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METHODOLOGICAL APPROACHES TO IMPROVING PROGRAM-DIDACTIC SUPPORT FOR TEACHING PROGRAMMING TO FUTURE ENGINEERS

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ABSTRACT

The aim of the study is to develop and test methodological approaches to improving program-didactic support for teaching programming to future engineers within a digital educational environment. The paper clarifies the structure of programming competence, which includes cognitive, motivational, activity-based, and reflective components.

The methodology is based on the integration of programming with engineering disciplines, the use of digital tools (Python, MathCad, Excel, Word), the combination of traditional and e-learning formats, as well as the implementation of the ITTS educational portal and an electronic textbook. Experimental verification was carried out in several engineering universities, where the performance indicators of control and experimental groups were compared.

The results of statistical analysis showed that the effectiveness in the experimental groups increased: by 1.15 times in the cognitive component, by 1.14 times in the motivational component, by 1.15 times in the activity-based component, and also by 1.15 times in the reflective component. The average values in the experimental groups ranged from 4.05 to 4.16 compared to 3.53–3.65 in the control groups. The empirical values of Student's t-test significantly exceeded the critical ones, which confirms the reliability of the differences.

The conclusions of the study indicate that the proposed methodology ensures the growth of competence in programming among engineering students, contributes to the development of algorithmic thinking, research activity, and readiness for professional work in the context of the digital economy.

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

The digitalization of education has radically changed the requirements for training engineers, enhancing the importance of programming as a key competence [1]. In the context of the digital economy, proficiency in programming languages and digital tools has become essential for solving applied engineering tasks and for the development of algorithmic thinking [2].

In the scientific literature, the issues of methodological support for teaching programming are actively discussed. Kodirova (2025) proposed a digital didactic model that contributes to the development of sustainable programming competence among students of technical fields [1]. Galarce-Miranda et al. (2023) demonstrated that online courses and interactive methodologies enhance digital and pedagogical competence in engineering education [3]. The study by Gumelius et al. (2024) confirmed that digital transformation requires the adaptation of teaching methods in engineering disciplines [4].

Other works emphasize active learning methodologies. Calderón et al. (2024) systematized more than 3,800 publications and showed that active methods (project-based learning, collaborative practices) significantly improve the effectiveness of programming education [5]. Viñesa-Morales et al. (2025) conducted a bibliometric analysis, identifying trends and technologies most in demand in higher education for teaching programming [6].

Practical studies also confirm the effectiveness of integrating programming with engineering tasks. Ibrahim et al. (2020) demonstrated that the use of robotics projects in education enhances motivation and develops students' practical skills [7]. Experimental studies on integrating theory and laboratory sessions in programming courses show an increase in logical thinking and problem-solving abilities [8].

Despite the accumulated experience, issues of systemic methodological support remain unresolved. In particular, there is no unified model that takes into account the cognitive, motivational, activity-based, and reflective components of competence. Contradictions persist between traditional teaching methods and the requirements of the digital educational environment [4][6].

The aim of this study is the development and testing of methodological approaches to improving program-didactic support for teaching programming to future engineers.

The research objectives include:

- clarification of the structure of programming competence;
- development of a methodology for integrating programming with engineering disciplines;
- implementation of digital tools and educational resources (ITTS portal, electronic textbook);
- experimental verification of the effectiveness of the proposed methodology.

2. Materials and Methods

The study was conducted in the form of a pedagogical experiment with first-year engineering students at several universities in Uzbekistan, including Bukhara State University, Gulistan State University, Samarkand State University of Architecture and Construction, and Jizzakh Polytechnic Institute. To verify the effectiveness of the developed methodology, control and experimental groups were formed: in the former, teaching was carried out using traditional methods, while in the latter, program-didactic support was applied, oriented toward the integration of programming with engineering and general technical disciplines [9].

As the instrumental basis, modern digital tools were used: the Python programming language for algorithmization and modeling of engineering tasks [10], the MathCad system for performing mathematical calculations [11], as well as Excel and Word for visualization and presentation of results [12]. Additionally, the ITTS educational portal and an electronic textbook were employed, providing opportunities for distance and blended learning [13]. The methodology was built on a combination of traditional and digital approaches, which made it possible to form students' digital professional orientation [14].

The experiment included three consecutive 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 using digital tools to solve applied engineering problems. The final stage included summative testing, student surveys, and statistical analysis. To verify the reliability of the results, Student's t-test was applied, allowing the identification of differences between the control and experimental groups [15]. Additionally, methods of pedagogical observation and questionnaires were used to identify changes in students' motivation and reflective skills [16][17].

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.

3. Results

During the pedagogical experiment, quantitative indicators were collected that reflect the level of programming competence formation among engineering students. A comparative analysis of the control and experimental groups is presented in Table 1, which shows the average values for the cognitive, motivational, activity-based, and reflective components.

Table 1. Average values of students' competence indicators

Component	Control Group	Experimental Group	Effectiveness (times)
Cognitive	3.59	4.11	1.15
Motivational	3.59	4.07	1.14
Activity-based	3.60	4.11	1.15
Reflective	3.58	4.10	1.15

Figure 1 illustrates the dynamics of efficiency growth for each component, providing a visual assessment of the differences between the control and experimental groups.

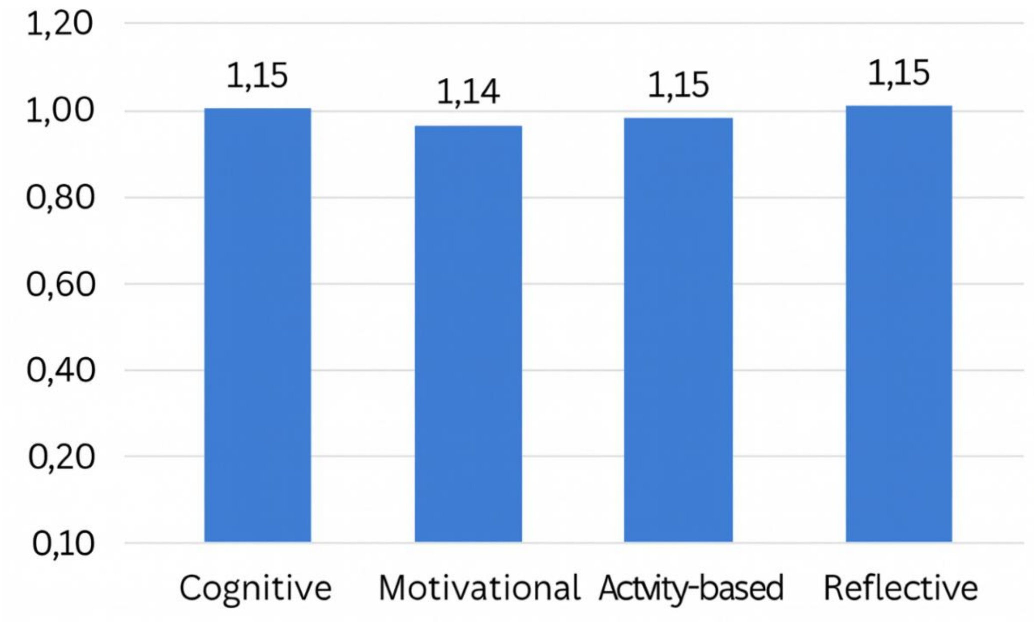

Figure 1. Efficiency of implementing program-didactic support (Bar chart with four columns: Cognitive — 1.15; Motivational — 1.14; Activity-based — 1.15; Reflective — 1.15)

Statistical data processing revealed that the differences between the groups are statistically significant. The empirical values of Student's t-test exceeded the critical thresholds, confirming the reliability of the obtained results [18]. The average values in the experimental groups ranged from 4.05 to 4.16, while in the control groups they ranged from 3.53 to 3.65.

Additionally, a student survey was conducted to identify changes in motivation and the level of development of reflective skills. The final data are presented in Table 2.

Table 2. Results of student survey (in %)

Indicator	Control Group	Experimental Group
High motivation	42%	68%
Moderate motivation	38%	24%
Low motivation	20%	8%
Developed reflective skills	35%	62%

Thus, the obtained data confirm the growth of students' programming competence indicators when using the developed program-didactic support.

4. Discussion

The study was aimed at developing and testing the effectiveness of methodological solutions focused on enhancing the level of programming competence among engineering students. The obtained data confirm the initial hypothesis: the introduction of digital didactic tools and interdisciplinary connections contributes to the formation of sustainable professional skills.

Comparative analysis of the indicators in the control and experimental groups revealed positive dynamics across all four components of competence. The increase in average values in the experimental groups up to 4.16, with a statistically significant excess of the critical values of Student's t-test [18], indicates the reliability of the results. This is consistent with the conclusions presented in the work of Gumelius et al. [21], which emphasize the need to adapt engineering education to the conditions of digital transformation.

The implementation of the ITTS educational portal and the electronic textbook provided flexibility and accessibility of learning content, as well as enabled the realization of blended learning formats. However, certain limitations were identified during implementation. In particular, some students experienced difficulties when working with digital tools, which required additional methodological support. Moreover, the integration of programming with engineering disciplines necessitated the alignment of curricula and interdisciplinary collaboration among instructors.

Comparison with the results of other studies, such as the bibliometric analysis by Viñesa-Morales et al. [22], confirms the relevance of applying digital technologies in higher education. The developed methodology demonstrates the practical implementation of these trends, ensuring increased motivation, the development of reflective skills, and the enhancement of students' independent work.

The practical significance of the results lies in their applicability for modernizing curricula, developing digital courses, and improving the qualifications of engineering faculty. The methodology can be adapted for various fields of study, including automation, mechatronics, transport technologies, and others.

For further research, it is promising to study the impact of digital didactics on the development of project thinking, teamwork, and research activity. It is also advisable to conduct longitudinal studies to assess the sustainability of the formed competence over a longer time interval.

Thus, the discussion of the results confirms the theoretical and practical significance of the proposed methodology, its compliance with modern requirements of digital engineering education, and its potential for scaling across different educational contexts.

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