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Enhancing professional competencies of pre-service computer science teachers through blended learning: a quantitative study

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This study investigated the effectiveness of a blended learning model for developing pre-service computer science teachers' professional competencies, focusing on three components: subject competence, methodological competence, and ICT competence. A quasi-experimental pre-test/post-test design with a controlled condition was implemented using whole classes. The sample included 192 pre-service computer science teachers from two higher education institutions in Shymkent (U. Zhanibekov South Kazakhstan Pedagogical University, n = 146; M. Auezov South Kazakhstan University, n = 46). Participation was voluntary and informed consent was obtained before data collection. The experimental group (n = 97) completed a 30-week blended course delivered through the Blended Edu platform, which combined online learning activities with face-to-face learning, while the control group (n = 95) followed a standard face-to-face curriculum. Competencies were measured using standardized tests administered before and after the intervention. Post-test group differences were examined using independent sample t-tests and effect sizes (Cohen's d), accounting for baseline differences in ICT competence when interpreting. At post-test, the experimental group outperformed the control group on subjective competence (M = 70.0 vs. 65.0), $t(190) = 2.37$, $p = 0.019$, d = 0.43, and showed a small practical advantage on methodological competence (M = 63.2 vs. 60.4), $t(190) = 1.76$, $p = 0.081$, d = 0.32. The experimental group achieved higher post-test scores on ICT competence (M = 84.5 vs. 79.3), $t(190) = 3.62$, $p < 0.001$, d = 0.66, although this result should be interpreted in light of the baseline group differences. Overall, the study results suggest that a carefully designed blended learning approach can support the development of key professional competencies in pre-service IT teachers.

KEYWORDS
blended learning models, methodological and ICT competences, pre-service computer science teacher, professional competences, subject

1 Introduction

The rapid digitalisation of society has fundamentally transformed higher education, increasing expectations for universities to prepare graduates who can operate confidently in technology-rich environments. This challenge is particularly salient in teacher education, where future educators must not only master subject content but also be able to design and implement technology-enhanced learning environments. For pre-service computer science teachers, this dual requirement is especially demanding, as they are expected to integrate complex technical knowledge with effective pedagogical and digital practices.

In this regard, the preparation of computer science teachers occupies a special position: it is simultaneously content-intensive and highly dependent on the meaningful educational use of technology. As a result, the quality of teacher training increasingly depends on how well university programmes combine strong disciplinary foundations with effective instructional approaches that reflect contemporary learning environments.

Within this context, programming and computer science education have attracted sustained research attention. Prior studies have documented persistent challenges related to curriculum design, student engagement and conceptual understanding in programming courses, as well as the broader need to integrate computational thinking into school curricula. Research highlights difficulties teachers encounter when introducing computing concepts at school level and emphasises the importance of deep conceptual understanding for making abstract ideas accessible to learners (Yadav et al., 2016; Grover and Pea, 2013; Wing, 2006; Guzdial and Ericson, 2015; Drini, 2018).

These challenges are not limited to content mastery; they also raise questions about how computer science should be taught and what learning conditions best support the development of professional competence in future teachers. In this sense, instructional models that can support both conceptual understanding and active student engagement are becoming especially relevant in teacher education.

At the same time, blended learning has become increasingly prominent in higher education as an instructional approach that combines face-to-face instruction with online learning activities. Blended learning is commonly understood as the deliberate integration of in-person classroom experiences with computer-mediated instruction (Driscoll, 2002; Graham and Bonk, 2006; Garrison and Kanuka, 2004). Conceptual and empirical studies suggest that, when well designed, blended learning can support flexible, student-centred learning and improve academic achievement, engagement and satisfaction compared with purely traditional formats (Graham et al., 2013; Moskal et al., 2013; Anthony et al., 2019; Heba and Nouby, 2008; Wahab et al., 2016; Edward et al., 2018; Ismail et al., 2018).

Given the applied and practice-oriented nature of computer science teacher education, blended learning is often considered a particularly promising approach because it can combine structured guidance with opportunities for independent exploration, digital collaboration and iterative practice. However, its effectiveness cannot be assumed universally and requires context-specific empirical validation.

However, existing research on blended learning exhibits several limitations relevant to teacher education and computer science. First, many studies focus on general student populations or disciplines such as business or language learning, while pre-service teachers—and especially pre-service computer science teachers—are examined less frequently. Second, research in teacher education often prioritises self-reported attitudes or general pedagogical outcomes rather than clearly operationalised professional competences (Guillén-Gámez et al., 2020; Heba and Nouby, 2008; Ma'arop and Embi, 2016). Third, a substantial proportion of studies rely on descriptive designs or single-group evaluations, offering limited comparative evidence of the effectiveness of blended versus traditional instruction (Moskal et al., 2013; Ma'arop and Embi, 2016; Bervell and Umar, 2020). Finally, insufficient documentation of instructional design and learning scenarios remains a recurring problem, limiting reproducibility and practical application of research findings (Graham et al., 2013; Friesen, 2012; Wong et al., 2014; Ma'arop and Embi, 2016).

Taken together, these gaps indicate the need for research designs that (a) focus on pre-service computer science teachers, (b) examine professional competences through clearly operationalised dimensions, and (c) provide comparative evidence using rigorous evaluation methods. This, in turn, requires a conceptual framework that can meaningfully connect subject knowledge, pedagogy, and digital technology in the context of teacher education.

In parallel, the concept of teachers' professional competence has become central in discussions of teacher quality and effectiveness. Professional competence is typically conceptualised as an integrated system of knowledge, skills and dispositions that enables teachers to perform professional tasks effectively and to engage in continuous development. Within computer science teacher education, both international and regional scholarship highlights the multidimensional nature of professional competence, encompassing subject-matter, methodological and ICT-related components (Abdulgalimov, 2008; Kuzmina, 2004; Khmel, 2001; Kenzhebekov, 2005; Shayakhmetova, 2019; Akhmetov and Aleksandrova, 2010; Khutorskoy, 2005; Koshalkovskaya, 2025).

While this multidimensional view is widely recognised, studies differ in how these competence components are defined and measured, especially when technology integration is involved. To strengthen conceptual clarity and ensure comparability with existing research, the present study anchors competence development in established theoretical models of technology-enhanced teaching.

This study is grounded in the Technological Pedagogical Content Knowledge (TPACK) framework, which conceptualises effective teaching with technology as the intersection of content knowledge, pedagogical knowledge and technological knowledge. Within TPACK, technology integration is not treated as an isolated skill but as an integrated form of professional knowledge that enables teachers to design learning experiences where content, pedagogy and digital tools are aligned.

In addition, the digital dimension of the study is informed by the European Digital Competence Framework for Educators (DigCompEdu), which emphasises educators' ability to use digital technologies purposefully for teaching, assessment, learner engagement and professional collaboration. DigCompEdu provides a complementary perspective by focusing not only on technological proficiency but also on responsible and pedagogically meaningful use of digital tools in educational practice.

Building on these frameworks, the study operationalises professional competence through three interrelated components. Subject competence reflects strong disciplinary foundations in computer science, corresponding primarily to the content knowledge component of TPACK. Methodological competence represents pedagogical content knowledge in computer science, including lesson planning,

instructional strategies and assessment practices, aligning with the pedagogical dimension of TPACK. ICT competence captures students' ability to use digital tools confidently and reflectively in learning and teaching, corresponding to the technological dimension of TPACK and the applied educator-oriented digital practices emphasised in DigCompEdu. Thus, the selected competence dimensions are conceptually justified as theoretically grounded components of pre-service teachers' readiness to teach computer science in technology-rich learning environments.

For pre-service computer science teachers, three components of professional competence appear particularly critical. Subject competence involves deep and structured understanding of core computer science concepts and the ability to apply them in problem-solving contexts (Shulman, 1986; Bruner, 2009). Methodological competence refers to pedagogical content knowledge in computer science, including lesson design, instructional strategies and assessment practices that support student learning (Hubwieser et al., 2013). ICT competence encompasses the confident and reflective use of digital tools and resources for teaching, learning and professional collaboration, which is increasingly recognised as essential for effective teaching in contemporary educational environments (Guillén-Gámez et al., 2020; Balganova et al., 2024; Ashraf and Mollah, 2021; Balganova et al., 2025).

Importantly, these competence components should not be developed in isolation: professional readiness emerges when subject knowledge can be transformed into teachable forms through appropriate pedagogy and supported by digital tools that enhance learning processes. For this reason, instructional models that integrate these dimensions in practice are particularly relevant in pre-service teacher education.

In Kazakhstan and other post-Soviet educational contexts, professional competence development in teacher education has been widely discussed, with growing emphasis on the role of ICT and blended learning (Khmel, 2001; Kenzhebekov, 2005; Shayakhmetova, 2019). Existing studies suggest that blended and rotational models may support the development of subject and methodological competences in informatics education and that electronic resources can positively influence the professional preparation of future computer science teachers (Tkachuk, 2017; Balganova et al., 2024; Balganova et al., 2025).

At the same time, empirical evidence comparing blended learning with traditional instruction in terms of clearly defined competence outcomes remains limited, particularly for pre-service computer science teachers. This points to the need for studies that implement well-documented blended learning interventions and evaluate their effects on theoretically grounded competence dimensions.

Accordingly, this study examines how a blended learning model can support the development of pre-service computer science teachers' professional competence, specifically its subject, methodological, and ICT components. The study aims to design and implement a blended learning intervention and to evaluate its effectiveness compared with traditional face-to-face instruction. The research is guided by three questions: (1) To what extent does blended learning improve subject competence? (2) To what extent does it improve methodological competence? and (3) How does it affect ICT competence, considering potential baseline differences between student groups? Using a quasi-experimental pre-test/post-test control group design and competence-based assessment, the study provides empirical evidence on the effectiveness of blended learning in computer science teacher education and offers a documented intervention and operationalised measurement approach that can inform future research and instructional design.

2 Methodology

During the study, we used the "Flipped Classroom" and "Station Rotation" models of blended learning for future computer science teachers. The most common models of blended learning are the "flipped classroom" and "station rotation." In the first model, online learning is conducted at home and is combined with traditional classroom lessons. In the second model, the learning process is organized by creating various "stations" in the classroom, where students take turns working with the teacher, doing project work, and using web services. The flipped classroom model is a simple model of blended learning, the opposite of traditional learning, that is, the student independently analyzes the theory at home and performs practical tasks in the classroom. Based on this model, the student can master theoretical material at a convenient time and place using the gadget at hand in the form of audio, video, text. The effectiveness of this model is that the student can independently study various textbooks, dictionaries, reference books, Internet sources, etc. develops skills in working with sources, gets rid of the fear of not understanding the material, and gets the opportunity to practice more in the classroom. And the teacher does not waste time explaining new material and works with each student individually, depending on his level and characteristics. We have presented a model for using the flipped classroom in the classroom in the form of Table 1.

The Blended edu platform, which is recommended for use in the implementation of the "Flipped Classroom" model of blended learning, has been developed. Training according to the "Flipped Classroom" model consists of 4 stages:

Stage 1. Preliminary preparation stage. At this stage, students are provided with basic theoretical materials online. Video lectures and educational materials developed on the Blended edu platform can be presented at this stage. Students watch the lesson at a convenient time for them, understand it, and prepare their questions. This prepares them in advance for class discussions.

Stage 2. Discussion and practice stage in the auditorium. In the next stage, students apply the knowledge they have gained through Blended edu in the classroom. The teacher organizes group work or discussions during the lesson, allowing students to solve specific problems. Students' questions are discussed and misunderstandings are clarified. This improves the blended learning process by supplementing online learning with practical activities in the classroom.

Stage 3. Practical task performance stage. Students consolidate their knowledge through tests and tasks prepared in advance in Blended edu. The automated assessment system immediately checks students' assignments and displays the results, which develops their self-assessment skills.

Stage 4. The stage of final analysis and reflection. At the final stage, students analyze the work performed using Blended edu and understand the mistakes they made. This allows them to reflect, repeat the material, and analyze the learning results. The teacher organizes joint work aimed at systematizing students' knowledge, the results of which can be presented in the form of project defense. After assessing the work, the lesson is concluded, reflection is done, and homework is

TABLE 1 Flipped classroom model.

Learning environment	Teacher's actions	Student's actions
At home	Theoretical material is prepared in the form of text and interactive video.	Read the theoretical material, watch the interactive video and answer the questions.
	Creates tasks in interactive workbooks.	Completes the task in the interactive workbook.
	Prepares an online test.	Answers online test questions.
	They collect everything on one platform and send the link to the learner (https://blended-edu.kz/subject/16/chapter/2/lesson/356/)	The results are sent to the teacher via the platform (https://blended-edu.kz/subject/16/chapter/2/lesson/356/)
In the classroom	An interactive quiz is prepared to test students' mastery of the theoretical material.	Answers interactive questions related to theoretical material.
	The results of the interactive video response are displayed on the screen and discussed.	They share their thoughts and engage in debates.
	The task completed in the interactive workbook is displayed on the screen and discussed.	The student is working with errors.
	Explains the task to be performed and organizes its implementation.	Performs the task and discusses the results.
	Summarizes, evaluates, and reflects on the lesson.	Summarizes the topic.

assigned. The teacher can use the feedback system in Blended edu to provide individual advice to each student. Effective use of the Blended edu platform at each stage allows you to improve the quality of students' education and realize all the advantages of the "Flipped Classroom" model.

In the station rotation model, there are 3 learning stations: the first is work with a teacher, the second is online learning, and the third is group work. All students are required to complete the tasks assigned at these three learning stations. This model is implemented by dividing students into groups. During the lesson, each group performs the tasks assigned to them at the stations for a specific period of time. They must use their time effectively and be at all stations by switching between stations during the lesson. For example, when one group works under the guidance of a teacher, the second group performs tasks on a computer at an online learning station, and the third group works on group projects. Thus, students from each group rotate through all stations in turn, performing tasks. The purpose of the work station with a teacher in the station rotation model is to enable each student to use their time wisely to master their knowledge, develop their skills of independent work, and increase their responsibility. The purpose of the group work station is to provide students with the opportunity to apply their knowledge and skills in new experiences and situations, develop their communicative competence, and receive feedback from classmates.

At each of these stations, an environment should be created that develops students' cognitive activities. In addition, the time for each zone should be calculated depending on the complexity of the task, since it is assumed that during its implementation students will achieve high-quality learning outcomes. And according to the purpose of this model, students should not only understand the goals and objectives of the activities performed in each zone, but also feel, understand, and perform what specific actions need to be performed to achieve the goals of the lesson. We have presented a model for using station rotation in the classroom in the form of Figure 1.

2.1 Research design

The study employed a quasi-experimental pre-test/post-test control-group design with intact classes. Two existing class groups of pre-service computer science teachers participated: an experimental group (EG) receiving blended learning and a control group (CG) receiving traditional face-to-face instruction. Individual random assignment was not feasible due to organisational and institutional constraints; therefore, intact classes were assigned to conditions.

To reduce instructional variability, both groups (a) studied the same courses during the same academic period, (b) followed the same learning objectives and assessment criteria, and (c) were taught by the same instructors. The planned instructional dose (total expected workload) was aligned across conditions through a common syllabus, a shared topic sequence, equivalent graded assignments, and identical grading rubrics (see Section 2.3).

Interim assessments. Regular online formative assessments (quizzes and practical exercises) were conducted on the Blended Edu platform over a 30-week period to provide feedback and monitor progress. These formative assessments did not constitute a standardized interim posttest based on the developed criterion-based instruments and were not included in the main statistical analysis of effectiveness; the main analysis was based on comparable pretest-posttest measurements conducted under identical conditions during school hours.

2.2 Setting and participants

The study involved 192 third- and fourth-year pre-service computer science teachers from two higher education institutions in Shymkent, Republic of Kazakhstan: (1) U. Zhanibekov South Kazakhstan Pedagogical University ($n = 146$) and (2) M. Auezov South Kazakhstan University ($n = 46$). Participation was voluntary, and informed consent was obtained from all participants prior to data collection.

Control Group

Students in the control group studied in a traditional face-to-face format based on the standard curriculum. Instruction consisted of in-person lectures and practical classes. Learning materials were provided by instructors (printed and/or electronic), and students completed individual assignments outside class without a structured learning-management platform.

Experimental Group

Students in the experimental group studied using a blended learning model supported by the Blended Edu platform,

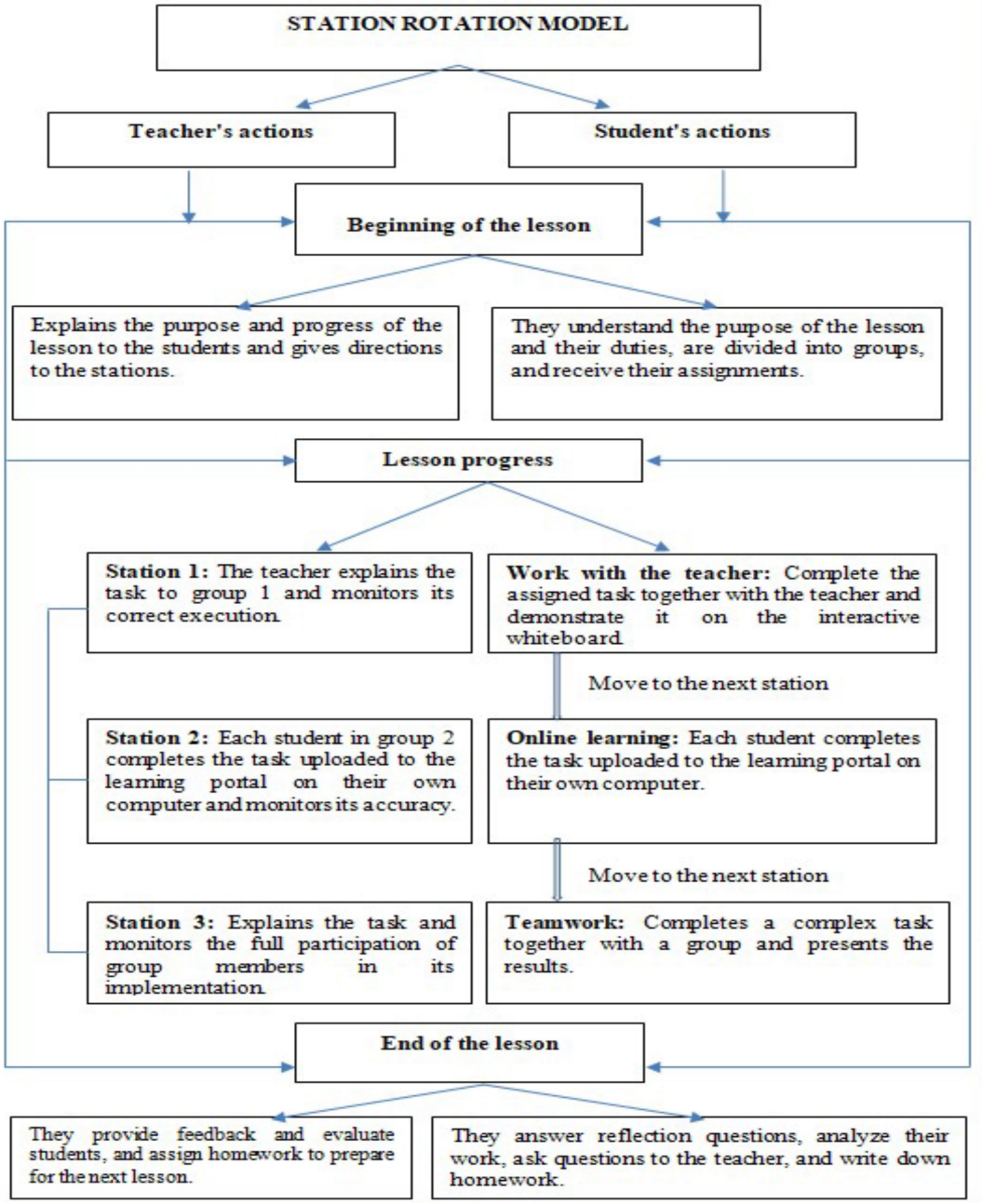

FIGURE 1
The station rotation model.

implemented in the courses Fundamentals of Web Programming and Electronic Learning on the Web Platform with in the teacher education programme.

Delivery format and instructional dose. The blended intervention combined approximately 60% online and 40% face-to-face instruction over 30 weeks. The intended weekly rhythm was fixed across modules:

- Online self-paced instruction: short video lectures and electronic texts (≈ 2–3 h/week);
- Online practice and formative assessment: interactive tasks, programming exercises, quizzes (≈ 1–2 h/week);
- Face-to-face practical session: application-focused work, discussion, troubleshooting, and feedback (2 academic hours/week).

To ensure equivalence of instructional volume between the experimental and control groups, the same course topics, learning outcomes, assessed assignments, and evaluation criteria were used in both groups. In the experimental group, online components replaced a corresponding portion of the in-class instruction typically provided in the control group, while the total planned weekly workload remained comparable across all conditions. Instructor feedback and evaluation criteria were identical across all groups.

2.3 Intervention and procedure

The intervention lasted a total of 30 weeks. The control group followed a traditional instructional format: students attended in-person lectures and practical classes, worked with printed and

teacher-provided materials, and completed individual assignments without a structured online component.

The experimental group studied using the Blended Edu platform.

An online educational platform called "Blended Edu" has been created for students in the subjects "Fundamentals of Web Programming" and "Electronic Learning on the Web Platform" of the educational program "Training of Computer Science Teachers." The platform works in the format of a website (Figure 2).

The platform consists of 2 sections:

1 Training section for students;
2 Management section for teachers.

The user must register and log in to the platform by filling in their personal information (Figure 3).

In our case, we considered the subjects "Fundamentals of Web Programming" and "Electronic Learning on the Web Platform" for students of the educational program "Training of Computer Science Teachers" on the blended learning platform.

When entering the training section for students, a list of educational programs appears. When choosing the desired educational subject, the user is registered for the subject. Then, by selecting the subject modules, he can study and master the relevant knowledge at a convenient time and in a convenient place. The effectiveness of the platform lies in this. The platform includes theoretical lessons, practical lessons, video lessons from the YouTube channel, interactive tasks, script and code writing programs, testing, control questions, feedback with the teacher, chat, communication via Zoom, and the ability to perform individual tasks. An electronic textbook has been created that teaches the JavaScript environment. The student can download and install it for himself. It will be an auxiliary tool.

Testing procedure

Before the intervention began, both groups received a pre-test. All tests were administered during regular class hours under comparable conditions. Evaluations were conducted by course instructors in coordination with the research team using pre-defined criteria.

2.4 Instruments

To assess the development of professional competences in pre-service computer science teachers, three criterion-based instruments were used to measure subject competence, methodological competence, and ICT competence. The instruments were developed in alignment with the learning outcomes of the courses *Fundamentals of Web Programming*and *E-Learning on a Web Platform*, and were conceptually grounded in the TPACK framework and the educator-oriented digital competence perspective emphasised in DigCompEdu. In this conceptualisation, subject competence corresponds primarily to content knowledge, methodological competence to pedagogical content knowledge, and ICT competence to the effective and purposeful use of digital tools for teaching and learning.

In addition, students in the experimental group were administered a 13-item questionnaire to examine their perceptions of blended learning, self-assessed digital readiness, and the perceived effectiveness of the blended model components. The survey results are presented descriptively to contextualize the implementation and were not included in the main effectiveness analysis (Figure 4).

2.4.1 Instrument development and expert review

Instrument development followed four steps. First, course learning outcomes and modules were mapped onto competence indicators across three dimensions (subject, methodological, and ICT). Second, an item pool and performance tasks were drafted for each dimension. Third, the instruments and scoring rubrics were reviewed by an expert panel (computer science education, pedagogy/instructional design, and educational technology; $N = 3–5$) to ensure relevance, clarity, and alignment with the competence framework. Fourth, a pilot administration was conducted to verify feasibility, time requirements, and scoring procedures. Based on expert feedback, ambiguous items were revised, overlaps were removed, and rubric descriptors were refined to support consistent interpretation.

Subject competence: Subject competence was measured with a written–practical test in web programming (25 items: 15 multiple-choice and 10 open-ended tasks). The tasks focused on HTML structure and table markup (e.g., appropriate use of <table>, <tr>, <td>, <th>). Scores were reported on a 0–100 scale. Open-ended tasks were rated using an analytical rubric assessing (1) correctness of syntax and logic, (2) compliance with required structure/tags, and (3) functionality and absence of critical errors.

Methodological competence: Methodological competence was assessed through performance-based tasks targeting pedagogical content knowledge in computer science (e.g., lesson design, selection of

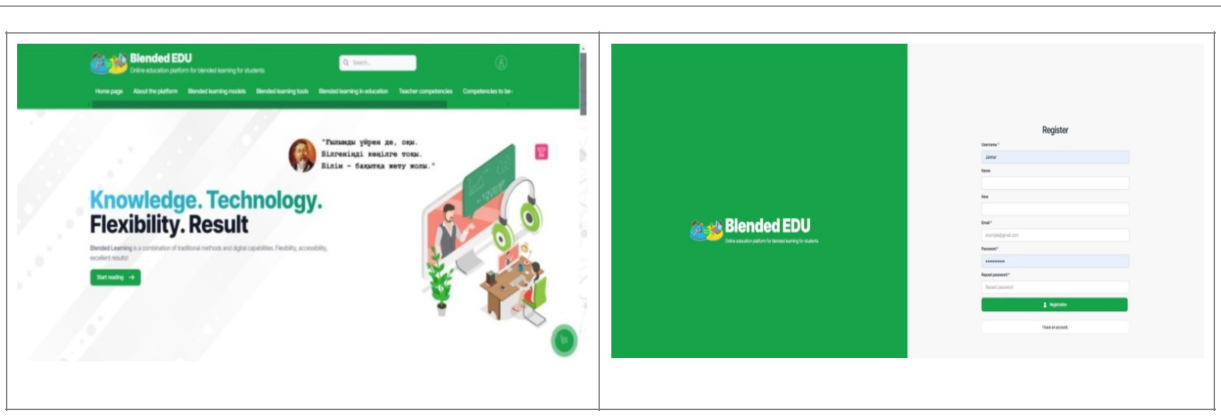

FIGURE 2
Home and registration page.

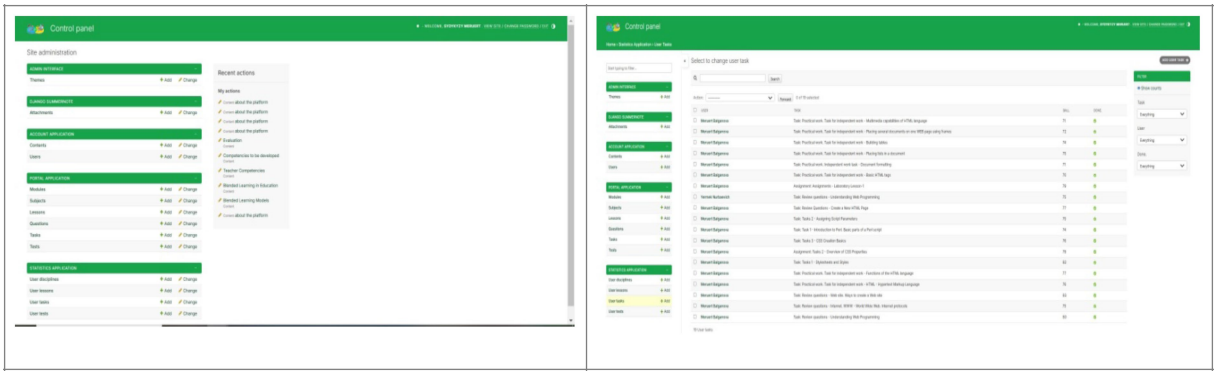

FIGURE 3
Control panel and statistics page.

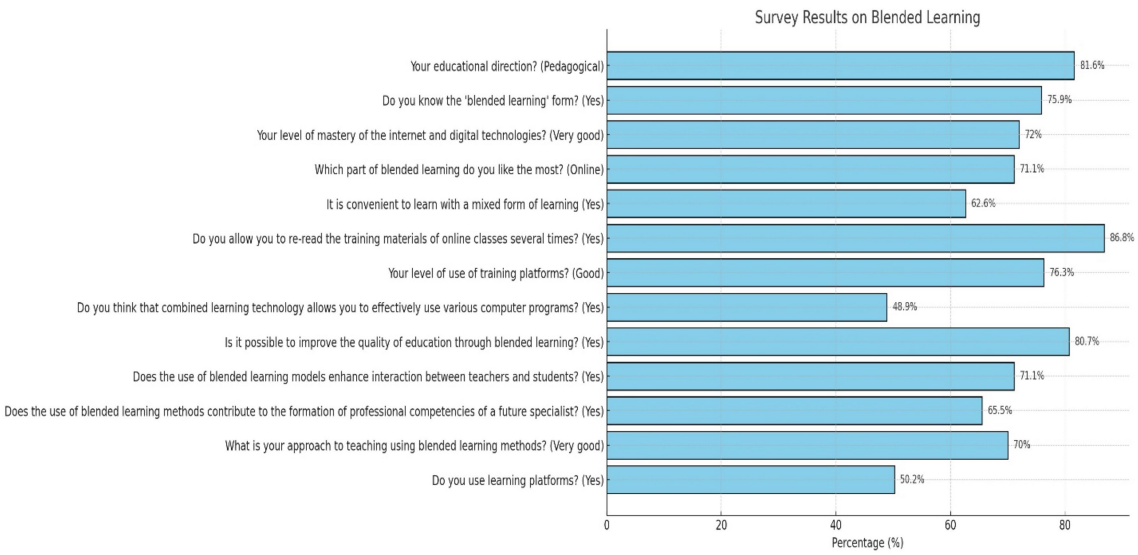

FIGURE 4
Survey results on blended learning.

strategies, sequencing of activities, and assessment planning). Students developed and justified an instructional scenario aligned with a given topic and learning objectives. Performance was scored on a 0–100 scale using an analytical rubric.

ICT competence: ICT competence was assessed with a criterion-based performance task in which students planned the use of digital tools to support blended instruction (e.g., selection of resources, organisation of online activities, development/adaptation of digital tasks, and feedback/communication tools). Scoring followed an analytical rubric focusing on pedagogically purposeful technology integration.

2.4.2 Validity evidence

Content validity was supported through expert review of the competence coverage and item relevance (see Section 2.4.1). Instruments were designed to ensure representative sampling of course content and competence indicators within each dimension. The expert panel confirmed that the tasks adequately reflected the intended competence constructs and were appropriate for the target level of training.

Construct validity was addressed through the theoretical alignment of the three competence dimensions with established models. Specifically, the competence structure was mapped onto the TPACK framework (content, pedagogy, technology and their integration) and complemented by DigCompEdu principles emphasising educators' purposeful digital practices in learning design, implementation, and feedback.

Criterion-related validity was evaluated by examining the consistency of competence scores with external performance indicators available in the programme, such as students' final course outcomes and final project performance. This triangulation supported the interpretation that competence measurements reflected broader learning achievements rather than isolated task performance.

2.4.3 Reliability evidence

The reliability of the instruments was examined using both internal consistency and inter-rater agreement procedures, depending on item format.

For the subject competence test, internal consistency reliability for the multiple-choice section was estimated using KR-20/

Cronbach's alpha, appropriate for dichotomous or scaled test items. For total subject competence scores combining test and open-ended tasks, reliability was additionally examined via composite consistency indicators, ensuring stability of the measurement.

For rubric-scored performance tasks (open-ended HTML assignments and competence tasks assessed via rubrics), inter-rater reliability was evaluated. Two independent raters (course instructors and research team member) underwent calibration training (rubric familiarisation, joint scoring of pilot responses, discussion of discrepancies). They then scored student work independently. Inter-rater agreement was estimated using ICC/Cohen's kappa.

2.4.4 Rubrics and scoring criteria

Analytical rubrics were used to ensure transparent and comparable scoring across competence dimensions. Each rubric included multiple criteria with three performance levels (low, moderate, high), reflecting increasing completeness, correctness, and pedagogical appropriateness.

- *Subject competence (open-ended HTML tasks):* (1) syntax/logic correctness; (2) required structure and tag use; (3) functionality and absence of critical errors.
- *Methodological competence:* (1) alignment of objectives, content, and activities; (2) appropriateness of instructional strategy; (3) sequencing and scaffolding; (4) assessment and feedback design.
- *ICT competence:* (1) appropriateness of digital tool selection; (2) alignment with learning objectives and pedagogical integration; (3) technical correctness and usability; (4) feedback/communication features and responsible use.
- Full rubric descriptors and scoring scales are provided in Appendix 1 to support transparency and reproducibility.

2.5 Data analysis

Data analysis was conducted primarily quantitatively using SPSS Statistics. The Shapiro–Wilk test was used to assess the normality of score distribution. Since the data met the assumptions for parametric analysis, independent-samples t-tests were used to compare mean scores between the experimental and control groups, and paired-samples t-tests were used to examine within-group changes from pre- to post-test.

Effect sizes were calculated using Cohen's d to assess the practical significance of statistically significant differences. The significance level for all analyses was set at $\alpha = 0.05$.

The equivalence of baseline data between groups was tested using independent-samples t-tests for each competency area. Because significant differences in ICT competency were observed at pre-test, the results regarding ICT competency in the discussion section were interpreted with caution.

3 Results

The results are presented in two sections. First, we compare the baseline equivalence of the experimental (EG) and control (CG) groups. Second, we report the effects of the blended learning intervention on the three competence areas.

3.1 Baseline equivalence at pre-test

Table 2 presents the pre-test descriptive statistics for subject, methodological and ICT competence.

3.1.1 ICT competence

At pre-test, a statistically significant difference between groups was observed for ICT competence. The experimental group demonstrated higher ICT competence (M = 78.3) than the control group (M = 72.6), $t(192) = 3.08$, $p = 0.003$, 95% CI [2.03, 9.37], Cohen's d = 0.56, indicating a moderate effect size.

Shapiro–Wilk tests indicated that ICT competence scores did not deviate significantly from normality in either group (EG: W = 0.98, $p = 0.21$; CG: W = 0.97, $p = 0.15$). This baseline nonequivalence represents a potential threat to internal validity for ICT-related outcomes and is therefore taken into account when interpreting post-test results.

3.2 Changes in competences following the intervention (post-test)

After the 30-week intervention, both groups completed post-tests assessing subject, methodological and ICT competences. Descriptive statistics are presented in Table 3, and between-group comparisons at post-test are summarised in Table 4.

3.2.1 Subject competence

Both groups improved from pre-test to post-test (EG: M = 61.0 → 70.0, SD = 12.0; CG: M = 59.0 → 65.0, SD = 11.0). At post-test, the between-group difference was significant: $F(1, 192) = 5.62$, $p = 0.019$, $\eta^2 = 0.028$.

3.2.2 Methodological competence

Both groups improved from pre-test to post-test (EG: M = 55.0 → 63.2, SD = 8.9; CG: M = 56.0 → 60.4, SD = 8.5). The post-test difference was not statistically significant: $F(1, 192) = 3.10$, $p = 0.081$, $\eta^2 = 0.016$.

3.2.3 ICT competence

Because the groups differed at pre-test, an ANCOVA was conducted with post-test ICT competence as the dependent variable, group as the fixed factor, and pre-test ICT competence as the covariate. The group × pre-test interaction was not significant: $F(1,$

TABLE 2 Pre-test descriptive statistics for subject, methodological and ICT competence.

Competence	Group	*N*	Mean (M)	SD
Subject competence	EG	97	61.0	13.0
	CG	95	59.0	10.0
Methodological competence	EG	97	55.0	10.0
	CG	95	56.0	9.0
ICT competence	EG	97	78.3	10.1*
	CG	95	72.6	10.1*

*Approximate pooled standard deviation derived from the independent-samples *t*-test.

TABLE 3 ANCOVA results on post-test ICT competence (controlling for pre-test ICT competence).

Source	Type III sum of squares	df	Mean square	F	*p*	Partial η^2
ICT competence (pre-test)	1820.45	1	1820.45	29.10	<0.001	0.133
Group (EG vs. CG)	598.72	1	598.72	9.56	0.002	0.048
Error	11850.30	189	62.70			
Total	–	–				

Dependent variable: Post-test ICT competency rating. Covariate: Pre-test ICT competency rating. EG, experimental group (n = 97); CG, control group (n = 95).

188) = 1.21, p = 0.273. After adjustment, the group effect was significant: $F(1, 189) = 9.56$, $p = 0.002$, partial $\eta^2 = 0.048$. The pre-test ICT score was a significant covariate: $F(1, 189) = 29.10$, $p < 0.001$, partial $\eta^2 = 0.13$. Adjusted means were higher in the EG (M_adj = 83.8, SE = 0.80, 95% CI [82.2, 85.4]) than in the CG (M_adj = 79.9, SE = 0.82, 95% CI [78.3, 81.5]).

3.3 Summary of between-group effects at post-test

To summarise the effects of the intervention, Table 4 presents the independent-samples t-tests and effect sizes for the three competence domains at post-test.

For subject competence, the experimental group outperformed the control group, with a statistically significant difference and a small-to-moderate effect (d = 0.43) (Table 5–7).

For methodological competence, the difference favoured the experimental group but did not reach statistical significance (p = 0.081), corresponding to a small effect (d = 0.32).

For ICT competence, intergroup differences in the posttest were assessed taking into account the non-equivalence of the pretest using ANCOVA (see Section 3.2.3), which presents the adjusted group effect and adjusted means.

Statistical analysis was performed using IBM SPSS Statistics 26.0, using descriptive statistics, t-tests, ANCOVA, and correlation analyses.

Between-group comparisons at the final post-test (Week 30) are presented in Table 4. A statistically significant difference in favour of the experimental group was observed for subject competence, with a small-to-moderate effect size. For methodological competence, the difference did not reach statistical significance, although a small effect size was observed. For ICT competence, the experimental group demonstrated significantly higher post-test scores with a medium-to-large effect; however, this result should be interpreted cautiously due to baseline differences between groups.

As a result of the study, the following main methods of effective use of courses developed on the Blended edu platform for future computer science teachers in organizing blended learning were proposed:

1 Combining theory and practice: Explaining theoretical materials in traditional lessons and allowing students to complete practical tasks and tests on the same topic through Blended edu. This helps students consolidate the theory and test their knowledge.
2 Self-study: Providing students with the opportunity to learn independently by posting video lectures and additional materials on the Blended edu platform. This approach helps students learn at their own time and at their own pace.
3 Automated tests and assessments: By posting interactive tasks and tests of different levels on the Blended edu platform, students' knowledge can be quickly and accurately assessed. Automated assessment saves the teacher's time and allows students to quickly understand their mistakes.
4 Providing feedback: Providing students with the opportunity to correct their mistakes and develop their skills in finding

TABLE 4 Adjusted (estimated cut-off) means of ICT competency.

Group	Adjusted mean (Madj)	SE	95% CI
EG	83.8	0.80	[82.2, 85.4]
CG	79.9	0.82	[78.3, 81.5]

TABLE 5 Homogeneity of regression slopes.

Effect	F	*pd*
Group × ICT_pre	1.21	0.273

TABLE 6 Post-test descriptive statistics (week 30) for subject, methodological and ICT competence.

Competence	Group	*N*	Mean (M)	SD
Subject competence	EG	97	70.0	12.0
	CG	95	65.0	11.0
Methodological competence	EG	97	63.2	8.9
	CG	95	60.4	8.5
ICT competence	EG	97	84.5	8.2
	CG	95	79.3	7.5

EG, experimental group (blended learning); CG, control group (traditional instruction). Descriptive statistics refer to the final post-test administered at Week 30. Only participants with complete pre- and post-test data were included in the analysis.

TABLE 7 Between-group comparisons at post-test (week 30).

Competence	*t*(192)	*p*	Cohen's *d*
Subject competence	2.37	0.019	0.43
Methodological competence	1.76	0.081	0.32
ICT competence	3.62	< 0.001	0.66

EG, experimental group; CG, control group. d = Cohen's effect size. Results are based on independent-samples t-tests. ICT competence results should be interpreted with caution due to significant baseline differences between groups at pre-test.

the right solutions by providing automatic feedback on their answers in Blended edu.

5 Creating an individual learning trajectory: Providing students with tasks and courses of varying complexity based on their individual needs. This allows each student to receive education at their own level. An excerpt from the lesson is shown in Appendix 1.

Thus, organizing blended learning using the Blended edu platform allows students to understand the complexities of computer science and teachers to comprehensively assess the level of students' knowledge. In addition, this approach helps to effectively use the capabilities of digital education, as well as form ICT competencies.

Subject competence (post-test): $F(1, 192) = 5.62$, $p = 0.019$, $\eta^2 = 0.028$.

Methodological competence (post-test): $F(1, 192) = 3.10$, $p = 0.081$, $\eta^2 = 0.016$.

ICT competence (ANCOVA, adjusted): $F(1, 189) = 9.56$, $p = 0.002$, partial $\eta^2 = 0.048$.

ICT pre-test covariate: $F(1, 189) = 29.10$, $p < 0.001$, partial $\eta^2 = 0.13$.

As an analysis of the work of the Blended edu platform shows, this resource is useful for organizing certain stages of blended learning in computer science. When used correctly, educational platforms can increase the efficiency of the learning process, improve the quality of education and the level of learning of students. One of the main advantages of Blended edu is the ability to automate assessment processes and provide instant feedback. This reduces the teacher's workload for checking assignments and allows students to receive instant suggestions for correcting their mistakes. In addition, Blended edu offers a wide range of tools for monitoring student progress, which helps the teacher to identify difficulties in mastering the material in a timely manner and correct the learning process. However, the implementation of the platform requires not only technical resources, but also the readiness of teachers to master new technologies and adapt traditional teaching methods. It is also important to ensure technical accessibility to allow students to use the platform without any problems. In conclusion, the use of the Blended edu platform in the training of future computer science teachers in a blended learning format is of great benefit. This platform combines traditional educational methods with modern digital tools, making the learning process flexible and accessible. As a result of the effective use of the Blended edu platform, future teachers will be able to actively use digital technologies in their activities, which will form their professional qualifications, as well as provide great support for the development of subject, methodological and ICT competence and meet the requirements of modern education.

4 Discussion

This study compared a blended learning model delivered via the Blended Edu platform with traditional face-to-face instruction in developing pre-service computer science teachers' professional competences. The results showed stronger gains for the experimental group (EG) in subject competence, a modest advantage in methodological competence, and a positive adjusted effect in ICT competence, although ICT conclusions should be interpreted with caution due to baseline differences.

4.1 Subject competence

Blended learning produced the clearest advantage in subject competence. This finding aligns with studies showing that blended formats can enhance achievement when online and face-to-face components are coherently integrated and provide regular opportunities for practice and feedback (Graham and Bonk, 2006; Garrison and Kanuka, 2004; Moskal et al., 2013; Anthony et al., 2019). In computer science education, conceptual mastery typically requires repeated practice and structured engagement (Guzdial and Ericson, 2015; Drini, 2018). In the present intervention, the modular online materials and interactive tasks likely supported systematic learning, while face-to-face sessions enabled clarification and higher-order application, consistent with the view of blended learning as instructional redesign rather than an add-on (Garrison and Kanuka, 2004; Moskal et al., 2013).

4.2 Methodological competence

Methodological competence improved in both groups, with a small advantage for the EG. This pattern is plausible because pedagogical competence develops gradually through sustained practice, reflection, and feedback (Hubwieser et al., 2013; Shulman, 1986). Blended environments may support this development through lesson planning tasks, digital artefact creation, and structured reflection activities (Ma'arop and Embi, 2016). The observed trend therefore corresponds to prior evidence that methodological gains are often incremental and require longer-term, practice-oriented learning experiences (Hubwieser et al., 2013; Shulman, 1986).

4.3 ICT competence

ICT competence results were influenced by initial group differences, as the EG entered with higher ICT scores. After baseline adjustment, the blended condition showed additional ICT competence development. This outcome is consistent with research emphasising that educator digital competence grows through meaningful technology use embedded in teaching-related tasks rather than isolated technical training (Guillén-Gámez et al., 2020). At the same time, baseline imbalance highlights the role of learner readiness in blended learning outcomes (Ismail et al., 2018), underscoring the need for targeted scaffolding so that technology-rich environments do not amplify existing gaps (Purnima, 2002; Balganova et al., 2025).

4.4 Implications

The findings suggest that competence-oriented blended course design can strengthen subject learning through modular structure, continuous practice, and timely feedback (Graham et al., 2013; Anthony et al., 2019; Kaur, 2013). For methodological development, blended formats can complement teacher preparation by supporting lesson design and reflective work with digital artefacts (Hubwieser et al., 2013; Shulman, 1986; Ma'arop and Embi, 2016). Given baseline ICT differences, programmes should diagnose digital readiness early and provide scaffolding for less confident learners (Purnima, 2002; Ismail et al., 2018; Balganova et al., 2025).

4.5 Limitations

This study used a quasi-experimental design with intact groups, which limits causal inference, particularly for ICT competence due to baseline non-equivalence. The sample was drawn from a single regional context, restricting generalisability. Competence measurement relied on course-based written and performance tasks, while direct observation of teaching practice and long-term follow-up were beyond the study scope. Future research could incorporate qualitative methods and learning analytics to clarify engagement patterns and identify which blended design elements most strongly support competence growth.

5 Conclusion

This study examined the impact of a blended learning model on the development of professional competence among pre-service computer science teachers. Three competence domains were analysed—subject competence, methodological competence, and ICT competence—using a quasi-experimental pre-test/post-test control-group design. The blended learning condition was implemented through the Blended Edu platform and compared with traditional face-to-face instruction.

Overall, the findings suggest that blended learning can contribute meaningfully to competence development in computer science teacher education. The experimental group achieved significantly higher post-test outcomes in subject competence and demonstrated a small practical advantage in methodological competence compared with the control group. These results indicate that a well-structured integration of online resources and classroom-based instruction can support deeper understanding of core computer science concepts and provide additional opportunities for practising lesson planning and other pedagogical skills.

ICT competence outcomes require more cautious interpretation. Although the experimental group showed higher post-test ICT scores, baseline non-equivalence between groups limits strong causal conclusions. The adjusted analysis suggests a positive association between the blended learning model and ICT competence development; however, future research employing randomisation or stronger baseline control is needed to clarify the magnitude and stability of this effect.

In conclusion, this study contributes comparative, competence-based evidence supporting the value of blended learning for the preparation of future computer science teachers. By combining flexible online learning, interactive practice, and targeted face-to-face support, blended learning can enhance key components of professional competence. At the same time, the results highlight the importance of accounting for students' initial ICT readiness and incorporating scaffolding strategies to ensure that blended learning environments remain inclusive and beneficial for learners with different levels of digital experience.

This study advances the literature by providing comparative evidence on blended learning effects across multiple competence domains in pre-service computer science teacher education. The results offer both empirical support and practical guidance for designing competence-oriented blended courses that integrate subject learning, pedagogical development, and technology use.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary material.

Ethics statement

The studies involving humans were approved by Ethics Committee Uzbekali Zhanibekov South Kazakhstan Pedagogical University, Shymkent, Kazakhstan. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

MB: Formal analysis, Writing – original draft. EA: Writing – original draft, Conceptualization, Validation. GB: Writing – review & editing, Visualization, Software. KT: Writing – review & editing, Data curation, Resources. BM: Writing – review & editing, Data curation, Resources. HB: Writing – review & editing, Conceptualization, Methodology, Data curation. LS: Writing – review & editing, Conceptualization, Methodology, Data curation.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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