Effectiveness of Team-based STEM Learning with Digital Projects in Developing Students' Professional Competence

Akbope Baimuratova [1,*], Anara Karymsakova [1], Meruert Serik [1], Zhandos Zulpykhar [1], and Lili Nurliyana Abdullah [2]

[1] Department of Computer Science, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan
[2] Department of Computer Science & IT, University of Putra Malaysia, Serdang, Malaysia
Email: akbope1992@yandex.kz (A.B.); hatae@mail.ru (A.K.); serik_meruerts@mail.ru (M.S.); astzhan@gmail.com (Z.Z.); liyana@upm.edu.my (L.N.A.)
*Corresponding author
Manuscript received May 13, 2026; revised May 29, 2026; accepted July 9, 2026; published November 12, 2026

***Abstract*—The rapid digital transformation of education requires universities to develop students' professional competence through innovative and practice-oriented learning approaches. In this context, team-based Science, Technology, Engineering, and Mathematics (STEM) learning combined with digital project activities has become an important pedagogical strategy for improving students' practical, communicative, and technological skills. The purpose of this study was to evaluate the effectiveness of team-based STEM learning and digital projects in supporting students' professional competence formation. The study employed an Educational Design Research (EDR) approach combined with a quasi-experimental design. A total of 150 students from L.N. Gumilyov Eurasian National University participated in the research and were divided into experimental and control groups. The experimental group participated in team-based STEM activities involving digital project development, while the control group studied using traditional instructional methods. Data was collected through professional competence assessment scales, observation checklists, expert evaluation sheets, and student feedback questionnaires. The reliability of the research instruments was confirmed by Cronbach's alpha values ranging from 0.84 to 0.91. The results demonstrated that the proposed model had a high level of practicality, with an average implementation rate of 86%. The findings also revealed a significant improvement in the professional competence of students in the experimental group compared to the control group. The N-gain value of 0.38 indicates a moderate improvement, suggesting that the intervention produced meaningful but not maximal growth in professional competence. The most noticeable improvements were observed in digital project development, teamwork, and the practical application of STEM knowledge. The study offers practical implications for STEM lecturers by showing how structured teamwork, role distribution, digital project tasks, and competency-based assessment can be integrated into higher education courses.**

***Keywords*—STEM learning, professional competence, higher education, digital literacy, collaborative learning, professional skills development**

I. Introduction

In the context of digital transformation, modern education is undergoing significant changes affecting the content of education, teaching methods, organization of the educational process and requirements for the training of future specialists [1–3]. The traditional learning model, based primarily on the transfer of ready-made knowledge, is gradually giving way to more flexible, practice-oriented and technologically rich approaches. In this context, Science, Technology, Engineering, and Mathematics (STEM) education, which combines science, technology, engineering and mathematics into a single interdisciplinary system of student training, is of particular importance.

The modern labor market requires graduates not only to have theoretical knowledge, but also the ability to apply it in real professional situations. Therefore, professional competence formation is becoming one of the key tasks of higher education. Professional competence includes subject knowledge, practical skills, digital literacy, teamwork, critical thinking, creativity, communication, and willingness to solve complex problems [4–6]. Students' ability to work on digital projects becomes especially important, since it is project activity that allows them to combine theory with practice and form skills that are in demand in a professional environment.

One of the most effective approaches to the development of such competencies is team STEM training [7–9]. Unlike traditional individual assignments, teamwork allows students to assign roles, jointly analyze a problem, propose solutions, develop digital products, and evaluate the results of their activities. This format promotes the development of responsibility, leadership skills, professional communication and the ability to make decisions in a collaborative environment. In addition, team-based STEM education provides students with an interdisciplinary interaction experience, which is especially important for future professional activities.

Digital projects within the framework of STEM education act not only as a means of verifying knowledge, but also as a tool for developing professional skills [10–12]. The development of digital educational resources, applications, interactive models, web platforms, simulations, or analytical tools helps students gain a deeper understanding of the concepts being studied and see their practical value. In the process of creating such projects, students learn how to plan work, use digital technologies, analyze data, present results, and justify decisions. This strengthens students' readiness for professional practice.

However, practice shows that many students, despite their general familiarity with digital technologies, have difficulty applying them independently in professionally oriented projects [13, 14]. Digital tools are often used in fragments and are limited to presentations, ready-made templates, or simple online resources. At the same time, the skills of designing, developing, analyzing, and team solving STEM problems remain insufficiently developed. This indicates the need to introduce educational models that systematically

combine teamwork, digital technologies, and professionally focused STEM tasks.

In this study, team-based STEM learning is considered as a pedagogical approach aimed at developing students' professional competence through the implementation of digital projects. The main idea is that students do not just study individual disciplinary knowledge, but apply it in joint project activities. This approach allows us to form not only cognitive results, but also practical, communicative and digital components of professional competence.

The relevance of the research is determined by the need to prepare students who are able to work effectively in a digital environment, apply STEM knowledge in practice, interact in a team and create professionally significant digital products. Despite the widespread use of STEM education and project-based learning, the question of how exactly digital team projects affect the development of students' professional competence remains poorly understood [15–17]. In this regard, this study explores the potential of team-based STEM learning and digital projects as a means of strengthening students' professional readiness.

Although previous studies have widely examined STEM education, project-based learning, and collaborative learning, several unresolved issues remain. First, many studies focus mainly on learning outcomes or student engagement, while the development of professional competence as a multidimensional construct is less clearly operationalized. Second, digital projects are often discussed as technological tools, but their role in systematically developing teamwork, communication, practical application, and reflective skills remains insufficiently explained. Third, limited empirical evidence exists on how Educational Design Research (EDR) can be combined with a quasi-experimental design to both develop an instructional model and evaluate its impact on professional competence in higher education. These gaps justify the need for the present study.

The novelty of this study lies in the development and empirical testing of an integrated team-based STEM learning and digital project model that combines three elements within one instructional framework: collaborative STEM problem solving, structured digital project development, and competency-oriented assessment. Unlike traditional STEM or project-based learning models, which often focus either on disciplinary knowledge or project outcomes, the proposed model connects each project stage with specific components of professional competence, including STEM knowledge, practical application, digital literacy, teamwork, communication, presentation, and reflection.

In this study, the STEM elements were integrated as follows. The Science component was reflected in the analysis of real educational and professional problems. The Technology component was represented by the use of digital tools, learning platforms, data visualization software, and project development applications. The Engineering component was implemented through project design, prototyping, testing, improvement, and presentation of digital products. The Mathematics component was reflected in data analysis, interpretation of results, measurement, comparison, and evidence-based decision-making. Thus, STEM was applied not as a set of separate disciplines, but as an integrated framework for solving practice-oriented professional tasks.

The model also differs from general collaborative learning approaches because teamwork is not used only as a form of classroom interaction, but as a structured mechanism for role distribution, project planning, digital product development, peer monitoring, and final reflection. Therefore, the proposed model provides a more systematic pathway for transforming STEM knowledge into professional competence in higher education.

The proposed model is grounded in three complementary theoretical perspectives. First, constructivist learning theory emphasizes that knowledge is actively constructed through authentic problem-solving and social interaction. Second, project-based learning theory highlights the importance of engaging students in meaningful tasks that require the application of interdisciplinary knowledge to real-world challenges. Third, collaborative learning theory suggests that teamwork, peer interaction, and shared responsibility contribute to deeper learning and the development of professional competencies. The integration of these perspectives provides the theoretical foundation for the team-based STEM learning and digital project model proposed in this study.

The purpose of the study is to determine the pedagogical potential of team-based STEM learning and digital projects for student competence growth.

The research aims to address the following issues:

(1) How does team-based STEM learning affect the development of students' professional competence?
(2) Which components of professional competence are most actively formed during the implementation of digital projects?
(3) How effective is the use of digital projects in team-based STEM activities compared to traditional forms of education?
(4) What pedagogical conditions are necessary for the successful implementation of team-based STEM learning in the educational process?

This study is focused on substantiating and evaluating the effectiveness of team-based STEM learning based on digital projects as a modern tool for the formation of students' professional competence.

This study contributes to the existing literature by providing empirical evidence on the effectiveness of team-based STEM learning supported by digital projects in higher education. The findings demonstrate that the integration of collaborative learning, digital project development, and competency-oriented assessment can enhance students' professional competence, particularly in teamwork, communication, digital project development, and the practical application of STEM knowledge. The study also offers a practical instructional framework that can be adapted for STEM-oriented professional training in higher education institutions [18, 19].

II. Materials and Methods

A. Research Design

In this study, the Educational Design Research (EDR) approach was used in combination with a Quasi-experimental method. This design made it possible to develop and test a

team-based STEM learning model supported by digital projects and to assess its impact on student competence growth.

The EDR procedure consisted of three main stages. The first stage was preliminary research, which included analysis of students' needs, identification of professional competence gaps, and review of relevant STEM, project-based, and collaborative learning literature. The second stage was prototyping, during which the team-based STEM learning and digital project model, learning materials, worksheets, digital project tasks, and assessment rubrics were developed and refined through expert feedback. The third stage was assessment, which included validation of the model, practicality evaluation during classroom implementation, and quasi-experimental testing of students' professional competence development.

The study was conducted in stages and included the design of an educational model, pilot testing, changes and subsequent full implementation in the educational process. At the EDR stage, the focus was on consistently improving the content of STEM assignments, teamwork structures, and digital project materials based on student and faculty feedback. The model was developed by the authors based on literature analysis, Educational Design Research (EDR) principles, expert feedback, and the learning objectives of the intervention. No artificial intelligence tool was used to generate the model. The quasi-experimental stage was aimed at verifying the effectiveness of the proposed model in improving students' professional readiness.

The study participants were divided into two groups. The experimental group was trained using a team-based STEM approach and carried out digital projects related to solving practice-oriented professional tasks. The control group was trained according to the traditional model, based mainly on individual performance of tasks without the systematic inclusion of digital projects and team-based STEM activities. The study was conducted at the L.N. Gumilyov Eurasian National University in 2025. 150 students took part in it. The sample was formed on the basis of existing academic groups using cluster selection. The experimental group included 75 students, the control group—75 students. The overall structure of the research design, including the validation and effectiveness evaluation phases, is presented in Table 1.

Table 1. Two-phase research design

Phase	Purpose	Data sources	Analysis
Phase 1. Model validation and practicality assessment	To validate the team-based STEM learning and digital project model	Expert evaluation sheets, observation checklists, teacher logs, student feedback	Content validity, Cronbach's alpha, Guttman scale, descriptive statistics
Phase 2. Evaluation of professional competence development	To examine the impact of the model on students' professional competence	Pre-test, post-test, competence assessment tool, observation data	Shapiro–Wilk, Levene's test, t-test, N-gain, Cohen's d

Source: Developed by the authors.

The analytical procedures were aligned with the two-phase research design. During Phase 1, descriptive statistics, expert evaluation, content validity assessment, and reliability analysis were used to evaluate the validity and practicality of the model. During Phase 2, quasi-experimental statistical procedures, including t-tests, N-gain analysis, and effect size calculations, were applied to evaluate changes in students' professional competence. This alignment ensured methodological consistency between the research design, data collection procedures, and analytical methods.

The study consisted of two interconnected phases. The first phase focused on the validation and practicality assessment of the proposed team-based STEM learning and digital project model. The second phase examined the effectiveness of the model in improving students' professional competence through a quasi-experimental comparison of the experimental and control groups.

The educational intervention lasted eight classes, totaling 16 academic hours.

The duration of eight sessions was selected because the intervention was designed as a short-term instructional module embedded within an existing university course. The purpose was not to measure long-term professional competence formation, but to examine whether structured team-based STEM activities with digital projects could produce measurable short-term changes in key competence indicators. To reduce observation bias, two independent observers used the same structured checklist and assessment rubric. Before the intervention, the observers discussed the criteria to ensure a common understanding of each indicator. Observation results were compared and averaged to improve consistency. The detailed structure of the eight-session intervention is shown in Table 2.

Table 2. Overview of the eight-session team-based STEM learning and digital project intervention

Session	Main activity	Digital project task	Tools	Assessment focus
1	Introduction, team formation	Problem selection	Google Classroom, Padlet	Problem understanding
2	STEM problem analysis	Project idea and objectives	Miro, Google Docs	Planning
3	Role distribution	Project design plan	Trello, Canva	Teamwork
4	Digital product development I	Prototype creation	Scratch/App Inventor/Excel	Digital skills
5	Digital product development II	Testing and correction	Google Sheets, Python/GeoGebra	Practical application
6	Data analysis	Interpretation of results	Excel, Google Forms	Analytical thinking
7	Presentation preparation	Final digital product	Canva, PowerPoint	Communication
8	Presentation and reflection	Project defense	LMS, rubric	Reflection

Source: Authors' own elaboration based on research data (2025).

The team formation strategy, role distribution, project types, and assessment criteria used during the intervention are summarized in Table 3.

The chosen research design made it possible to compare the results of students who studied in a team-based STEM learning environment with digital projects with the results of

students who completed traditional training, and to determine the impact of the proposed model on the development of their professional competence.

Table 3. Team formation and assessment rubric

Component	Description
Team size	4–5 students
Team formation	Heterogeneous grouping
Roles	Leader, Designer, Data Analyst, Presenter
Project types	STEM simulations, dashboards, mobile app prototypes, digital resources
Assessment criteria	STEM knowledge, project quality, teamwork, problem solving, communication, reflection
Scale	1–5 points

Source: Authors' own elaboration based on research data (2025).

B. Team Formation and Digital Project Development

Students in the experimental group were organized into teams of 4–5 members. Team formation was conducted using a heterogeneous grouping strategy to ensure diversity in academic performance, digital skills, communication abilities, and prior STEM experience. Each team selected a project leader, a digital designer, a data analyst, and a presentation coordinator. Role rotation was encouraged throughout the intervention to provide students with experience in different aspects of collaborative project work.

The digital projects were designed to address authentic STEM-related problems and professional tasks. Depending on the project topic, students developed digital educational resources, interactive STEM simulations, web-based learning materials, data visualization dashboards, mobile application prototypes, and digital presentations. Each project required students to apply STEM knowledge, use digital technologies, analyze information, and collaboratively develop a final digital product.

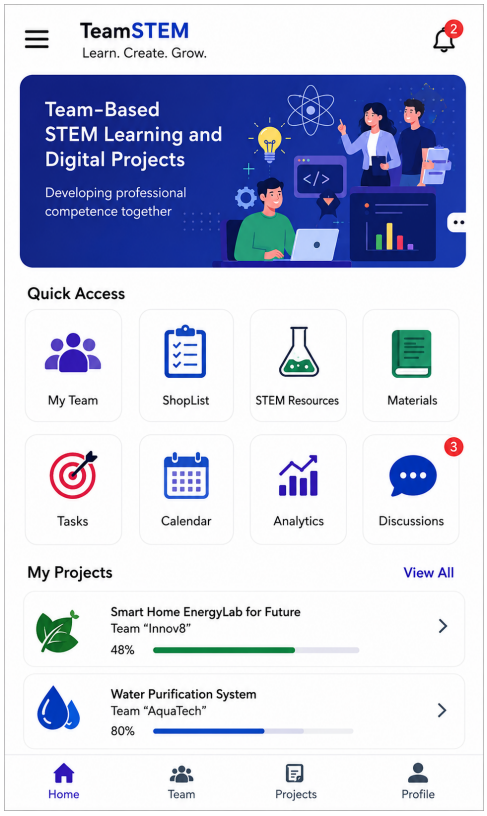
Student performance was assessed using a competency-oriented rubric that included six criteria: STEM knowledge application (20%), digital project quality (20%), teamwork and collaboration (20%), problem-solving ability (15%), communication and presentation skills (15%), and reflection and self-assessment (10%). Each criterion was evaluated on a five-point scale ranging from 1 (very low) to 5 (excellent). The rubric was used by instructors and expert observers throughout the intervention to ensure consistency and transparency of assessment.

C. Research Tools

This study used a set of research and teaching tools: lesson plans, worksheets for students, digital project assignments, materials for team-based STEM activities, expert assessment sheets, observation maps and scales for assessing students' professional competence. The professional competence assessment tool consisted of 30 items grouped into six components: STEM knowledge, practical application of knowledge, digital project development, teamwork, communication and presentation, and reflection and self-assessment. Each component included five items evaluated on a five-point Likert scale. The total score was converted into a 100-point scale and used for pre-test and post-test comparison.

In this study, professional competence was operationalized through six measurable indicators. STEM knowledge refers to students' understanding of interdisciplinary concepts and principles. Practical application refers to the ability to use STEM knowledge to solve professionally oriented tasks. Digital project development refers to the ability to design, create, test, and improve a digital product. Teamwork refers to role distribution, collaboration, shared responsibility, and joint decision-making. Communication and presentation refer to the ability to explain project results clearly and justify decisions. Reflection and self-assessment refer to students' ability to evaluate their own contribution, identify strengths and weaknesses, and formulate strategies for improvement.

The experimental group implemented a model of team-based STEM learning based on the implementation of digital projects. The learning process included six consecutive stages: (1) identifying a key problem or research question; (2) planning a digital STEM project; (3) assigning roles and developing a project schedule; (4) monitoring the progress of teamwork; (5) evaluating the resulting digital product; (6) reflection and analysis of acquired experience. Each stage was aimed at developing professional knowledge, practical skills, digital literacy, teamwork, and the ability to apply a STEM approach to solving professionally oriented tasks.



Source: Developed by the authors.

Fig. 1. Structure of the digital team-based STEM learning module and competency assessment system.

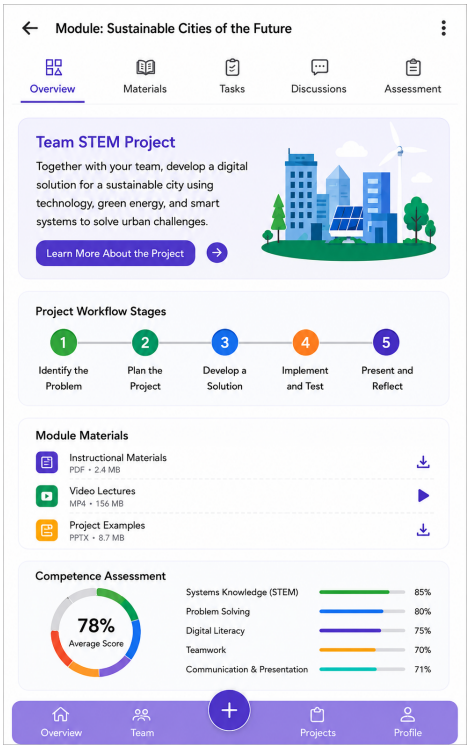
The control group used traditional teaching, which included a teacher's explanation, presentation of theoretical

material, individual assignments, and classroom discussion. Unlike the experimental group, the control group did not use system digital projects and team-based STEM activities.

The digital project materials were developed considering the research objectives and are focused on the formation of students' professional competence. They included theoretical materials, project instructions, worksheets, assessment criteria, teamwork assignments, and self-assessment elements. Special attention was paid to ensuring that digital projects were related to real professional situations and required students not only to know the theory, but also to apply it in practice.

Fig. 1 illustrates the structure of the digital team-based STEM learning module and shows the relationship between team-based STEM activities, digital project development, and professional competence assessment.

Fig. 2 presents the main dashboard of the TeamSTEM platform used to organize collaborative digital project work during the intervention.



Source: Developed by the authors.

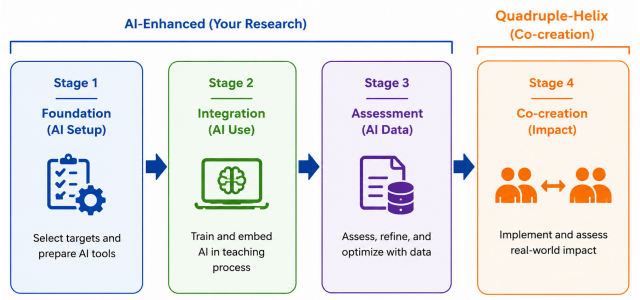
Fig. 2. Main dashboard of the TeamSTEM platform for collaborative STEM projects.

D. Data Collection

As shown in Fig. 3, the data collection process in this study included three main stages: validation, evaluation of practicality, and evaluation of the effectiveness of the digital project-based team-based STEM learning model. First, an analysis of students' educational needs related to professional skill development was carried out. Based on this analysis, a model of team-based STEM learning was developed with the inclusion of digital projects as a practice-oriented learning tool [20].

At the validation stage, the developed model, training materials, digital project assignments, worksheets and assessment tools were handed over to experts to verify their substantive and constructive validity. The expert group included experts in the field of STEM education, digital educational technologies and professional training of students. The experts assessed the compliance of the model with the research objectives, the logical stages of teamwork, the quality of digital tasks, the clarity of instructions, and the suitability of tools for assessing professional competence. The comments received were used to refine the materials before they were introduced into the educational process.

Fig. 3 summarizes the overall research procedure, including model validation, classroom implementation, data collection, and effectiveness assessment.



Source: Developed by the authors.

Fig. 3. General research scheme showing the Educational Design Research (EDR) stages and the quasi-experimental effectiveness evaluation phase.

At the stage of assessing practicality, it was analyzed to what extent the developed model can be applied in the educational process. For this purpose, observation maps, teacher's journals, and student feedback sheets were used. The observation was carried out during the classes and was aimed at assessing how consistently the stages of team-based STEM learning are implemented: problem statement, project planning, role allocation, digital product development, testing, presentation and reflection. The model was considered practical if its stages were understandable to students, feasible within the academic time and consistent with the goals of professional competence formation.

At the stage of effectiveness assessment, the impact of team-based STEM learning and digital projects on the development of students' professional competence was tested. For this, a Quasi-experimental design was used with two groups: experimental and control. Prior to the start of the training, both groups underwent an entrance test aimed at determining the initial level of professional competence. The experimental group then studied using a team-based STEM approach and completed digital projects, while the control group followed a traditional model that included lecture explanations, discussions, and individual assignments.

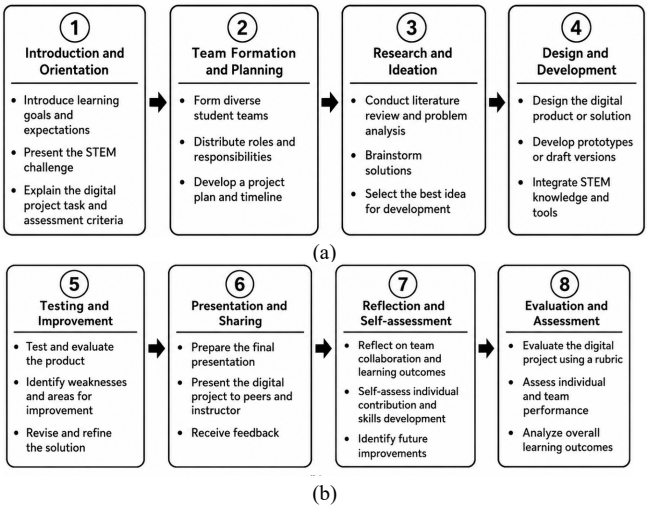
The preliminary analysis showed that students' professional competence was not sufficiently developed before the intervention. In particular, students experienced difficulties in applying STEM knowledge to practice, developing digital project products, organizing teamwork, presenting project results, and conducting meaningful reflection. The pre-test results also confirmed that both the experimental and control groups were initially at the "below average" level of professional competence. Therefore, the intervention was designed to address these weaknesses through structured teamwork, digital project development, and competency-oriented assessment.

After completing the training intervention, both groups underwent final testing. Additionally, the students of the

experimental group filled out a feedback questionnaire to assess their perception of teamwork, digital projects, and the practical significance of the proposed model. The effectiveness was determined based on a comparison of the results of entrance and final testing, as well as an analysis of the dynamics of professional competence indicators.

The assessment of professional competence included the following indicators: possession of STEM knowledge, the ability to apply knowledge in practical situations, the ability to develop a digital project product, teamwork skills, communication, analytical thinking, presentation of results and reflection on professional growth.

Fig. 4(a) presents the planning and development stages of the team-based STEM learning and digital project intervention.



Source: Developed by the authors.

Fig. 4. Research implementation stages. (a) Planning and development stages. (b) Implementation and evaluation stages.

To ensure procedural accuracy, data collection was coordinated with the model implementation stages shown in Fig. 4. Validity data was collected at the design and development stage of the model using expert assessment sheets. Data on practicality was recorded during the implementation of the model through observation, teacher logs, and student responses. Performance data was collected at the final stage using entrance and final testing, as well as an analysis of the increase in the results of students' professional competence.

E. Data Analysis

The data analysis in this study was carried out in three directions: the validity and reliability of the tools, the practicality of the model and the effectiveness of training.

The validation procedure involved five experts: two specialists in STEM education, one specialist in digital educational technologies, one expert in educational measurement and assessment, and one university instructor with experience in project-based learning. The experts evaluated the relevance, clarity, structure, and pedagogical suitability of the lesson plans, digital project tasks, worksheets, observation checklist, student feedback questionnaire, and professional competence assessment scale.

Content validity was assessed using expert judgment based on a 5-point Likert scale. The experts evaluated whether each item corresponded to the intended component of professional competence. The instruments were revised according to expert comments before the main intervention. Construct validity was supported by aligning the instrument structure with six components of professional competence: STEM knowledge, practical application, digital project development, teamwork, communication and presentation, and reflection.

To assess the validity of measuring instruments (questionnaires, checklists, professional competence scales), the expert assessment method was used, as well as an analysis of internal consistency.

The reliability of the scales was determined using the Cronbach's alpha coefficient. The interpretation criteria for Cronbach's alpha values are presented in Table 4.

Table 4. Criteria for interpreting Cronbach's Alpha reliability values

The value of α	The level of reliability
≥0.90	Very high
0.80–0.89	High
0.70–0.79	Acceptable
<0.70	Low

Source: Authors' own elaboration based on research data (2025).

Additionally, an analysis of the consistency of the points was carried out, which made it possible to exclude weak or incorrect elements of the scales.

The practicality of the team-based STEM learning model was assessed based on observation of its implementation in the educational process.

For this purpose, the following were used:

- Observation checklists,
- Teacher's journals,
- Student feedback questionnaires.

The results were recorded on a binary scale (1—completed, 0—not completed), after which the percentage of model implementation was calculated. The criteria used to interpret the practicality level of the model are shown in Table 5.

Table 5. Criteria of practicality

Percentage of completion	The level of practicality
86–100%	Very high
76–85%	High
60–75%	Average
55–59%	Low
0–54%	Very low

Source: Authors' own elaboration based on research data (2025).

The model was considered practical when reaching at least the "average" level.

Before applying parametric tests, the normality of data distribution was checked using the Shapiro–Wilk test, and the homogeneity of variance was assessed using Levene's test. The N-gain score was calculated using the formula: g = (post-test score − pre-test score) / (maximum score − pre-test score). Cohen's d was calculated as the difference between mean scores divided by the pooled standard deviation. These procedures allowed the study to evaluate not only statistical significance but also the practical magnitude of the intervention effect. The results of the normality and homogeneity tests are presented in Table 6.

The results of the Shapiro–Wilk test indicated that all distributions were approximately normal ($p > 0.05$). The Levene's test confirmed homogeneity of variances between

the experimental and control groups ($p > 0.05$). Therefore, the assumptions required for parametric statistical analyses were satisfied, and t-tests were considered appropriate for further data analysis.

Table 6. Results of normality and homogeneity tests

Test	Statistic	p-value	Interpretation
Shapiro–Wilk (EG Pre-test)	0.972	0.118	Normal
Shapiro–Wilk (EG Post-test)	0.981	0.254	Normal
Shapiro–Wilk (CG Pre-test)	0.975	0.143	Normal
Shapiro–Wilk (CG Post-test)	0.978	0.197	Normal
Levene's Test	1.27	0.261	Homogeneous

Source: Authors' own calculations based on research data (2025).

The effectiveness of the model was assessed based on changes in the level of professional competence of students.

A quasi-experimental design was used with:

- input testing (pre-test),
- final testing (post-test).

The following statistical methods were used to analyze the data:

- t-test for dependent samples—to compare the results before and after training
- t-test for independent samples—to compare experimental and control groups
- N-gain—to evaluate the increase in results
- Cohen's d—to determine the effect size

The students' professional competence was assessed according to the following components:

(1) STEM knowledge
(2) Putting knowledge into practice
(3) Development of digital projects
(4) Teamwork
(5) Communication and presentation
(6) Reflection and self-assessment

The classification of students' professional competence levels used in this study is presented in Table 7.

Table 7. Levels of professional competence

Scores	Level
0–40	Low
41–55	Below average
56–70	Average
71–85	High
86–100	Very high

Source: Authors' own elaboration based on research data (2025).

The interpretation criteria for N-gain values and effect size are presented in Table 8.

Table 8. Interpretation of N-gain and effect size

Indicator	Meaning	Interpretation
N-gain	$g < 0.3$	Low gain
	$0.3 \le g \le 0.7$	Average
	$g > 0.7$	High
Effect size (d)	0.2	Small effect
	0.5	Average
	≥ 0.8	Great effect

Source: Authors' own elaboration based on research data (2025).

The proposed analytical procedures make it possible to evaluate tool reliability, assess the practicality of the model, and statistically examine its impact on students' professional competence.

III. Results and Discussion

The results are presented according to the four research questions of the study. First, the influence of team-based STEM learning on students' professional competence is examined through pre-test and post-test comparison. Second, the most actively developed competence components are analyzed using N-gain values. Third, the effectiveness of digital projects in comparison with traditional instruction is evaluated through experimental and control group comparisons. Fourth, the pedagogical conditions necessary for successful implementation are discussed based on validity, practicality, observation, and student feedback data.

A. Validity and Reliability of Tools

The evaluation of the developed materials was carried out by experts in the field of STEM education, digital educational technologies and professional training of students. The experts evaluated the content of the team-based STEM learning model, digital project assignments, worksheets, monitoring tools, and a professional competence assessment scale on a 5-point Likert scale. The results of the expert evaluation and reliability analysis of the research instruments are presented in Table 9.

Table 9. The results of the expert evaluation of the instruments

Instrument / Evaluation Scale	Number of Items	Cronbach's Alpha	Reliability Level
Lesson Plan Quality Evaluation Scale	10	0.87	High
Worksheet Evaluation Scale	8	0.89	High
Digital Project Material Evaluation Scale	9	0.88	High
Professional Competence Assessment Scale	30	0.91	Very High
Observation Checklist	18	0.84	High
Student Feedback Questionnaire	20	0.86	High

Source: Authors' own elaboration based on research data (2025).

The obtained values of Cronbach's alpha show that all the research tools have a sufficient level of internal consistency. The highest indicator was obtained for the student's professional competence assessment tool, which indicates the consistency of its components: STEM knowledge, practical application of knowledge, digital product development, teamwork, communication, presentation of results and reflection on professional growth.

The high reliability of the worksheets and digital project materials confirm that the assignments were logically related to the research objectives and corresponded to the stages of team-based STEM learning. Experts noted that the assignment structure allows students to consistently move from problem analysis to planning, role allocation, digital product creation, testing, and presentation of results.

The observation checklist also showed a high level of reliability. This means that its indicators allow us to capture the implementation of the main stages of the model in the educational process. At the same time, the experts recommended clarifying certain formulations of criteria related to evaluating team interaction and individual student contributions to project work. These clarifications were made before the main stage of the study.

The student feedback questionnaire also demonstrated a high level of internal consistency. This confirms its suitability for assessing students' perception of team-based STEM learning, digital projects, role allocation, the practical

significance of tasks and the impact of the model on the development of professional skills.

The results of the expert assessment and reliability analysis confirm that the developed tools are suitable for further use in the study. They allow us to correctly assess the process of implementing team-based STEM learning and its impact on the development of students' professional competence.

B. The Practicality of the Model

The practicality of the team-based STEM learning and digital projects model was assessed based on observations of its implementation in the educational process. The observation was conducted by two independent experts: a teacher and a specialist in the field of STEM education. During the eight training sessions, the completion of each stage of the model was systematically recorded in accordance with the developed lesson plan.

The data was analyzed using a qualitative descriptive approach and the Guttman scale, where each indicator was rated as "completed" (1 point) or "not completed" (0 points) [21]. Most stages of the model were successfully implemented during the intervention. The average implementation rate was 86%, which corresponds to the category of "very high practicality". The relationship between the model stages, educational activities, and professional competence components is summarized in Table 10.

Table 10. Implementation of the team-based STEM learning model and its contribution to the development of professional competence

The stage of the model	Educational activities	Components of professional competence
Problem statement	Students in teams analyze a professionally oriented task and formulate key questions for the project.	analytical thinking, STEM knowledge
Project planning	Project structure development, role allocation, choice of digital tools	teamwork, planning, digital literacy
Organization of the process	Project execution schedule, time allocation	self-organization, responsibility
Monitoring of execution	Monitoring progress, discussing difficulties, correcting decisions	critical thinking, collaboration
Presentation of results	Presentation of the digital product and discussion of the results	communication, presentation skills
Reflection	Analysis of the work performed identification of strengths and weaknesses	Reflections, professional development

Source: Authors' own elaboration based on research data (2025).

The results of the practicality evaluation for each stage of the proposed model are presented in Table 11.

Table 11. The results of the evaluation of the practicality of the model

The stage of the model	Average completion percentage	Category
Problem statement	89%	Very high
Project planning	86%	Very high
Organization of the process	83%	High
Monitoring of execution	89%	Very high
Presentation of results	87%	Very high
Reflection	80%	High
The average value	**86%**	**Very high**

Source: Authors' own elaboration based on research data (2025).

The highest implementation rates were observed at the stages of problem formulation and project monitoring (89% each). These results suggest that students were actively engaged in analyzing professional tasks, distributing team roles, and monitoring project progress. Such participation is important for developing responsibility, collaboration, and decision-making skills in STEM-oriented professional training [22].

At the reflection stage, the lowest score was obtained (80%). This is because students have not sufficiently developed the skills to analyze their own activities in depth and evaluate the results of teamwork. This result indicates the need to strengthen methodological support for reflective activity, including the development of clear criteria for self-assessment and the introduction of structured reflective tasks.

The practicality of the model is also confirmed by the characteristics of the digital design materials used. They have a clear structure, easy navigation and ensure the consistent passage of all stages of project activities. The use of digital tools helps to increase student engagement, develop independence and the effectiveness of the educational process [23, 24].

The experts' observations showed that the learning process was organized logically, the teacher's instructions were clear, and the students actively interacted with each other at all stages of the work. Therefore, the model can be considered applicable to real university teaching conditions.

It can be concluded that the team-based STEM learning and digital projects model has a high level of practicality and is effectively implemented in the educational process, contributing to the development of students' professional competence through teamwork and digital projects.

C. The Effectiveness of the Model

The effectiveness of the team-based STEM learning and digital projects model was assessed based on an analysis of changes in the level of professional competence of students before and after training. The transition of students to a higher level of professional competence based on the results of the final testing was considered as the main criterion of effectiveness. The pre-test and post-test results for the experimental and control groups are presented in Table 12.

Table 12. Results of pre-test and post-test assessment of students' professional competence

Group	N	Stage	Mean score	Level	Standard deviation
Experimental	75	Pre-test	48.6	Below average	7.4
	75	Post-test	68.2	Average	8.1
Control	75	Pre-test	49.3	Below average	6.8
	75	Post-test	52.7	Below average	7.0

Source: Authors' own elaboration based on research data (2025).

The results of the entrance test showed that in both groups the level of professional competence of students was at the "below average" level. After the model was implemented, the experimental group showed a significant increase in indicators to the "average" level, while the changes in the control group were insignificant.

These findings suggest that team-based STEM learning with digital projects contributed to measurable student competence growth.

The second performance indicator was the N-gain growth rate. In the experimental group, its value was 0.38, which

corresponds to the average level of growth, while in the control group this indicator was significantly lower.

To provide a more detailed analysis of student competence growth, N-gain values were calculated separately for each component of professional competence. The results are presented in Table 13.

Reflection and self-assessment showed the lowest N-gain value in the experimental group. This may be explained by the fact that reflective competence requires students to critically evaluate their own contribution, identify weaknesses, and formulate improvement strategies. These skills usually develop more slowly than teamwork or digital project development and require more structured reflective guidance.

Table 13. N-gain by professional competence components

Component	EG Pre	EG Post	EG N-gain	CG Pre	CG Post	CG N-gain
STEM knowledge	49.2	66.8	0.35	50.1	53.4	0.07
Practical application	47.8	69.5	0.42	48.9	52.1	0.06
Digital project development	45.6	70.4	0.46	47.3	51.8	0.09
Teamwork	50.3	72.1	0.44	51.0	54.0	0.06
Communication and presentation	49.1	67.3	0.36	49.8	52.5	0.05
Reflection and self-assessment	49.6	63.2	0.27	48.7	52.4	0.07

Source: Authors' own calculations based on research data (2025).

The moderate N-gain value of 0.38 should be interpreted critically. It indicates that the intervention contributed to meaningful improvement, but the growth was not high. This result may be explained by the relatively short duration of the intervention and by the complexity of professional competence, which usually requires longer and repeated practice. Therefore, the model should be viewed as a promising instructional approach rather than a complete solution for professional competence formation.

The N-gain analysis of individual components of professional competence (Fig. 5) showed that the experimental group showed a higher increase in all indicators: STEM knowledge, practical application, digital project development, teamwork and communication.

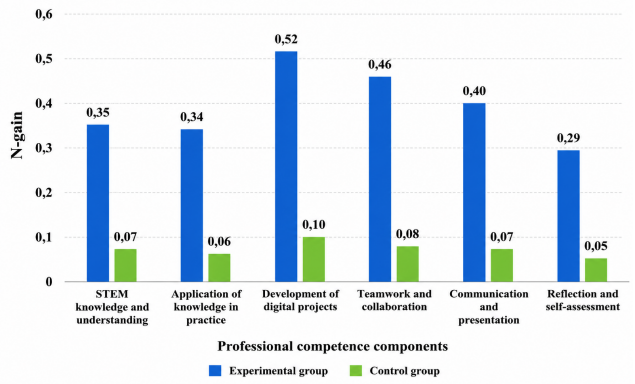


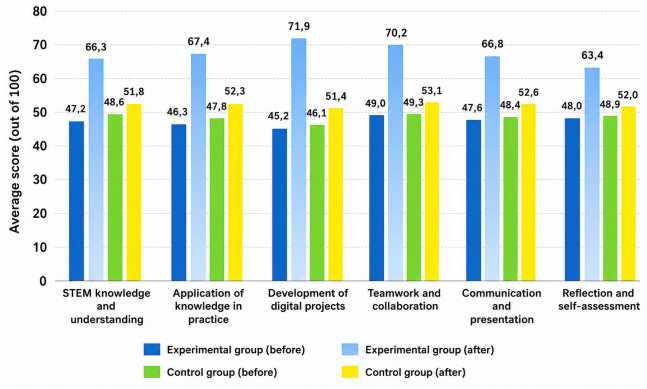
Fig. 5. N-gain in terms of professional competence components. Source: Developed by the authors. Note. The N-gain value is interpreted as follows: < 0.3—low growth; 0.3–0.7—medium growth; > 0.7—high growth.

A comparative analysis of the average values for individual components of professional competence before and after training (Fig. 6) showed that the greatest growth is observed in the following indicators:

- digital project development,
- Teamwork,
- Applying knowledge in practice.

There is also a slight improvement in the control group, but it remains at a low level and does not demonstrate stable dynamics.

After the implementation of the team-based STEM learning and digital projects model, a significant increase in the level of students' professional competence was observed across all components in the experimental group compared with the control group.



Source: Developed by the authors.

Fig. 6. Dynamics of professional competence by components.

To verify the statistical significance of the differences, the following tests were performed:

- a test for the normality of the data distribution,
- Sample uniformity test,
- T-test to compare the results.

The results are presented in Table 14.

The significant improvement observed in the experimental group can be explained by the active involvement of students in collaborative STEM problem-solving and digital project development. Unlike traditional instruction, where students mainly receive and reproduce theoretical knowledge, participants in the experimental group were required to design, develop, test, and present digital products related to authentic professional tasks. This process encouraged the practical application of STEM knowledge and promoted deeper engagement with the learning content [25, 26].

The strongest improvement was observed in digital project development and teamwork. These results may be attributed to the structured organization of group activities, including role distribution, project planning, collaborative decision-making, and continuous peer interaction. Working on shared digital products required students to communicate effectively, solve problems collectively, and coordinate their responsibilities, which directly supported professional skill development [27].

In contrast, reflection demonstrated the lowest practicality score among all components. One possible explanation is that students are generally less familiar with reflective practices and often experience difficulties critically evaluating their own contributions, strengths, and weaknesses. Reflection

requires higher-order metacognitive skills that typically develop gradually and may require additional methodological support and structured guidance from instructors [28].

Table 14. Statistical analysis of pre-test and post-test results

Comparison	Test	Mean difference	t-value	df	p-value	Cohen's d	Interpretation
Experimental group: pre-test vs post-test	Paired-samples t-test	19.6	15.42	74	<0.001	2.05	Large effect
Control group: pre-test vs post-test	Paired-samples t-test	3.4	2.91	74	0.005	0.39	Small effect
Experimental vs control group: pre-test	Independent-samples t-test	–0.7	–0.60	148	0.548	0.10	No significant difference
Experimental vs control group: post-test	Independent-samples t-test	15.5	12.53	148	<0.001	2.05	Large effect

Note: $p < 0.05$

Source: Authors' own elaboration based on research data (2025).

These findings are consistent with previous studies reporting that project-based STEM learning environments enhance student engagement, collaboration, problem-solving abilities, and professional skill development. The results also support the view that digital technologies alone do not automatically improve learning outcomes. Their effectiveness depends on the presence of a well-designed pedagogical structure that integrates collaborative learning, authentic tasks, continuous feedback, and competency-oriented assessment. Therefore, the positive outcomes observed in this study can be attributed not only to the use of digital tools but also to the systematic instructional design underlying the team-based STEM learning model.

More specifically, the findings are in line with Lee *et al.* [29], who emphasized that project-based learning can serve as a catalyst for integrated STEM education by helping students apply interdisciplinary knowledge to authentic problem situations. Similar results were reported by Tierney *et al.* [30], who found that project-based learning environments contribute to student engagement and the development of practical learning skills. In addition, Han *et al.* [31] showed that integrated STEM projects support deeper learning and the sustainable implementation of STEM education through authentic tasks, also demonstrated that collaborative project-based STEM activities improve communication and teamwork competencies. The present study extends these findings by showing that team-based STEM learning supported by digital projects can simultaneously improve professional competence, digital project development, teamwork, communication, and the practical application of STEM knowledge in higher education.

However, not all previous studies have reported uniformly positive effects of STEM and project-based learning interventions. For example, some researchers have noted that short-term STEM projects may improve engagement without producing substantial gains in higher-order competencies when instructional scaffolding is insufficient or teamwork is poorly structured. These findings suggest that the effectiveness of STEM interventions depends not only on project activities themselves but also on the quality of pedagogical design, assessment procedures, and collaborative learning support. The present study supports this interpretation by demonstrating that structured teamwork, role allocation, and competency-oriented assessment may contribute to stronger competence development outcomes.

The paired-samples t-test showed a statistically significant improvement in the experimental group after the intervention, $t(74) = 15.42$, $p < 0.001$. The effect size was large, Cohen's $d = 2.05$, indicating a strong practical effect of the team-based STEM learning and digital projects model on students' professional competence. In the control group, the improvement was statistically significant but smaller, $t(74) = 2.91$, $p = 0.005$, Cohen's $d = 0.39$. The independent-samples t-test showed no significant difference between the experimental and control groups at the pre-test stage, $t(148) = –0.60$, $p = 0.548$, but revealed a significant difference at the post-test stage, $t(148) = 12.53$, $p < 0.001$, Cohen's $d = 2.05$.

Overall, the findings suggest that the team-based STEM learning and digital projects model may serve as a promising instructional approach for supporting students' professional competence development. Its use contributes to:

- improving the level of students' professional competence;
- developing teamwork skills;
- developing digital project creation skills;
- improving the ability to apply knowledge in practical situations.

The use of team-based STEM learning with digital projects can be considered a promising instructional approach for preparing students for professional activity in the digital economy and modern educational environment.

With regard to the fourth research question, the findings indicate that several pedagogical conditions are necessary for the successful implementation of team-based STEM learning. These conditions include structured team formation, clearly defined project roles, authentic STEM-related digital tasks, competency-based assessment rubrics, continuous instructor feedback, and opportunities for reflection. The combination of these elements created a supportive learning environment that facilitated professional competence development.

IV. Conclusion

The findings of this study demonstrate that the proposed team-based STEM learning model supported by digital projects can effectively contribute to the development of students' professional competence in higher education. By integrating collaborative STEM problem-solving, structured digital project development, and competency-oriented assessment, the model provides a coherent instructional framework that supports improvements in STEM knowledge, practical application, teamwork, communication, digital project development, and reflective skills. Compared with

traditional instruction, students who participated in the intervention demonstrated substantially greater growth in professional competence, indicating the educational value of the proposed approach.

From a theoretical perspective, the study contributes to literature by integrating constructivist learning, project-based learning, and collaborative learning into a unified competency-oriented STEM framework. From a practical perspective, it offers a replicable model that can assist university instructors in organizing heterogeneous student teams, implementing authentic digital STEM projects, and applying competency-based assessment to strengthen students' professional readiness. The model may be adapted for engineering, computer science, teacher education, and other STEM-related higher education programs.

Several limitations should be acknowledged. The study was conducted at a single university with a relatively limited sample using a Quasi-experimental design; therefore, the findings should be interpreted as evidence of a positive association rather than definitive causality. Future research should involve larger multi-institutional samples, randomized experimental designs, and longer intervention periods to further examine the long-term effectiveness, generalizability, and transferability of the proposed model across different educational contexts.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Akbope Baimuratova, Anara Karymsakova, and Lili Nurliyana Abdullah conducted the literature search, analyzed the data and wrote the paper. Zhandos Zulpykhar and Meruert Serik visualized the data and reviewed the manuscript. All authors have accepted the final version of the manuscript.

REFERENCES

[1] S. Farias-Gaytan, I. Aguaded, and M. S. Ramirez-Montoya, "Digital transformation and digital literacy in the context of complexity within higher education institutions: A systematic literature review," *Humanities and Social Sciences Communications*, vol. 10, no. 1, 386, 2023. doi: 10.1057/s41599-023-01875-9

[2] J. Mattar, C. C. Santos, and L. M. Cuque, "Analysis and comparison of international digital competence frameworks for education," *Education Sciences*, vol. 12, no. 12, 932, 2022. doi: 10.3390/educsci12120932

[3] J. Cabero-Almenara, J. J. Gutiérrez-Castillo, F. D. Guillén-Gámez, and A. F. Gaete-Bravo, "Digital competence of higher education students as a predictor of academic success," *Technology, Knowledge and Learning*, vol. 28, no. 2, pp. 683–702, 2023. doi: 10.1007/s10758-022-09624-8

[4] A. Vercruyssen, W. Schirmer, N. Geerts, and D. Mortelmans, "How 'basic' is basic digital literacy for older adults? Insights from digital skills instructors," *Frontiers in Education*, vol. 8, 1231701, 2023. doi: 10.3389/feduc.2023.1231701

[5] H. H. Mira, R. Chaker, I. Maria, and H. Nady, "Review of research on the outcomes of embodied and collaborative learning in STEM in higher education with immersive technologies," *Journal of Computing in Higher Education*, vol. 37, no. 3, pp. 1161–1198, 2025. doi: 10.1007/s12528-024-09418-0

[6] V. Terzieva, E. Paunova-Hubenova, and S. Slavcheva, "Trends, challenges, opportunities, and innovations in STEM education," *IFAC-Papers Online*, vol. 58, no. 3, pp. 106–111, 2024. doi: 10.1016/j.ifacol.2024.07.134

[7] K. Bariyyah, S. Andrianie, R. D. Ariyanto, L. T. Soejanto, S. Setyorini, M. Oktasari, and I. Ifdil, "Shaping Future-Ready Learners: A Rasch Analysis of University Students' Digital Competence and Demographic Factors Using SDiCoS," in *Proc. 2025 11th International Conference on Education and Technology (ICET)*, 2025, pp. 366–374. doi: 10.1109/ICET67257.2025.11290902

[8] E. Perez, S. Manca, R. Fernández-Pascual, and C. McGuckin, "A systematic review of social media as a teaching and learning tool in higher education: A theoretical grounding perspective," *Education and Information Technologies*, vol. 28, no. 9, pp. 11921–11950, 2023. doi: 10.1007/s10639-023-11647-2

[9] S. Hamad, H. Tairab, Y. Wardat, L. Rabbani, K. AlArabi, M. Yousif, and G. Stoica, "Understanding science teachers' implementations of integrated STEM: Teacher perceptions and practice," *Sustainability*, vol. 14, no. 6, 3594, 2022. doi: 10.3390/su14063594

[10] P. L. Wu, "Effects of cooperative learning and situational simulation on nursing competence in clinical practice among nursing students: A quasi-experimental study," *Nurse Education Today*, vol. 144, 106464, 2025. doi: 10.1016/j.nedt.2024.106464

[11] M. Serik, G. Nurbekova, M. Mukhambetova, and Z. Zulpykhar, "Educational content and methods for big data courses," *World Transactions on Engineering and Technology Education*, vol. 20, no. 3, pp. 203–208, 2022.

[12] E. Milkova, M. Moldoveanu, and T. Krcil, "Sustainable education through information and communication technology: A case study on enhancing digital competence and academic performance of social science higher education students," *Sustainability*, vol. 17, no. 10, 4422, 2025. doi: 0.3390/su17104422

[13] I. Hovdar-Stojakovic, H. P. Steinbacher, M. Situm, and S. Märk, "Outlook and Future Developments," in *Innovative Teaching and Learning with Blended Learning*, Springer, 2026, Wiesbaden. doi: 10.1007/978-3-658-49213-7_8

[14] M. Rakhmetov, A. Sissenova, R. Moldasheva, A. Dautkulova, K. Uteuliyeva, and B. Orazbayeva "Methodological foundations of AI-driven distance learning platforms: Evidence from Learning analytics and structural Equation modeling," *Journal of Theoretical and Applied Information Technology*, vol. 104, no. 8, pp. 154–163, 2026.

[15] F. Beroíza-Valenzuela, N. Salas-Guzmán, and D. Huepe, "Bridging gaps: The role of gender and team composition in collective intelligence within STEM education," *Cogent Education*, vol. 12, no. 1, 2439655, 2025. doi: 10.1080/2331186X.2024.2439655

[16] G. Nurbekova *et al.*, "The use of information technology in preparation for international educational research," *Int. J. Inf. Educ. Technol.*, vol. 15, 8, pp. 1743–1751, 2025. doi: 10.18178/ijiet.2025.15.8.2375

[17] Z. Zulpykhar, M. Rakhmetov, B. Jugembayeva, D. Kapanova. and R. Zhilmagambetova, "Assessment using artificial intelligence in higher education: innovations and ethical challenges in the Ibero-American and Kazakh contexts—A mini-review," *Front. Educ.*, vol. 11, 1798126, 2026. doi: 10.3389/feduc.2026.1798126

[18] J. M. Fernández-Batanero, P. Román-Graván, M. Montenegro-Rueda, E. López-Meneses, and J. Fernández-Cerero, "Digital teaching competence in higher education: A systematic review," *Education Sciences*, vol. 11, no. 11, 689, 2021. doi: 10.3390/educsci11110689

[19] A. M. Abdo-Salloum and H. Y. Al-Mousawi, "Accounting students' technology readiness, perceptions, and digital competence toward artificial intelligence adoption in accounting curricula," *Journal of Accounting Education*, vol. 70, 100951, 2025. doi: 10.1016/j.jaccedu.2025.100951

[20] K. C. Margot and T. Kettler, "Teachers' perception of STEM integration and education: A systematic literature review," *International Journal of STEM Education*, vol. 6, no. 1, 2, 2019. doi: 10.1186/s40594-018-0151-2

[21] A. Žerovnik and I. N. Šerbec, "Project-Based Learning in Higher Education," in *Technology Supported Active Learning. Lecture Notes in Educational Technology*, Springer, 2021. doi: 10.1007/978-981-16-2082-9_3

[22] T. R. Kelley and J. G. Knowles, "A conceptual framework for integrated STEM education," *International Journal of STEM Education*, vol. 3, no. 1, 11, 2016. doi: 10.1186/s40594-016-0046-z

[23] T. D. Holmlund, K. Lesseig, and D. Slavit, "Making sense of 'STEM education' in K-12 contexts," *International Journal of STEM Education*, vol. 5, no. 1, 32, 2018. doi: 10.1186/s40594-018-0127-2

[24] M. Z. I. Pranjol and H. Akter, "Teaching Stem Subjects Through Project-Based Learning in a Global Classroom," in *Proc. 2025 IEEE Global Engineering Education Conference (EDUCON)*, 2025.

[25] C. Weerakoon, "Exploring the synergy of digital competence and photo-driven reflection: A pilot study on reflective thinking skill development in business education," *Cogent Education*, vol. 10, no. 2, 2282304, 2023. doi: 10.1080/2331186X.2023.2282304

[26] M. Carabregu-Vokshi, G. Ogruk-Maz, S. Yildirim, B. Dedaj, and A. Zeqiri, "21st century digital skills of higher education students during

Covid-19—Is it possible to enhance digital skills of higher education students through E-Learning?" *Education and Information Technologies*, vol. 29, no. 1, pp. 103–137, 2024. doi: 10.1007/s10639-023-12232-3

[27] F. Caena and C. Redecker, "Aligning teacher competence frameworks to 21st century challenges: The case for the European Digital Competence Framework for Educators (Digcompedu)," *European Journal of education*, vol. 54, no. 3, pp. 356–369, 2019. doi: 10.1111/ejed.12345

[28] L. Guttman, "A basis for scaling qualitative data," *American Sociological Review*, vol. 9, no. 2, pp. 139–150, 1944. doi: 10.2307/2086306

[29] M. Y. Lee and J. S. Lee, "Project-based learning as a catalyst for integrated STEM education," *Education Sciences*, vol. 15, no. 7, 871, 2025. doi: 10.3390/educsci15070871

[30] G. Tierney, C. Adams, and S. Ward, "In the service of student engagement: Project-based learning classrooms and teacher practices," *The Journal of Experimental Education*, vol. 93, no. 1, pp. 38–53, 2025. doi: 10.1080/00220973.2023.2287446

[31] J. Han, T. Kelley, and J. G. Knowles, "Building a sustainable model of integrated stem education: Investigating secondary school STEM classes after an integrated STEM project," *International Journal of Technology and Design Education*, vol. 33, no. 4, pp. 1499–1523, 2023. doi: 10.1007/s10798-022-09777-8

Copyright © 2026 by the authors. This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (CC BY 4.0).