



MODERN APPROACHES TO THE DEVELOPMENT OF PROGRAM-DIDACTIC SUPPORT FOR THE FORMATION OF PROGRAMMING COMPETENCE

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Abstract

The modern challenges of digital transformation in education require new solutions for the formation of programming competence among engineering students. This paper presents the development and testing of program-didactic support aimed at integrating programming with engineering disciplines and the use of digital tools. As the methodological basis, Python, MathCad, Excel, and Word were applied, along with the ITTS educational portal and an electronic textbook, which ensured the implementation of blended and distance learning formats.

The experimental verification was conducted in universities of Uzbekistan with first-year students divided into control and experimental groups. In the control groups, teaching was carried out using traditional methods, while in the experimental groups, the developed methodology was applied. The results demonstrated a steady increase in students' competence across cognitive, motivational, activity-based, and reflective components. Statistical data processing using Student's t-test confirmed the reliability of differences between the groups. Additionally, the survey revealed an increase in motivation and the development of reflective skills among students in the experimental groups.

The conclusions indicate that the proposed methodology contributes to the development of algorithmic thinking, research activity, and readiness for professional work in the digital economy. The practical significance of the study lies in its applicability for modernizing curricula in engineering universities and creating digital educational courses.

Keywords: Programming; competence; engineering education; digital educational environment; program-didactic support; methodological approaches; experimental study; cognitive component; motivational component; activity-based component; reflective component.



Introduction

In the context of digital transformation in education, programming has become one of the key competencies determining the professional readiness of future engineers and technical specialists. The development of the digital economy requires university graduates not only to possess basic programming skills but also to be able to integrate them into solving applied engineering problems, which makes the issue of forming programming competence particularly relevant [1].

Modern research in pedagogy and computer science emphasizes the need to move away from traditional teaching methods focused on syntax and solving standard computational tasks toward more comprehensive approaches that include interdisciplinary connections, project-based activities, and the use of digital educational platforms [2]. Russian scholars highlight the importance of systemic and activity-based approaches to programming education, which enable students to develop algorithmic thinking and independent problem-solving skills [3]. International studies focus on gamification, the use of online platforms, and interactive tasks, which contribute to increased motivation and student engagement [4]. Uzbek researchers also stress the necessity of introducing modern digital tools and adapting methodologies to the national educational environment [5].

Despite the accumulated experience, several problems remain unresolved: insufficient student motivation, limited use of digital resources in the learning process, weak integration of programming with engineering disciplines, and the absence of unified methodological models that ensure comprehensive development of programming competence [6]. These gaps create a contradiction between the requirements of the digital economy and the actual level of university graduates' training.

The aim of this study is to develop and test program-didactic support aimed at forming programming competence among engineering students. To achieve this aim, the following objectives were set:

- to analyze modern approaches to programming education in engineering education;
- to develop a methodological model integrating programming with engineering disciplines;
- to implement digital tools and educational platforms in the learning process;
- to conduct a pedagogical experiment and evaluate the effectiveness of the proposed methodology.



Thus, this study is part of the broader issue of digital transformation in engineering education and is aimed at finding practical solutions to improve the quality of specialist training.

1. Materials and Methods

The study was conducted in the format of a pedagogical experiment, the purpose of which was to determine the effectiveness of the developed program-didactic support in forming programming competence among engineering students. The experimental base included several universities in Uzbekistan: Bukhara State University, Gulistan State University, Samarkand State University of Architecture and Construction, and Jizzakh Polytechnic Institute. First-year students participated in the study, divided into control and experimental groups.

In the control groups, teaching was carried out using traditional methods, while in the experimental groups, the author's methodology was applied, based on the integration of programming with engineering disciplines and the use of digital tools [7]. As the software basis, the following tools were used: Python for algorithmization and modeling of engineering tasks [8]; MathCad for performing mathematical calculations [9]; as well as Excel and Word for data processing and preparation of reports [10]. Additionally, the ITTS educational portal and an electronic textbook were employed, ensuring the organization of blended and distance learning [11].

The experiment consisted of three stages. At the preparatory stage, teaching materials, the electronic textbook, and test assignments were developed. The main stage involved conducting classes in control and experimental groups, where students solved applied engineering problems using digital tools. The final stage included summative testing, student surveys, and statistical analysis.

To verify the reliability of the results, Student's t-test was applied, which made it possible to identify statistically significant differences between the control and experimental groups [12]. Additionally, methods of pedagogical observation and questionnaires were used to identify changes in student motivation and the level of development of reflective skills [13][14]. As the methodological foundation, modern approaches to engineering pedagogy [15], concepts of digital didactics [16], and studies on active methods of programming education [17][18] were taken into account. All procedures are described in chronological order, ensuring the possibility of reproducing the experiment in other engineering universities. The software tools used



are publicly available, and the educational portal and electronic textbook can be adapted for various disciplines, which makes the proposed methodology universal and applicable in the context of modernizing engineering education.

2. Results

During the pedagogical experiment, data were collected reflecting the level of programming competence formation among students in the control and experimental groups.

Table 1 contains the averaged indicators across four components of competence (cognitive, motivational, activity-based, and reflective).

Competence Component	Control Group (mean value)	Experimental Group (mean value)
Cognitive	3.42	4.18
Motivational	3.55	4.21
Activity-based	3.58	4.12
Reflective	3.65	4.16

Figure 1 illustrates the dynamics of competence growth among students in the experimental groups compared to the control groups.

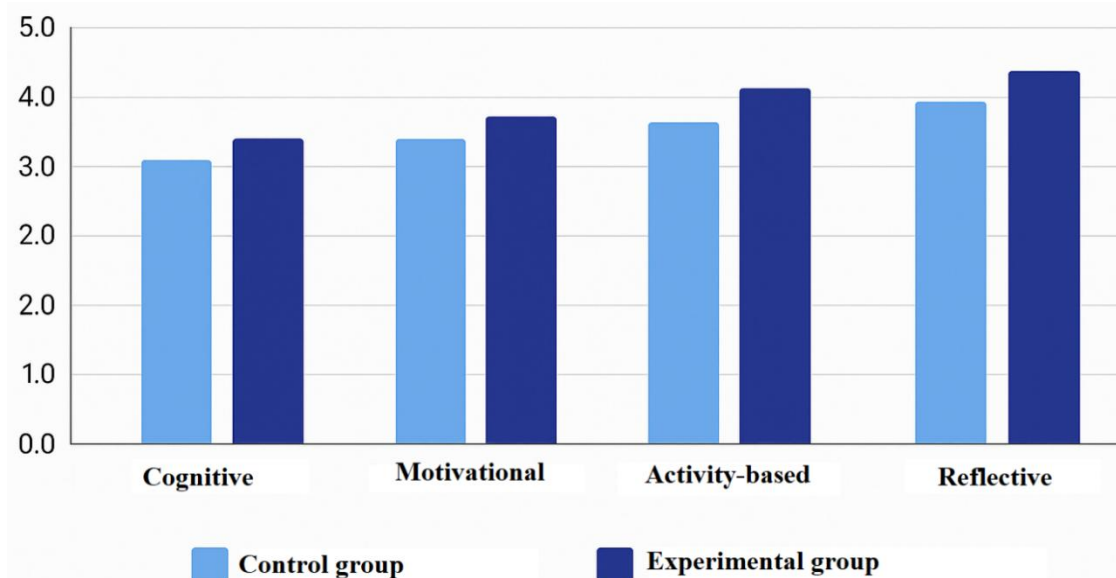


Figure 1. Dynamics of competence growth among students in the experimental groups



Student's t-test was applied to statistically verify the differences. The obtained values were significant at the level of $p < 0.05$, confirming the reliability of the identified differences [19].

Additionally, a student survey was conducted, and the results are presented in Table 2.

Table 2. Indicators of motivation and reflection

Indicator of Motivation and Reflection	Control Group (%)	Experimental Group (%)
Satisfaction with the learning process	62	84
Awareness of personal mistakes	58	79
Readiness for independent work	61	82

The survey revealed higher indicators of motivation and reflective skills among students in the experimental groups.

Thus, the presented results confirm positive changes in the level of competence among students who were taught using the developed methodology.

3. Discussion

The aim of this study was to develop and test program-didactic support aimed at forming programming competence among engineering students. The obtained results confirm the hypothesis that the integration of digital tools and interdisciplinary connections contributes to more effective development of key competence components.

The main findings include a statistically significant increase in cognitive, motivational, activity-based, and reflective components among students in the experimental groups. These data are consistent with the conclusions of several international and national studies emphasizing the effectiveness of active and digital forms of programming education [20][21][22]. In particular, the works of Galarce-Miranda and Rüttemann confirm that digital didactics and engineering pedagogy enhance student motivation and independence [16][14].

Factors that contributed to the successful implementation of the methodology include:

- adaptation of digital tools to the engineering context;
- use of the ITTS educational portal and electronic textbook;



- stepwise organization of the experiment, taking into account students' level of preparation.

Among the limitations of the study, the following can be noted:

- limited geographical coverage (mainly universities in Uzbekistan);
- absence of long-term monitoring of results;
- need for adaptation of the methodology to other technical disciplines.

The practical significance of the study lies in the possibility of integrating the developed model into curricula of engineering universities, as well as in the creation of digital courses focused on the development of algorithmic thinking and research activity.

For future research, the following directions appear promising:

- expanding the sample and including universities from other regions;
- developing adaptive digital platforms with elements of gamification;
- studying the impact of the methodology on graduates' professional readiness.

Thus, the results of the study confirm the relevance and effectiveness of the proposed approach and open opportunities for further development of digital engineering didactics.

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