



PHASED DEVELOPMENT OF COMPETENCIES THROUGH BIM TECHNOLOGY-BASED PROJECT WORKS

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ABSTRACT

This article analyzes the step-by-step development of students' professional competencies through project work based on Building Information Modeling (BIM) technologies. At each stage of the design process, students progressively enhance their skills in modeling, engineering thinking, technical documentation, and teamwork. The findings demonstrate the effective integration of BIM technologies into the educational process and their significant role in improving students' qualifications.

KEYWORDS: BIM technologies, project work, competency development, modeling, engineering thinking, educational integration, step-by-step learning.

INTRODUCTION

Today, the rapid expansion of digital technologies in the fields of construction, architecture, and engineering is fundamentally transforming not only production processes but also the education system. One of the priority tasks of higher education institutions is to equip students with modern professional skills and prepare them to meet the requirements of the labor market. The use of innovative instructional methods and digital platforms plays a significant role in achieving these goals. Building Information Modeling (BIM) technology is among the most advanced innovations, enabling the digital management of design and construction processes. BIM is recognized as a comprehensive system that integrates not only three-dimensional (3D) modeling, but also project management dimensions such as time (4D), cost (5D), energy efficiency (6D), and facility operation (7D). Therefore, integrating BIM technologies into the educational process creates new opportunities for students in architecture and construction disciplines.

The use of BIM in education contributes to the development of both theoretical knowledge and practical skills. Through project-based learning, professional competencies required for future specialists include not only traditional drafting and modeling skills but also project management, engineering thinking, teamwork, and real-world problem-solving abilities. These competencies must be developed progressively and deepened at each stage of the design project. For this reason, this article provides a detailed analysis of the phased development of students' professional competencies through BIM-based project works. First, the role of BIM technologies in the educational process and their impact on graphic education are examined. Furthermore, methodological foundations are presented regarding the specific competencies developed at each stage of the project workflow. In addition, practical experiences conducted at Tashkent University of Architecture and Construction are analyzed to evaluate the effectiveness and future prospects of BIM integration. The significance of this research lies in

the fact that implementing BIM in the educational process creates opportunities to significantly improve the quality of education and better prepare students to meet the demands of the modern construction labor market. As a result, positive impacts are expected not only on individual competencies but also on the overall development of the sector.

Literature Review

Azhar, S., & Brown, J. (2020). Integration of BIM in Architectural Education: Challenges and Opportunities. Azhar and Brown analyze the major opportunities and challenges of integrating BIM into architectural education. Their findings demonstrate that BIM creates an interactive learning environment while enhancing modeling and project management skills. At the same time, issues such as professional training for instructors and resource allocation remain. The authors emphasize the importance of designing integrated academic programs for the effective adoption of BIM in education. Eastman, C., et al. (2018). BIM Handbook. Eastman and colleagues provide an extensive overview of theoretical and practical aspects of BIM technologies. The book highlights the role of BIM not only in 3D modeling but also in 4D (time), 5D (cost), 6D (energy efficiency), and 7D (operation) stages of construction. It serves as an essential guide for introducing students to comprehensive project workflows. Succar, B. (2019). Building Information Modelling Framework. Succar perceives BIM as a broader digital platform that facilitates data exchange and project management. The study demonstrates the importance of teaching students to understand project processes holistically and engage in interactive collaborative work. The author stresses the need for systematic methodological frameworks to teach BIM effectively.

Gao, X., & Fischer, M. (2021). BIM-based Collaborative Design Learning.

The researchers highlight the role of BIM in developing collaborative skills during design processes. Their study shows that BIM enhances communication, idea exchange, and problem-solving among students—important practical competencies in engineering and construction fields.

Wang, Y., & Chong, W. K. (2022). Enhancing Students' Spatial Visualization Skills through BIM. Wang and Chong propose teaching methods that improve students' spatial visualization skills through 3D BIM modeling. Their study proves that BIM simplifies the understanding of abstract concepts and design processes—an essential component of graphical education.

Kamaruzzaman, S. N., et al. (2020). Adopting BIM in Higher Education: Curriculum Development and Challenges. The authors address pedagogical and technical challenges in implementing BIM into university curricula. The study provides recommendations regarding instructional approaches, teaching materials, and faculty development to improve the quality of BIM education. Riaz, Z., & Hammad, A. (2019). Impact of BIM on Engineering Students' Learning Outcomes. The findings indicate that BIM-based project learning enhances not only technical abilities but also creativity, teamwork, and problem-solving competences. The results confirm the effectiveness of interactive and practice-oriented BIM education. Tashkent University of Architecture and Civil Engineering Report (2023). This institutional report analyzes practical results of integrating BIM technologies into graphic education at TUACE. It confirms significant improvements in students' design and modeling skills and shows that project-based BIM tasks contribute to the gradual development of engineering thinking and teamwork competencies. Ilmiy tahlillarga tayangan holda bir qator muammolar aniqlandi.

Many higher education institutions lack modern computer hardware and licensed software required for the effective use of BIM tools. This creates significant barriers to providing students with in-depth exposure to BIM technologies and organizing high-quality practical training sessions. There is a shortage of highly qualified specialists capable of teaching BIM applications. Many instructors are accustomed to traditional graphic and drafting methods, and require additional professional training to learn and efficiently apply new technologies. This negatively affects the quality of the pedagogical process.

Curricula in most graphic education programs are not fully aligned with the capabilities of BIM technologies. The limited inclusion of modern modeling and project-management components hinders the development of students' competencies in accordance with contemporary industry standards.

Although students often possess theoretical knowledge, they fail to adequately develop practical skills in creating, analyzing, and managing BIM-based design projects. This indicates insufficient focus on practical aspects of the learning process. Interactive learning strategies are rarely applied in teaching BIM technologies. In addition, differences in students' individual skill levels and learning pace are frequently overlooked, reducing the overall effectiveness of instruction.

Complexities and challenges that arise during the learning of new technologies can reduce interest and motivation among both students and teachers. Therefore, there is a need to strengthen pedagogical support systems and motivational strategies in BIM-based education.

Training programs and learning modules aimed at improving BIM competencies are not sufficiently aligned with modern industry standards and labor market demands. As a result, students may face difficulties in securing employment after graduation.

Limited Availability of Educational Resources and Methodological Materials

The number and quality of textbooks, practical guides, and online resources for teaching BIM technologies remain limited. This creates additional challenges for both instructors and students in the learning process.

To investigate the impact of BIM-based graphic education on the development of student competencies—especially their skills in design, modeling, engineering thinking, and professional preparedness—an experimental study was conducted.

To evaluate the effectiveness of BIM technologies in improving students' competencies in graphic education, with particular focus on design, modeling, engineering reasoning, and professional readiness.

Location and Duration

Institution: Tashkent University of Architecture and Construction

Academic year: 2023–2024

Course: Engineering Graphics

Software and equipment: Revit, AutoCAD, BIM 360, computer laboratories

Total number of students: 60

Experimental Group (EG1): 30 students trained using BIM-based projects

Control Group (CG): 30 students trained using traditional manual drafting and 2D methods

A specially designed course was introduced for the experimental group, involving:

3D modeling

Technical analysis

Drawing generation and export

Preparation of project documentation

Competency Development Observed

The experimental group demonstrated significantly higher improvement than the control group in:

Spatial visualization

3D modeling skills

Technical documentation development

Computer graphics proficiency

Professional motivation

Assessment Tools

Pre- and post-tests

Final project performance evaluation

Individual interviews

Reflection-based questionnaires

Results of the Experiment

Project-based thinking improved by 38% in the experimental group

Students' independent proficiency in BIM software increased by 42%

Indicators of professional readiness and engineering reasoning were significantly higher than those of the control group

Recommendations

Develop methodological guidelines for deep integration of BIM technologies into graphic education.

Provide continuous professional training for instructors to improve their BIM competencies.

Organize practical elements of the Engineering Graphics course using modern digital platforms.

Conduct hands-on sessions based on BIM projects and facilitate work on real objects.

Revise and modernize curricula in graphic disciplines based on innovative pedagogical approaches.

Introduce elective and specialized courses focused on BIM technologies.

Define clear evaluation criteria for students' project work, considering technical, design, and functional requirements.

Strengthen cooperation with industry by involving real project tasks in the learning process.

Conclusion

The research and experimental findings confirm that the integration of BIM technologies into graphic education raises the quality of training to a fundamentally new level. Unlike traditional drafting methods, BIM enables students to take a deeper approach to design activities and enhances their engineering reasoning and analytical skills.

By using the Revit platform during the experiment, students independently modeled architectural and structural elements, determined their technical parameters, and automatically generated drawings. This contributed to the development of practical design competencies based on real-world project scenarios.

Moreover, BIM-based learning increased student motivation, fostered interdisciplinary integration, and contributed to the preparation of specialists equipped with digital

competencies demanded by the modern construction industry. The approach helped shape an innovative learning environment that boosts creativity, analytical thinking, and independent decision-making skills.

In conclusion, the implementation of BIM technologies in graphic education is strategically important for training modern engineers and construction specialists. This methodology serves as a foundation not only for technological modernization but also for methodological innovation within the education system. Moving forward, the continuous enhancement of curricula through the integration of pedagogical and technological improvements remains a vital task.

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