

Article

# Implementing Problem-Based Learning To Enhance Students' Algorithmic Competence

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**Abstract:** This article explores the implementation of problem-based learning (PBL) technology to enhance students' algorithmic competence, a critical skill in the field of computer science and education. Despite the recognized importance of algorithmic competence, there remains a gap in effective teaching methodologies that engage students and foster deep understanding. This study employed a mixed-methods approach, incorporating both qualitative and quantitative data from pedagogical experiments conducted among second-year students at the Navoi State Pedagogical Institute. The findings indicate that PBL significantly improves students' ability to understand and apply algorithms, with the experimental group showing a 9.8% higher mastery rate compared to the control group. The results suggest that integrating PBL into the curriculum can activate cognitive processes, enhance creative thinking, and promote teamwork. These implications highlight the potential of PBL as a transformative educational strategy in developing essential algorithmic skills in students.

**Keywords:** : Students, Algorithmization, Lecture Training, Algorithmic Competence, Problem-Based Learning, Problem-Based Assignments.

## 1. Introduction

“Programming languages”, “Modern programming languages”, elective subjects related to algorithms and programming are of great importance among the subjects that are taught as professional subjects in the training of future teachers of “Informatics and Information Technologies” in pedagogical universities. our republic is enough. Algorithmization of various processes, the content of these subjects includes the programming languages Scratch, Python, S++, Delphi, S++ Builder, Java, which are used for algorithmization of mathematical examples and problems, performing numerical calculations based on algorithms, various applications, pedagogical software allows you to prepare tools, database management projects and web applications. When developing these applications, the development of algorithmic competence of students of pedagogical universities is of current importance. [1-5].

Therefore, improving the forms, methods and tools of the educational process aimed at developing students' algorithmic competence

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is considered one of the important issues in pedagogical higher education institutions. Therefore, it is necessary to improve the system of organization of algorithm training, including lecture training, in higher education institutions.

**Literature review.** By providing theoretical information in lectures on algorithmization and programming, students are focused on increasing motivation for algorithmization of examples and problems and their programming, developing logical and algorithmic thinking, and developing creative abilities to develop various projects [5-7]. Therefore, special attention was paid to the use of problem-based learning technology, which is one of the modern approaches, when organizing lectures on algorithmization. The use of problem-based educational technologies is effective in developing students' knowledge, skills, competencies and competencies in the algorithmization of various processes.

So the purpose of the study was to use problem-based learning technology in the development of algorithmic competence of students at pedagogical universities.

In this regard, studies of the methodology for using problem-based educational technology in the system of lifelong education in our country, the CIS countries and abroad were carried out by such scientists as L.V. Pilipets, E.Yu. Nikitina, D.N. Butorin, G.K. Selevko, Semra Sungur, Nurullizam Jamiat, Gary J. Hill.

According to these scientists, "problem-based educational technology is one of the types of developmental education, the content of which consists of a system of problematic tasks of varying complexity. In the course of their implementation, students acquire new knowledge and ways of acting. In this process, students' creative abilities such as imagination, cognitive motivation, algorithmic and effective thinking are formed" [8-10].

At the same time, problem-based learning implies a set of interrelated actions, such as the formation of problem situations and tasks based on the formation of problem problems and situations, control of students over the solution of these problems, verification of solutions, systematization and consolidation of acquired knowledge.

In this regard, according to Zh.O. Tolipova, "problem-based educational technologies are used to increase the level of knowledge acquisition by students, bringing skills to the level of competence, in which the student analyzes educational material, compares, synthesizes, generalizes." Information and receives new information. In other words, he

applies previously acquired knowledge and skills in new situations, deepens and expands knowledge” [10]. According to Semra Sungur, “problem-based learning increases students’ motivation and interest in science, develops algorithmic and cognitive thinking” [11]. According to Gary Hill, “Problem-based learning involves creating a problem situation and implementing a true creative process by guiding the search for a solution to the problem. Therefore, understanding, acceptance and resolution of these problematic situations occur with the independence of students, but under the general guidance of a professor-teacher in the process of joint interaction” [12].

At the same time, I.Yu. Lerner, T.V. Kudryavtsev, Yu.K. Babansky, F.Yu. Tokhirov also expressed their opinion on the possibilities of problematic educational technologies and their use.

In particular, I. Yu. Lerner believes that the essence of problem-based education lies in “student participation in solving new cognitive and practical problems in a certain system under the guidance of a professor, consistent with the educational goals of a higher educational institution” [13] ; p. 114]. T.V. Kudryavtsev considers “the problem-based educational process as setting didactic tasks for students, solving them and mastering the principles of generalizing knowledge and problematic tasks” [14; p. 49]. According to F. Ya. Tokhirov, “one of the most effective ways to develop students’ algorithmic thinking, including algorithmic thinking about programming, is problem-based learning, since it is close to creative activity and is characterized by the use of hypotheses, evidence and experiments.” In problem-based learning, the teacher does not convey knowledge in a ready-made form, but sets a task for the student, interests him, and makes him want to find a solution. In searching for these tools and methods, the student acquires new knowledge. In this process, students develop logical and algorithmic thinking” [15]. Similar concepts are reflected in the studies of Yu.K. Babansky [16; p. 78].

M.I. Makhmutov also proposes a method of problem-based learning for the development of algorithmic thinking and algorithmic competence. According to him, “problem situations are created taking into account the peculiarities of science. In this case, a problematic situation is created in accordance with the acquired knowledge of students. In this case, students come to a conclusion that contradicts the facts. At the same time, additional information is needed to eliminate the contradiction that has arisen. This view of a problem situation arouses great interest among students. Therefore, the efficiency of this process is high” [17].

## 2. Materials and Methods

The methodology employed in this study to evaluate the effectiveness of problem-based learning (PBL) in developing students' algorithmic competence involved a comprehensive experimental design. The research was conducted at the Navoi State Pedagogical Institute among second-year students enrolled in the "Mathematics and Computer Science" course. The study comprised 114 students, divided into experimental and control groups. The experimental group was taught using PBL strategies, while the control group received traditional lecture-based instruction. To ensure a robust analysis, the methodology included a detailed process of creating problem situations that required algorithmic solutions, thereby engaging students in active learning.

Initially, theoretical information on search algorithms and sample algorithms was provided to the students. The professor guided the experimental group through creating and solving problem situations, using algorithmic computer programs to enhance understanding. During the first stage, students were given theoretical data and pre-prepared sample algorithms. In the second stage, they encountered semi-independent activities, where they had to identify and correct flaws in incomplete algorithms. This approach fostered a deeper engagement with the material, requiring students to apply their knowledge to new situations.

For the independent activity stage, students created algorithms for moderately complex problems with minimal guidance. In the final creative activity stage, students were challenged to independently develop algorithms for more complex problems, requiring a high level of logical and algorithmic thinking. To measure the effectiveness of PBL, a mathematical and statistical analysis was conducted using the Student-Fisher test, comparing the performance of the experimental and control groups. The results demonstrated a significant improvement in the experimental group, confirming the hypothesis that PBL enhances algorithmic competence. This methodology provides a structured approach to integrating PBL in educational settings, offering practical insights into its application and benefits.

### 3. Results

In our opinion, problem-based methods are based on the active cognitive activity of students, which consists in creating problem situations, updating knowledge, analyzing, searching and solving complex problems that require the ability to see events and patterns behind individual facts. A professor-teacher creates a problem situation, guides students to solve it, and organizes a search for a solution. In the process of finding a solution, the student acquires new knowledge and masters new methods of action.

Problem-based learning is a method that actively involves students in solving real or simulated problems, stimulating their analytical, critical thinking, collaboration and communication skills. Using this technology, students' algorithmic competence can be effectively developed.

Problem-based learning ensures students' active participation in the learning process. Instead of just passively receiving information, they actively participate in problem solving and research [10].

The problems presented by problem-based learning are usually practical, allowing students to see their knowledge and skills directly applied in the real world. This encourages them to learn and understand algorithms [10].

Problem-based learning helps students develop critical thinking. They encourage analyzing information, searching for solutions, evaluating alternatives, and making informed decisions [15].

The use of problem-based learning technology in the development of students' algorithmic competence allows us to create a stimulating and interactive environment that promotes a deepening of understanding of the material and the development of skills necessary for the successful application of algorithms in real situations [7].

Based on the results of the analysis of the works of the above-mentioned scientists, we can conclude that it is advisable to use problem-oriented educational technologies when conducting lectures on the development of algorithmic competence of students.

In this regard, in the research of F. Ya. Tokhirov, depending on the type of interaction between teachers and students, he conventionally identifies four levels of problem-based education: 1. Stage of non-independent activity. 2. Stage of semi-independent activity. 3. Stage of independent activity. 4. Stage of creative activity [7].

Therefore, based on these stages, a methodology was developed for using problem-based educational technology in the development of students' algorithmic competence (on the topic of search algorithms).

1. Stage of non-independent activity. In this case, the professor-teacher provides students with theoretical information about search algorithms and pre-prepared sample algorithms. Presenting and algorithmic computer programs can be used to provide these theoretical data and algorithms.

Information technology makes learning more interesting and interactive. Algorithm visualization, simulations, and other technical tools help students better understand complex concepts and apply them in practice [2].

For example, an algorithm for the following problem is presented:  $x$  and  $y$  ( $x < y$ ) are positive and integers. Algorithm for finding odd numbers from  $x$  to  $y$  and their sum (see Figure 1).

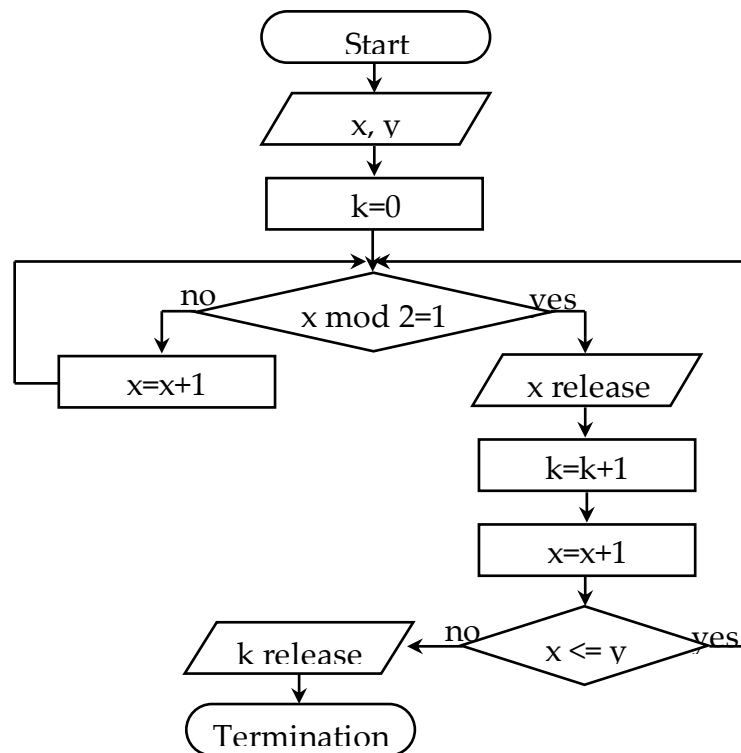


Figure 1. Block diagram of the algorithm

2. Stage of semi-independent activity. At this stage, only a part of the algorithm of examples and problems related to the topic is presented in an incomplete state. In this, students try to find the algorithm flaw based on creating a problem situation related to algorithmization. For example, a part of the algorithm for the following problem is presented: given a natural number  $n$ . Algorithm for finding natural divisors of number  $n$  (see Figure 2).

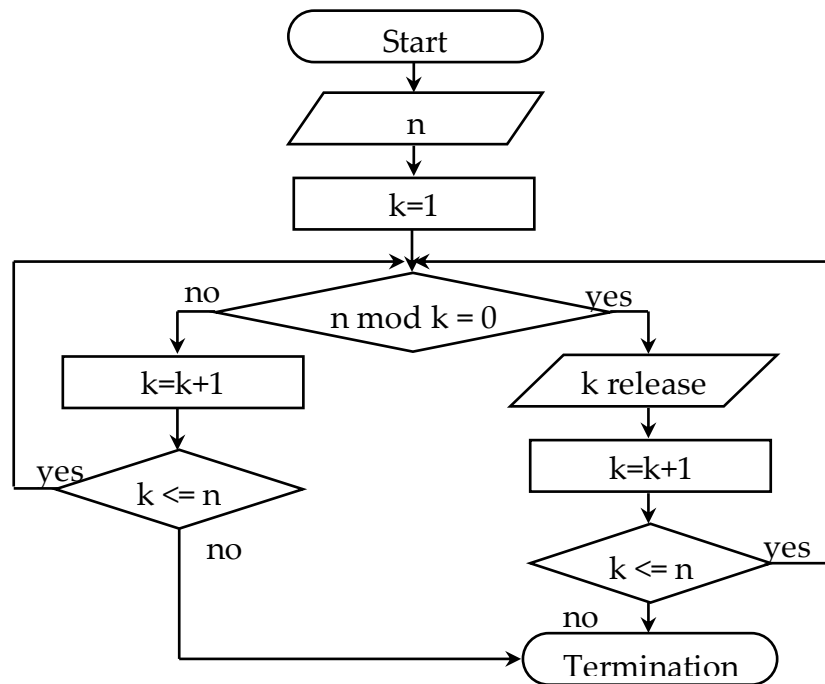


Figure 2. Block diagram of the algorithm.

3. Stage of independent activity. In this process, students use the acquired knowledge in new situations. Students who engage in independent algorithmic learning often develop more enthusiasm and interest in the learning process, which encourages their active participation and learning.

In this case, students create an algorithm of average complexity, the professor-teacher hardly gives any recommendations. For example, a task is given to create an algorithm for the following problem: a natural number  $n$  is given. Create an algorithm for finding whether the number  $n$  is prime or not (see Figure 3).

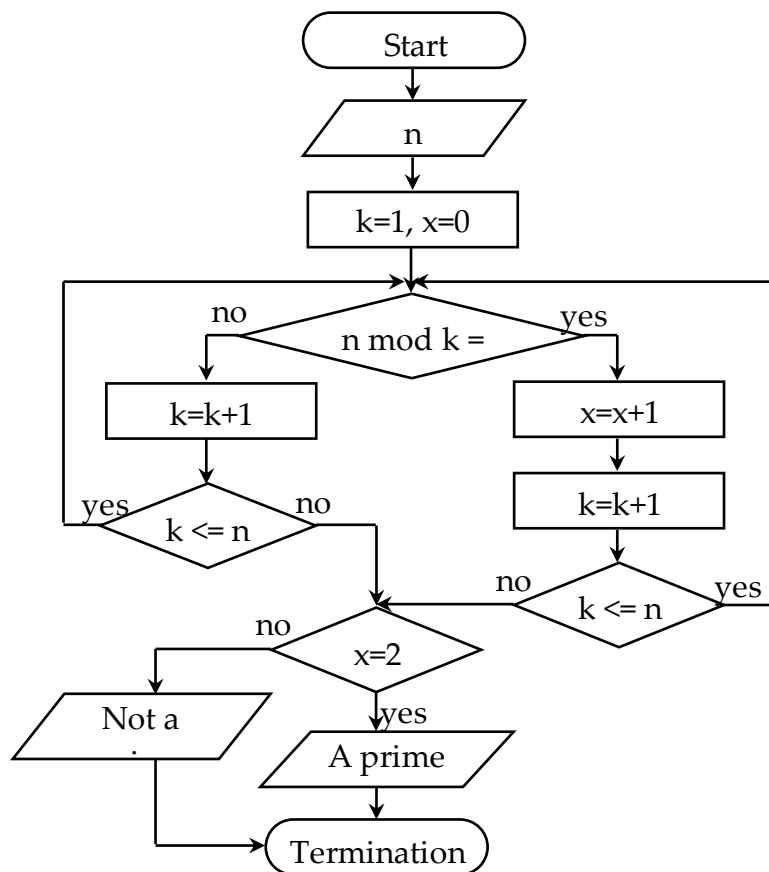


Figure 3. Block diagram of the algorithm.

4. Stage of creative activity. In this process, a creative approach, performing independent work that requires algorithmic and logical thinking, finding new ways to solve a given problem, and independent proof are carried out [15]. At this stage, students look for a solution to the task given by the professor and take a creative approach to this process. Creative thinking helps to find new and original approaches to solving problems. At this stage, the task of creating an algorithm for the following problem can be given: natural numbers  $a$  and  $b$  are given. Create an algorithm that determines whether numbers  $a$  and  $b$  are mutually friendly numbers (see Figure 4).

Students are required to create an algorithm of the problem independently. A student who can find friendly numbers in the above problem can create an algorithm for the problem.

Friendly numbers are natural numbers, each of which is equal to the sum of its different natural divisors. For example, 220 and 284 are friendly numbers. Natural divisors of 220: 1, 2, 4, 5, 10, 11, 20, 22, 44, 55, 110; the sum of these is equal to 284. Natural divisors of the number 284: 1, 2, 4, 71, 142; their sum is equal to 220 [18].

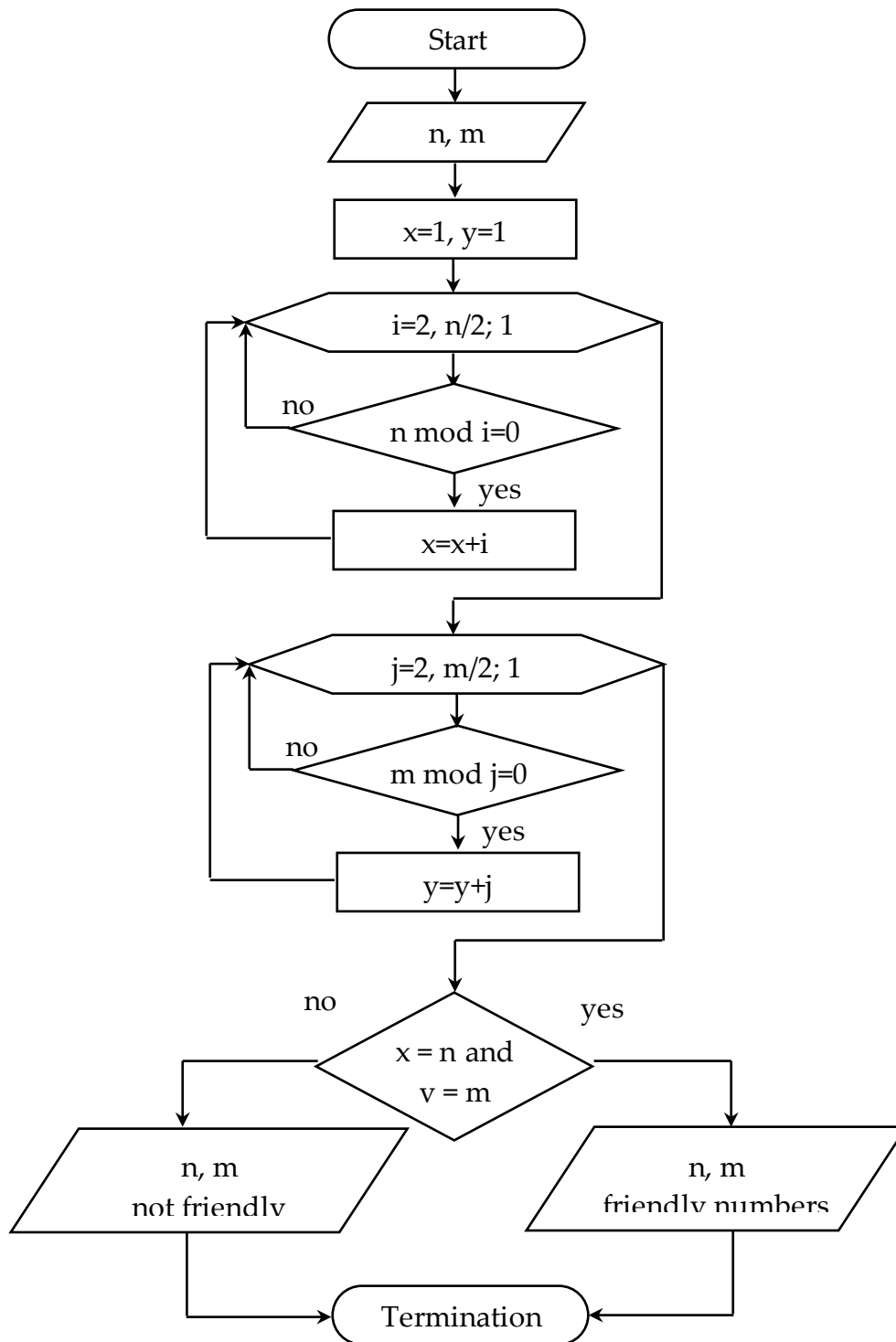


Figure 4. Block diagram of the algorithm.

The above steps can be applied to all algorithmic topics.

This sequence helps to more effectively use problem-based learning technology in lectures to develop students' algorithmic competence.

In order to determine the effectiveness of the methodology developed as part of the study, pedagogical experiments were conducted. The experiments were conducted among 2nd year students of the "Mathematics and Computer Science" course at the Navoi State

Pedagogical Institute. A total of 114 students were involved in the experimental and control groups.

At the end of the experiment, a mathematical and statistical analysis was carried out based on the Student-Fisher test in order to verify the reliability of the results of students in the experimental and control groups.

When using this criterion, suitable mean values for samples

$$\bar{X} = \frac{1}{n} \sum_{i=1}^4 n_i X_i, \text{ dispersion coefficients } D_n = \sum_{i=1}^3 \frac{n_i (x_i - \bar{X})^2}{n-1}, \text{ mean}$$

square deviations  $\tau_n = \sqrt{D_n}$ , variation indices  $\delta_n = \frac{\tau_n}{\bar{X}}$ , reliable

deviations of assessment  $\Delta_n = t_{ku} \cdot \frac{D_n}{\sqrt{n}}$ , and formulas

$$P = \frac{\bar{X}}{3} \cdot 100\% - \frac{\bar{Y}}{3} \cdot 100\% \text{ were used to determine the mastery indices.}$$

According to the calculation result, it was found that the average mastery rate of the experimental group was higher than the control group, i.e. it increased by 9.8%.

#### 4. Discussion

The study concluded that the implementation of problem-based learning (PBL) significantly enhances students' algorithmic competence, as evidenced by the 9.8% higher mastery rate in the experimental group compared to the control group. This improvement highlights the effectiveness of PBL in engaging students in active learning, fostering critical thinking, and developing problem-solving skills. The findings suggest that integrating PBL into educational curricula can stimulate cognitive processes, enhance creative thinking, and promote teamwork, making it a promising approach for pedagogical practices. Future research should explore the long-term effects of PBL on algorithmic competence and its applicability across different educational contexts and subjects.

## 5. Conclusion

The study concluded that the implementation of problem-based learning (PBL) significantly enhances students' algorithmic competence, as evidenced by the 9.8% higher mastery rate in the experimental group compared to the control group. This improvement highlights the effectiveness of PBL in engaging students in active learning, fostering critical thinking, and developing problem-solving skills. The findings suggest that integrating PBL into educational curricula can stimulate cognitive processes, enhance creative thinking, and promote teamwork, making it a promising approach for pedagogical practices. Future research should explore the long-term effects of PBL on algorithmic competence and its applicability across different educational contexts and subjects.

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