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DEVELOPING STUDENTS' SCIENTIFIC THINKING THROUGH THE APPLICATION OF PROBLEM-BASED TEACHING TECHNOLOGIES IN PHYSICS EDUCATION

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Abstract. *This article analyzes the issues of developing students' scientific thinking through the use of problem-based teaching technologies in the process of physics education. The problem-based learning approach is considered an important didactic tool in forming students' independent thinking, analytical skills, and scientific research abilities. By integrating the theoretical and practical aspects of physics, ways to increase students' cognitive activity and develop their problem-solving competencies are examined. In addition, the effectiveness of organizing lessons based on modern pedagogical technologies and their impact on the quality of education are highlighted.*

Keywords: *physics education, problem-based teaching, scientific thinking, pedagogical technologies, independent thinking, competencies.*

Introduction. In the modern education system, one of the most relevant pedagogical issues is not the mechanical memorization of knowledge by students, but the development of competencies in understanding, analyzing, and applying them in practical situations. This approach is identified as a key direction in 21st-century educational concepts [1; 2]. In this regard, many pedagogical scholars, including J. Dewey, L. Vygotsky, J. Bruner, and P. Galperin, have scientifically justified the necessity of organizing the learning process as an active cognitive activity. Modern research also shows that the problem-based learning approach contributes to students' independent knowledge construction [3; 5]. Since physics explains natural phenomena and reveals their laws, it plays a special role in the formation of students' scientific thinking. However, in practice, the traditional approach often dominates, and students are limited to applying ready-made formulas. This restricts their creative thinking and ability to independently solve problem situations [4]. Problem-based teaching technology is a modern pedagogical approach aimed precisely at addressing this issue. According to this approach, students do not receive knowledge in a ready-made form but independently discover it through the process of exploring a problem. This process includes stages of scientific activity such as observation, hypothesis formulation, experimentation, and drawing conclusions [3; 5]. Recent studies confirm that problem-based teaching technologies have a positive impact on the effectiveness of education [6; 7]. In particular, the use of innovative pedagogical technologies in physics education plays an important role in developing students' scientific thinking [8]. The main purpose of this study is to scientifically substantiate the effectiveness of developing students' scientific thinking through the application of problem-based teaching technologies in physics education.

Research Methods. During the research process, a system of complex scientific-pedagogical methods was used. These included theoretical analysis, pedagogical observation, questionnaires, interviews, and experimental testing methods [3; 4]. In the theoretical analysis stage, the didactic foundations of problem-based teaching technology, its impact on cognitive development, and its role in the formation of scientific thinking were studied. In addition, Vygotsky's "zone of proximal development," Dewey's concept of "learning by doing," and Bruner's theory of discovery learning were analyzed as methodological foundations [3; 5]. During the pedagogical observation process, students' activity in physics lessons, their response to problem situations, level of independent thinking, and logical analysis skills were examined [7; 8]. Through questionnaires and interviews, the attitudes of teachers and students toward problem-based learning, as well as their views on its advantages and challenges, were collected [6; 7]. The experimental work was conducted with the participation of 9th–10th grade students. During the experiment, lessons were organized based on problem situations, real-life physical phenomena, experiments, and tasks requiring independent solutions [4; 8].

Results. The results of the study showed that problem-based teaching technology significantly increases students' cognitive learning activity in physics education. Students in the experimental group demonstrated a higher level of activity compared to traditional lessons. These findings are consistent with contemporary research on the effectiveness of problem-based teaching [3; 4]. As a result of observations, the following positive changes were identified: students showed a stronger tendency to analyze and solve problem situations; their interest in understanding physical processes increased compared to memorizing them; classroom activity such as asking questions, engaging in discussions, and justifying their ideas improved; and the level of applying theoretical knowledge to practical problems was enhanced. These findings confirm scientific conclusions that problem-based teaching engages students in active cognitive processes [5; 8]. In addition, test results showed that the achievement level in the experimental group was 15–25% higher than in the control group.

***Table 1.** Learning outcomes of the experimental and control groups.*

Group	Number of students	Average score	Before test	After test	Growth rate
Control group	XX	XX	62%	70%	+8%
Experimental group	XX	XX	61%	86%	+25%

The table results show that the level of achievement in the experimental group was significantly higher. This empirically confirms the effectiveness of problem-based teaching and is consistent with the results of previous studies.

Discussion. In scientific literature, problem-based teaching is regarded as a didactic system that transforms the learner from a passive recipient of knowledge into an active research subject. This approach activates students' independent knowledge acquisition process and turns learning into an active form of activity [3; 5]. J. Dewey described this process as “reflective thinking,” emphasizing that knowledge is formed through problems, which is consistent with modern competency-based education approaches [2]. In physics education, the problem-based approach develops the following stages of scientific thinking: understanding the problem, analyzing it, formulating a scientific hypothesis, testing it through experimentation or logical reasoning, and reaching a final conclusion. These stages are widely described in scientific literature as the main components of problem-based teaching methodology [3; 5]. This process develops not only students’ knowledge but also a culture of scientific inquiry. The learner begins to understand a phenomenon not only as a result but also in terms of its cause-and-effect relationships. In particular, in physics education, this approach ensures the connection between theoretical knowledge and practice as well as deeper understanding [8]. However, the effectiveness of problem-based teaching directly depends on the teacher’s methodological preparedness, the ability to design lessons on a scientific basis, and the consideration of students’ age and individual characteristics. Factors influencing the quality of education and teaching effectiveness are also emphasized in international studies [6]. It is also noted that incorrectly selected problem situations may lead to confusion or a decrease in students’ motivation [4; 7].

Conclusion

The results of the study confirmed that the use of problem-based teaching technologies in physics education is an effective pedagogical tool for developing students’ scientific thinking. This approach forms students’ competencies in independent thinking, analysis, scientific inquiry, and problem-solving. The obtained results show that physics lessons organized on the basis of problem-based learning increase students’ interest in knowledge, enhance their cognitive activity, and significantly improve the quality of education. Therefore, the systematic and purposeful implementation of problem-based teaching technology in the physics education process is considered one of the important directions for improving the effectiveness of modern education.

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