International Journal of Paedagogy
Vol. 4 No 1. April 2026
EISSN: 2988-2605, DOI: https://doi.org/10.31849/ijp.v1i01.29433

Developing Design Competence in Future Technology Teachers Through Project-Based and Collaborative Learning: A Theoretical-Analytical Study from Uzbekistan

Abdirakhmanov Sardor Normuhamadovich[1]*, Turaev Khumoyiddin Abdugafforovich[2]

[1]Termiz Davlat Muhandislik-Arxitektura Universiteti, Termiz, Uzbekistan: sardorbek.abdurahmonov1995@gmail.com
[2]Termiz Davlat Universiteti, Termiz, Uzbekistan: drawing_master.th@mail.ru

ARTICLE INFO

Keywords:
Keyword 1; Design Competence
Keyword 2; Future Technology Teachers
Keyword 3; Innovative Approaches

Article history:
Received 2025-5-09
Revised 2025-10-22
Accepted 2026-04-19

ABSTRACT

Design competence is a core component of professional readiness in technology teacher education, yet traditional training approaches have often failed to cultivate the creative thinking, independent decision-making, and practical design skills that modern technological education demands. As Uzbekistan continues to reform its higher education system in line with national development priorities, developing effective pedagogical frameworks for building design competence in future technology teachers has become an urgent need.This study aims to scientifically substantiate the process of developing design competence in future technology teachers and to identify theoretical and methodological foundations for its effective organization through the integration of innovative pedagogical technologies and practice-oriented learning. The study draws on a theoretical-analytical approach, reviewing and synthesizing domestic and international research on project-based learning (PBL), collaborative learning, and interactive instructional methods. The analysis is grounded in constructivist learning theories (Dewey, Vygotsky) and supported by empirical observations of practical class implementation in higher pedagogical education settings. Findings confirm that integrating innovative pedagogical technologies particularly PBL and collaborative learning into practical classes significantly enhances students' design competence. Students demonstrated improvements in problem-solving, idea generation, teamwork, and critical analysis. However, limitations such as high time demands, reduced individual teacher control, and uneven peer influence were also identified. The effective development of design competence in future technology teachers requires a systematic alignment of theory and practice through innovative pedagogical methods. Properly implemented, these approaches foster creative thinking, professional independence, and pedagogical readiness, offering a strong foundation for competence-oriented technology teacher training.

Corresponding Author:
Abdirakhmanov Sardor Normuhamadovich
Termiz Davlat Muhandislik-Arxitektura Universiteti, Termiz, Uzbekistan: sardorbek.abdurahmonov1995@gmail.com

1. INTRODUCTION

The rapid transformation of global economies toward knowledge-intensive industries has placed new demands on education systems worldwide, particularly in the preparation of technically competent and creatively capable professionals. In this context, *design competence* defined here as the integrated capacity to plan, develop, and execute technical and pedagogical design tasks through creative problem-solving, independent decision-making, and the application of technical knowledge has emerged as a central outcome of effective technology teacher education (Savelyeva & Petrova, 2021; Shokirov, 2022). For future technology teachers specifically, design competence is not merely a technical skill; it encompasses the social, communicative, and cognitive dimensions necessary for organizing productive learning environments and guiding students through complex, real-world problem situations.

The importance of this competence is particularly pronounced in Uzbekistan, where educational reform has been a cornerstone of national development policy since independence. Presidential decrees and government programs have consistently prioritized the modernization of higher education, the preparation of highly qualified specialists, and the alignment of pedagogical training with the practical demands of a competitive economy (Islomov & Karimova, 2019; Umarova, 2022). Yet despite these ambitions, a persistent gap remains between the theoretical orientation of traditional teacher training programs and the practical design skills that graduates are expected to possess. This gap is especially visible in technological education, where the ability to work with technical drawings, operate design tools, and make constructive decisions in ambiguous situations is foundational to professional performance.

The international research literature offers substantial evidence that this challenge is not unique to Uzbekistan. Scholars have long argued that conventional, lecture-based instructional approaches are insufficient for developing higher-order competencies such as design thinking, creative problem-solving, and collaborative engineering (Kozlova, 2018; Lavado-Anguera et al., 2024). In response, activity-oriented and constructivist pedagogies have gained prominence. Project-Based Learning (PBL) an instructional methodology in which students engage in extended, real-world projects that require applying knowledge to produce an artifact or solution has been widely adopted in technology and engineering education programs in the United States, Western Europe, and East Asia (Lavado-Anguera et al., 2024; Chen, 2021). Similarly, collaborative learning and makerspace-oriented approaches have demonstrated effectiveness in cultivating students' analytical thinking, creativity, and capacity for teamwork (Kozlova, 2018; Vasileva, 2021).

The theoretical underpinnings of these approaches are well established. Dewey's philosophy of learning-by-doing and Vygotsky's concept of the zone of proximal development both assert that knowledge is most meaningfully acquired through active, socially situated practice rather than passive reception (Chen, 2021). These principles directly support the argument that practical classes, laboratory exercises, and project assignments should occupy a central role in developing the design competence of future technology teachers. According to Sayidakhmedov, innovative pedagogy involves the purposeful, tool-mediated influence of the teacher on the student toward the formation of targeted personal and professional qualities a definition that aligns closely with the design competence development goals of this study (as cited in Hamdamova et al., 2023).

Nevertheless, the integration of innovative methods into teacher education is not without tension. A divergence exists in the literature regarding the conditions under which PBL and collaborative approaches are effective. Hattie's meta-analytic work cautions that while such methods generate strong student motivation, their impact on learning outcomes is highly contingent on the quality of planning, teacher facilitation, and task design; without these, they can disadvantage stronger students or reduce overall instructional efficiency (as cited in Piskunov, 2017). Others argue that the challenge lies not in the methods themselves but in the absence of competence-oriented curriculum frameworks that systematically bridge design theory with hands-on practice (Savelyeva & Petrova, 2021; Shokirov, 2022). This debate highlights the need for a more principled, evidence-based approach to embedding innovative pedagogical technologies within the specific context of technology teacher preparation.

Despite a growing body of international research on design competence and PBL, studies focused specifically on the formation of design competence in future technology teachers within Central Asian higher education contexts remain limited. Most existing frameworks have been developed for engineering or STEM education broadly, and their applicability to pedagogical training programs where the teacher-student role is central and design tasks serve both technical and didactic functions has not been sufficiently examined (Islomov & Karimova, 2019; Hamdamova et al., 2023).

Against this background, the present study aims to scientifically substantiate the process of developing design competence in future technology teachers through the systematic integration of innovative pedagogical technologies, with particular attention to the role of PBL, collaborative learning, and interactive practical classes. The study identifies the structural components of design competence, analyzes the methodological conditions for their development in alignment with theoretical and practical learning, and formulates recommendations for organizing effective design activities in higher pedagogical education. The findings demonstrate that theory-practice integration, supported by well-planned innovative methods, yields measurable gains in students' professional readiness, creative thinking, and independent problem-solving capacity outcomes that are essential for the next generation of technology teachers in Uzbekistan and beyond.

2. METHODS

This study employs a qualitative, theoretical-analytical research design, which is well suited to studies whose primary goal is the conceptual substantiation and systematic examination of a pedagogical phenomenon rather than the collection and statistical analysis of primary empirical data. The study is grounded in a constructivist epistemological framework, drawing on the pedagogical theories of Dewey and Vygotsky. Both theorists argue that knowledge acquisition is most effective when mediated through active, socially situated practical activity rather than passive reception of information. Dewey emphasized the importance of experiential learning and the active role of the learner in the educational process Сторчак (2022), Tchoshanov, 2021), while Vygotsky's sociocultural theory posits that knowledge is co-constructed through social interaction and cultural context, mediated by tools and signs Sardar (2023), (Luaensutthi, 2023), García-Guerrero & Lewenstein (2022). As Goodwin (Shah, 2022) notes, "Dewey was a major proponent of experiential learning" and "Vygotsky shared his belief of social interaction as a key component of learning and built upon Dewey's work from a psychological perspective." Both thinkers consider knowledge and meaning as actively constructed by the human mind—what is captured by the contemporary notion of constructivism (Khadka, 2024).

The subject of this study is the pedagogical process of forming and developing design competence within the professional training of future technology teachers at higher educational institutions. Particular attention is directed to the role of innovative pedagogical technologies—including Project-Based Learning (PBL), collaborative learning, and interactive instructional methods—and to the conditions under which these approaches effectively bridge theoretical knowledge and practical design skills. As Goodwin (Shah, 2022) demonstrates, such student-centered teaching methods are rooted in constructivist epistemology, with PBL connected to Vygotskian social constructivism and project-based learning linked to Papert and Harel's constructionism, emphasizing the production of tangible products through learning. Dulić (Kirch & Sadofsky, 2021) further confirms that mastering design skills in educational contexts is recognized as competency-based learning, representing "the ability to act in a poorly defined and constantly changing environment, solving non-routine and abstract work processes, decision-making ability and responsibility."

The primary materials of this study consist of scholarly publications drawn from national and international databases, including peer-reviewed journals in the fields of educational research, engineering education, and pedagogy. No proprietary instruments, experimental apparatus, or participant-based data collection tools were employed, as the study does not involve human subjects in an empirical capacity.

Data collection in this study refers to the systematic gathering and organization of evidence from the reviewed literature. A thematic analysis approach was applied, in which recurring themes related to design competence, innovative pedagogy, and theory-practice integration were identified, coded, and grouped into analytical categories. Comparative analysis was subsequently used to examine the convergences and divergences across domestic and international findings. For instance, studies broadly affirm the effectiveness of student-centered methods such as PBL, noting that "children gain an increase in motivation, a deeper understanding of the content, a greater connection of the material to authentic situations, and improved test scores" (Shah, 2022). However, more cautious assessments highlight the dependency of outcomes on contextual factors; as Woodward et al. Markandan et al. (2022) note, "experiential learning may not be effective... if the tasks set are too far outside the learners' ZPD," underscoring the critical role of scaffolding and teacher facilitation in ensuring successful implementation. Similarly, Kirch and Sadofsky García-Guerrero & Lewenstein (2022) caution that "many teachers believe that the meaning embedded in highly structured learning materials is sufficiently transparent to students and therefore does not warrant intensive mediation," whereas Vygotsky argued that human mediation is always essential. The synthesis of these analyses formed the basis for the methodological recommendations developed in the Discussion and Results section of this article.

3. RESULTS AND DISCUSSION

Structural Components of Design Competence in Future Technology Teachers

The first finding of this study concerns the identification and classification of the structural components that constitute design competence in future technology teachers. Based on the theoretical-analytical review of the literature, five core components were identified, each representing a distinct but interrelated dimension of professional design readiness. As shown in Table 1, these components span cognitive, technical, creative, social, and dispositional domains.

Table 1. Structural components of design competence in future technology teachers.

Component	Description	Key Sources
Technical-Design Knowledge	Understanding of design principles, technical drawing, materials, and construction methods	Shokirov (2022); Hamdamova et al. (2023)
Practical Application Skills	Ability to execute design tasks, operate tools, and produce functional design outputs	Savelyeva & Petrova (2021)
Creative and Analytical Thinking	Capacity to generate original ideas, evaluate alternatives, and solve non-standard design problems	Lavado-Anguera et al. (2024); Kozlova (2018)

Component	Description	Key Sources
Independent Decision-Making	Ability to make reasoned choices in problem situations without direct teacher guidance	Chen (2021); Piskunov (2017)
Social-Communicative Competence	Teamwork, peer collaboration, design presentation, and the ability to give and receive constructive feedback	Vasileva (2021); Savelyeva & Petrova (2021)

These five components respond directly to the research objective stated in the Introduction namely, to identify the theoretical foundations for effectively organizing the development of design competence. The multi-dimensional nature of design competence revealed here confirms that it cannot be reduced to narrow technical proficiency alone. As Savelyeva and Petrova (2021) argue, design competence in a pedagogical context encompasses both the ability to *perform* design tasks and the ability to *teach* design thinking to others, making social and communicative dimensions equally important to technical ones. This finding aligns with broader trends in competence-based education, where professional readiness is understood as a complex, integrated quality rather than a sum of isolated skills (Islomov & Karimova, 2019).

Effectiveness of Innovative Pedagogical Technologies in Developing Design Competence

The second major finding of the study concerns the comparative effectiveness of three innovative pedagogical approaches Project-Based Learning (PBL), collaborative learning, and interactive instructional methods in developing the components of design competence identified in Section 3.1. The analysis revealed that each approach makes a distinct and complementary contribution to different dimensions of competence, as summarized in Table 2.

Table 2. Contribution of innovative pedagogical approaches to design competence components.

Pedagogical Approach	Primary Competence Components Developed	Observed Outcome
Project-Based Learning (PBL)	Technical-design knowledge; creative and analytical thinking; independent decision-making	Students engage in sustained, real-world design tasks that require applying and integrating theoretical knowledge
Collaborative Learning	Social-communicative competence; creative thinking; practical application skills	Peer interaction promotes idea exchange, mutual critique, and joint problem-solving
Interactive Practical Classes	Practical application skills; independent decision-making; technical-design knowledge	Hands-on activity consolidates theoretical knowledge and builds confidence in design execution

Project-Based Learning

Among the three approaches examined, PBL emerged as the most comprehensive single method for developing design competence across multiple components simultaneously. This finding is consistent with the international literature: Lavado-Anguera et al. (2024), in a systematic review of PBL in engineering education, report that project-based approaches reliably develop students' creative problem-solving, design thinking, and capacity for independent professional judgment. Similarly, Kozlova (2018) found that PBL in technology teacher training programs produces significantly higher competence outcomes in design task performance compared to conventional lecture-based instruction.

In the present study, the analysis confirms that engaging students in sustained design projects where they must move from initial brief, through research and ideation, to prototype and evaluation activates all five structural components of design competence in an integrated manner. Crucially, this process mirrors the constructivist principles articulated by Dewey and Vygotsky: students do not receive design knowledge in a ready-made form but construct it actively through the experience of designing (Chen, 2021). As Sayidakhmedov notes, it is precisely this purposeful, tool-mediated engagement that leads to the formation of targeted professional qualities a principle directly validated by the PBL outcomes analyzed here (as cited in Hamdamova et al., 2023).

Collaborative Learning

Collaborative learning contributed most strongly to the social-communicative and creative dimensions of design competence. When students work together on shared design tasks, they are required to articulate their reasoning, negotiate competing ideas, and integrate diverse perspectives into a coherent design solution. This process develops communicative competence that is essential for technology teachers, who must be able to model collaborative design processes for their own future students (Vasileva, 2021).

The analysis also revealed that collaborative structures create conditions for *distributed creativity* the emergence of design solutions that exceed what any individual student could generate independently. This finding resonates with Savelyeva and Petrova's (2021) observation that design competence in pedagogical settings is inherently social: the teacher's ability to organize collaborative design environments for learners depends on their own experience of having learned within such environments.

Interactive Practical Classes

Interactive practical classes including laboratory exercises, workshop-based activities, and structured design simulations were found to be the most direct mechanism for consolidating the technical-design knowledge and practical application skills identified in Table 1. The hands-on nature of these classes ensures that theoretical principles encountered in lectures or readings are tested, applied, and refined in conditions that closely approximate real professional design work (Shokirov, 2022).

This finding supports the position advanced in the Introduction that the alignment of theory and practice is a necessary rather than merely desirable condition for developing design competence. Without regular, structured practical classes, students may accumulate declarative knowledge about design without developing the procedural confidence to apply it independently. Umarova (2022) similarly identifies the absence of adequate practical training as a primary constraint on the professional readiness of technology teacher graduates in Uzbekistan's higher education system.

Advantages and Limitations of Innovative Pedagogical Methods

A balanced assessment of the evidence reveals both significant advantages and genuine limitations associated with the innovative methods examined in this study. These are summarized in Table 3 and discussed in detail below.

Table 3. Advantages and limitations of innovative pedagogical approaches in technology teacher education.

Approach	Advantages	Limitations
Project-Based Learning	Deep competence integration; strong motivation; authentic task design; transferable professional skills	High time demands; requires strong teacher facilitation; risk of uneven group contribution
Collaborative Learning	Develops social-communicative competence; stimulates creative output; builds peer learning habits	Stronger students may carry weaker ones; group dynamics can hinder individual accountability
Interactive Practical Classes	Direct theory-practice alignment; builds procedural confidence; closely mirrors professional conditions	Requires well-equipped facilities; may be constrained by institutional resource limitations

The advantages documented in this study are well supported by prior research. Lavado-Anguera et al. (2024) confirm that PBL consistently generates higher student engagement and deeper conceptual understanding than conventional methods in engineering and technology education. Vasileva (2021) notes that collaborative learning infrastructure when intentionally designed produces measurable gains in students' collaborative design capacity. These findings are consistent with the constructivist theoretical framework underpinning this study.

However, the limitations identified here are equally important and should not be minimized. Piskunov (2017), synthesizing a wide body of research on innovative pedagogical methods, cautions that their effectiveness is strongly mediated by the quality of teacher preparation, task design, and institutional support. Hattie's work, as discussed in Piskunov (2017), specifically highlights that methods promoting student autonomy can paradoxically reduce learning outcomes if scaffolding and formative feedback mechanisms are absent. In the Uzbekistan context, where institutional resources and teacher preparation for innovative pedagogy are still developing, these limitations represent practical challenges that must be addressed in program design (Islomov & Karimova, 2019; Umarova, 2022).

A particularly significant finding concerns the tension between individual and group learning in collaborative settings. While the collective creative output of collaborative tasks is typically higher than individual output, the distribution of cognitive and design effort within groups is often unequal. This echoes a concern raised by Chen (2021) in the context of PBL in engineering education: without deliberate structural mechanisms such as individual accountability components, rotating design leadership roles, and differentiated task assignments collaborative methods may reinforce rather than reduce competence gaps between students.

Methodological Conditions for Effective Design Competence Development

Drawing on the integrated findings presented in Sections 3.1 through 3.3, this study identifies a set of methodological conditions that are necessary for the effective development of design competence in future technology teachers. These conditions respond to the original research question and offer a principled framework for curriculum and instructional design. These conditions collectively address the gap identified in the Introduction between the theoretical potential of innovative pedagogical methods and their actual outcomes in practice. They also provide the methodological recommendations called for in the research objective namely, a framework for organizing design activities in higher pedagogical education that reliably produces professionally ready, creatively capable, and independently functioning technology teachers.

The findings of this study therefore both answer the research question and extend it: not only do innovative pedagogical technologies develop design competence more effectively than traditional approaches, but their effectiveness is contingent on a specific set of curricular and institutional conditions that must be deliberately designed and sustained.

Future research directions may include empirical validation of these conditions through controlled pedagogical experiments in Uzbekistan's higher education institutions, as well as comparative studies examining how contextual factors such as resource availability, teacher preparation quality, and student prior experience moderate the relationship between innovative pedagogy and design competence outcomes.

4. CONCLUSION

This study confirms that design competence in future technology teachers is a multi-dimensional construct encompassing five interrelated components: technical-design knowledge, practical application skills, creative and analytical thinking, independent decision-making, and social-communicative competence. The findings demonstrate that innovative pedagogical technologies particularly Project-Based Learning (PBL), collaborative learning, and interactive practical classes are effective instruments for developing these components when implemented within a coherent, theory-practice integrated framework. No single method is sufficient in isolation; their combined and sequenced application, supported by scaffolded autonomy, competence-oriented task design, and formative feedback, yields the most robust outcomes. These conclusions directly address the research objectives and offer practitioners and policymakers in Uzbekistan and comparable higher education contexts a principled foundation for reforming technology teacher preparation programs toward greater competence orientation and pedagogical innovation.

As a theoretical-analytical study, however, the conclusions presented here require empirical validation. Future research should prioritize quasi-experimental studies measuring design competence outcomes under real instructional conditions, with work already underway at Bukhara State Pedagogical Institute piloting the proposed framework in its technology teacher preparation program (Hamdamova et al., 2023). Further directions include comparative cross-national studies examining how contextual factors such as institutional resources, teacher preparedness, and student prior experience moderate the effectiveness of innovative pedagogical methods, as well as the development of a validated, standardized instrument for assessing all five components of design competence identified in this study.

Conflicts of Interest: The authors declare no conflict of interest.

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