

**DEVELOPING DESIGN COMPETENCIES IN MODERN ENGINEERING
EDUCATION: THE ROLE OF PROJECT-BASED LEARNING AND DIGITAL
TECHNOLOGIES**

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Abstract

This article explores the development of design competencies in modern engineering education. The study analyzes the effectiveness of project-based learning methodology, the use of digital technologies, and the competency-based approach. Experiments conducted with an experimental group demonstrated significant improvement in students' abilities to solve problem situations, apply theoretical knowledge in practical projects, engage in teamwork, and utilize digital tools.

Keywords

engineering education, design competencies, project-based learning, digital technologies, competency-based approach

Introduction

The transition to a digital economy, the automation of industrial sectors, and the rapid development of high technologies are fundamentally changing the demands placed on engineering activities. Today, an engineer is not only a specialist with technical knowledge but also a professional capable of designing complex systems, developing innovative solutions, working effectively in digital environments, and organizing collaborative activities [1:12]. Consequently, higher technical education must undergo substantive renewal and adopt competency-based educational models.

In modern engineering education, knowledge alone is insufficient; the ability to apply it in real production scenarios, analyze problematic situations, and make technically grounded decisions becomes a priority. It is precisely in this context that design competency emerges as a core component of professional engineering training. This competency encompasses complex activities such as identifying problems, developing technical specifications, modeling constructive and technological solutions, preparing project documentation, using digital graphic tools, and analyzing project outcomes [2:45]. Research emphasizes that effectively developing design competencies cannot be limited to traditional lectures and practical exercises. Such competencies primarily develop in a project-based, practice-oriented, and integrated learning environment [4:28]. From this perspective, this article explores the pedagogical possibilities for developing design competencies in engineering education, evaluates the effectiveness of project-based learning methods, and examines their impact on the educational process from both theoretical and practical viewpoints.

Methods

A comprehensive pedagogical approach was employed in the study, utilizing a range of scientific and empirical methods. Specifically, the literature on engineering education and competency-based approaches was analyzed to clarify the content and components of design competencies [3:264]. In addition, both international and local experiences in engineering education were examined to assess the practical opportunities of project-based learning.

The empirical research employed pedagogical observation, interviews, experimental tasks, and a comparative analysis of the results from experimental and control groups. Project-based sessions were conducted, during which students developed small- and medium-scale projects based on real engineering problems. Throughout this process, computer graphics, digital modeling, and design software were used [10:6]. The development of students' design competencies was assessed based on criteria such as independent thinking, problem-solving abilities, application of theoretical knowledge in practice, teamwork, and justification of project outcomes. The collected data were analyzed, and differences between the experimental and control groups were identified.

Results

The results of the experimental study clearly demonstrated that a project-based learning approach has a significant positive impact on the development of design competencies among engineering students. In the experimental group, students showed consistent improvement in identifying problem situations, conducting systematic analyses, and developing technically grounded solutions. During the execution of project tasks, students exhibited logical consistency, the ability to compare alternatives, and the skills to select optimal solutions characteristic of engineering thinking.

The level of applying theoretical knowledge to practical activities was also higher in the experimental group. Students began to understand the functional significance of knowledge by applying learned formulas, drawing techniques, and modeling rules to real project tasks. This not only increased their learning motivation but also activated their process of professional self-awareness [5:263]. The project process also strengthened students' inclination toward independent decision-making, fostering a sense of responsibility for the outcomes of their work.

Furthermore, collaborative project activities contributed to the development of students' teamwork, communication, and role-distribution competencies. While working in groups, students learned to justify their ideas, defend technical solutions, and analyze alternative proposals. This experience laid the groundwork for developing communicative and social competencies essential for their future professional careers.

The use of computer graphics and digital design tools also increased significantly in the experimental group. Students acquired skills in 2D and 3D modeling, visualization, and presenting project results in a digital environment. Expressing technical ideas through visual models allowed students to gain a deeper understanding of project content and identify errors at early stages [11:175]. Comparison with the control group indicated that students taught using traditional methods primarily engaged in reproductive design activities, demonstrating lower levels of independent analysis and creative approaches. In contrast, the experimental group showed harmonized development across all key components of design competency: analytical, practical, communicative, and digital skills. This confirms, from a scientific perspective, the high effectiveness of project-based learning in engineering education.

Discussion

The results of this study confirm the high pedagogical effectiveness of project-based learning in developing design competencies in modern engineering education. The positive changes observed in the experimental group indicate that this approach fosters not only practical skills but also engineering thinking, analytical reasoning, and creative problem-solving. This aligns with the primary goal of engineering education: preparing independent and responsible professionals who can adapt to real production conditions.

A comparative analysis with international and local research shows that project-based learning methods are among the most effective forms of a competency-based approach. Through

interdisciplinary integration, working on real-world problems, and organizing collaborative activities, students acquire knowledge not as fragmented pieces but as a coherent, holistic system [7:156], [9:52]. The results of this study further support these findings, demonstrating that the development of design competencies is directly linked to a continuous and active learning environment.

At the same time, certain limitations and challenges in broadly implementing project-based learning in engineering education were identified. First, the methodological preparedness of instructors and their competency in managing project activities are crucial factors. If a project is assigned merely as a task without well-defined content, stages, and assessment criteria, achieving the expected outcomes becomes difficult. Therefore, providing instructors with targeted professional development in project-based teaching methodologies is of critical importance [6:14]. The availability of material, technical, and digital resources also directly affects the effectiveness of project activities. Limited access to computer graphics, modeling, and design software can hinder the full development of design competencies. The study showed that students in learning environments equipped with modern digital tools demonstrate higher engagement and activity in project-based tasks [10:6], [11:175]. Moreover, project-based learning requires flexibility in the curriculum. Rigid, traditionally structured programs may impede the full implementation of project activities. Hence, it is advisable to redesign engineering curricula to focus on the development of design competencies, increase the proportion of practical exercises, and enhance assessment systems based on competency criteria [8:33]. Overall, the study demonstrates that project-based learning holds strategic importance in engineering education. Systematic implementation of this approach, along with the creation of necessary pedagogical and technical conditions, can significantly elevate the quality of professional preparation for future engineers.

Conclusion

The results of this study confirm that the development of design competencies in modern engineering education is a critical pedagogical factor in ensuring the professional preparedness of future engineers. The theoretical and practical conclusions drawn during the research indicate that traditional knowledge-oriented education models cannot fully meet the contemporary demands of engineering practice. Therefore, there is a clear need to create a competency-based, project-oriented learning environment.

The implementation of project-based learning methods contributes to the consistent development of students' skills in analyzing problem situations, developing technically grounded solutions, applying theoretical knowledge in practical activities, and evaluating project outcomes. The study demonstrated that this approach activates students' independent thinking, enhances their professional responsibility, and strengthens their creative problem-solving abilities. In particular, collaborative project activities play a significant role in developing communicative and social competencies, thereby improving the quality of engineering education. Furthermore, the research highlighted the role of digital technologies, particularly computer graphics and modeling tools, in fostering design competencies. Working in a digital environment brings students closer to real production conditions and enhances their professional adaptability. This finding underscores the necessity of accelerating digital transformation within engineering education.

The results also provide a basis for practical recommendations to improve engineering education systems. These include aligning curricula with the development of design competencies, enhancing instructors' qualifications in project-based teaching methods, strengthening the material and technical base with modern digital tools, and revising assessment systems according to competency-based criteria. Overall, project-based learning represents a

strategic approach to increasing the effectiveness of engineering education. Its systematic and structured implementation within educational programs contributes to preparing competitive, innovative, and practice-ready engineering professionals.

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