Global evidence and a case study of Kazakhstan," *Sustainability*, vol. 15, no. 20, 14725, 2023. doi: 10.3390/su152014725
[33] G. S. Ayapbergenova *et al.,* "Developing project skills in future prımary school teachers within the university-based initial teacher education," *Science for Education Today,* vol. 10, no.6, pp. 7–26, 2018. doi: 10.1007/s10758-018-9382-z
[34] S. V. Kraineva and O. R. Shefer, "On the formation of very high competencies in bachelor's degree students using information and communication technologies," *Scientific and Technical Information Processing*, vol. 44, no. 2, pp. 94–98, 2017. doi: 10.3103/S0147688217020046
[35] V. A. Belevitin *et al.,* "Integrated approach to modeling ic competence in students," *International Journal of Engineering & Technology*, vol. 7, no. 4, 38, pp. 60–62, 2018. doi: /10.14419/ijet.v7i4.38.24321
[36] P. Redmond and J. Lock, "Secondary pre-service teachers' perceptions of Technological Pedagogical Content Knowledge (TPACK): What do they really think?" *Australasian Journal of Educational Technology,* vol. 35, no. 3, 2019. doi: 10.14742/ajet.4214
[37] M. L. Niess, and H. Gillow-Wiles, "Online instructional strategies for enhancing teachers' TPACK: Experiences, discourse, and critical reflection," in *Handbook of Research on TPACK in the Digital Age*, IGI Global Scientific Publishing, pp. 257–278, 2019. doi: 10.4018/978-1-5225-7001-1.ch012
[38] H. Ateş and M. Köroğlu, "Online collaborative tools for science education: Boosting learning outcomes, motivation, and engagement," *Journal of Computer Assisted Learning,* vol. 40, no. 3, pp. 1052–1067, 2024. doi: 10.1111/jcal.12931
[39] M. Selfa-Sastre *et al.,* "The role of digital technologies to promote collaborative creativity in language education," *Frontiers in psychology*, vol. 13, 828981, 2022. doi: 10.3389/fpsyg.2022.828981
[40] I. Nazlidou *et al.,* "Innovative and interactive technologies in creative product design education: A review," *Multimodal Technologies and Interaction*, vol. 8, no. 12, 107, 2024. doi: 10.3390/mti8120107
[41] M. Bisogno *et al.,* "Identifying future directions for IC research in education: A literature review," *Journal of Intellectual Capital*, vol. 19, no. 1, pp. 10–33, 2018. doi: 10.1108/JIC-10-2017-0133
[42] A. N. Saleem, N. M. Noori, and F. Ozdamli, "Gamification applications in E-learning: A literature review," *Technology, Knowledge and Learning*, vol. 27, no. 1, pp. 139–159, 2022. doi: 10.1007/s10758-020-09487-x
[43] Y. Ospankulov *et al.,* "Examining the relationships between primary school students' participation in sports and technology addictions," *International Journal of Education in Mathematics, Science and Technology,* vol. 11, no. 3, pp. 804–819, 2023. doi: 10.46328/ijemst.3177
[44] A. Syaikhu, "Enhancing education through online Project-Based Learning (PBL): Strategies, challenges, and outcomes in the digital era," *EDUCATIO: Journal of Education*, vol. 9, no. 2, pp. 265–277, 2024. doi: 10.29138/educatio.v9i4.1671
[45] L. A. Outhwaite, A. Gulliford, and N. J. Pitchford, "A new methodological approach for evaluating the impact of educational intervention implementation on learning outcomes," *International Journal of Research & Method in Education*, vol. 43, no. 3, pp. 225–242, 2020. doi: 10.1080/1743727X.2019.1657081
[46] D. Hamilton *et al.,* "Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design," *Journal of Computers in Education*, vol. 8, no. 1, pp. 1–32, 2021. doi: 10.1007/s40692-020-00
[47] J. Bi *et al.,* "Investigating the impact of technology-based education on academic motivation, academic perseverance, and academic self-efficacy in English language learning skills," *Education and Information Technologies,* vol. 29, no.15, pp. 20523–20545, 2024. doi: 10.1007/s10639-024-12712-0
[48] M. Shonfeld and N. Magen-Nagar, "The impact of an online collaborative program on intrinsic motivation, satisfaction and attitudes towards technology," *Technology, Knowledge and Learning*, vol. 25, no. 2, pp. 297–313, 2020. doi: 10.1007/s10758-017-9347-7
[49] A. L. Rodrigues, "Digital technologies integration in teacher education: the active teacher training model," *Journal of E-learning and Knowledge Society,* vol. 16, no.3, pp. 24–33, 2020. doi: 10.20368/1971-8829/1135273
[50] C. Fernández-Morante *et al.,* "Teachers' digital competence. The case of the university system of Galicia," *Journal of New Approaches in Educational Research*, vol. 12, no. 1, pp. 62–76, 2023. doi: 10.7821/naer.2023.1.1139
[51] V. Gabarda Méndez *et al.,* "Digital competence of training teachers: Results of a teaching innovation project," *Education Sciences,* vol. 13, no. 2, 162, 2023. doi: 10.3390/educsci13020162
[52] L. P. Carvalho *et al.,* "Predictors of digital competence of public university employees and the impact on innovative work behavior," *Administrative Sciences,* vol. 13, no. 5, 131, 2023. doi: 10.3390/admsci13050131
[53] L. Zhu, Z. Lian, and M. Engström, "Use of a flipped classroom in ophthalmology courses for nursing, dental and medical students: A quasi-experimental study using a mixed-methods approach," *Nurse Education today,* vol. 85, 104262, 2020. doi: 10.1016/j.nedt.2019.104262
[54] S. Stenbom and L. Geijer, "Primary school teachers' perception of digital transformation and their teaching role," *Scandinavian Journal of Educational Research,* vol. 69, no. 5, pp. 1131–1144, 2025. doi: 10.1080/00313831.2024.2394395
[55] L. Aleksieva, "Preparing pre-service teachers for the digital transformation of education: Exploring university teacher educators' views and practical strategies," *Education Sciences*, vol. 15, no. 4, 404, 2025. doi: 10.3390/educsci15040404
[56] M. Alférez-Pastor *et al.,* "Training digital competencies in future primary school teachers: A systematic review," *Education Sciences,* vol. 13, no.5, 461, 2023. doi: 10.3390/educsci13050461
[57] C. Tang *et al.,* "Improving student creativity through digital technology products: A literature review," *Thinking Skills and Creativity,* vol. 44, 101032, 2022. doi: 10.1016/j.tsc.2022.101032
[58] A. Saad and S. Zainudin, "A review of Project-Based Learning (PBL) and Computational Thinking (CT) in teaching and learning," *Learning and Motivation*, vol. 78, 101802, 2022. doi: 10.1016/j.lmot.2022.101802
[59] J. P. L. Tan *et al.,* "Educating for twenty-first century competencies and future-ready learners: Research perspectives from Singapore," *Asia Pacific Journal of Education*, vol. 37, no. 4, pp. 425–436, 2017. doi: 10.1080/02188791.2017.1405475
[60] A. Royani *et al.,* "A comparative analysis of learning outcomes in the faculty of education in Indonesia, Malaysia, and Singapore," *Jurnal Basicedu,* vol. 6, no. 2, pp. 3138–3146, 2022. doi: 10.31004/basicedu.v6i2.2479
[61] M. Rubio-Gragera, J. Cabero-Almenara, and A. Palacios-Rodríguez, "Digital innovation in language teaching—Analysis of the digital competence of teachers according to the DigCompEdu framework," *Education Sciences,* vol. 13, no. 4, 336, 2023. doi: 10.3390/educsci13040336
[62] G. M. Chans and M. Portuguez Castro, "Gamification as a strategy to increase motivation and engagement in higher education chemistry students," *Computers*, vol. 10, no. 10, 132, 2021. doi: 10.3390/computers10100132