ANNOTATION

for the dissertation work towards the degree of Doctor of Philosophy (PhD) in the educational program «8D01501 – Physics»

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Features of the application of problem-based learning technology in the «Mechanics» of physics

General Characteristics of the Study. The dissertation is devoted to the study of the features of teaching the "Mechanics" section of the school physics curriculum using problem-based learning (PBL) technology, as well as to the experimental investigation of its impact on students' conceptual understanding and their attitudes toward physics.

Relevance of the Research

The rapid development of scientific and technological progress and the growing demand for engineering professions highlight the importance of high-quality physics education in secondary schools. As a fundamental science that explains the laws governing natural phenomena, physics plays a crucial role in shaping students' scientific worldview and developing their abilities to analyze data, draw conclusions, model phenomena, and apply knowledge to real-life situations. Solving physics problems enhances logical and mathematical-analytical thinking, while experimental activities foster skills in observation, measurement, and data processing, thereby strengthening students' research competencies. Ultimately, this contributes to the development of students' scientific culture and supports their future professional orientation.

In today's labor market, the high demand for technical professions is reflected in the state's increased focus on preparing engineering and scientific personnel. In the 2025–2026 academic year, more than 77,000 educational grants were allocated, of which 18,846 were assigned to engineering, manufacturing, and construction fields, and 9,188 to natural sciences, mathematics, and statistics. These figures demonstrate the strategic importance of technical education. However, international research findings indicate that students' scientific literacy remains insufficient. According to the 2022 results of the Programme for International Student Assessment (PISA), conducted by the Organisation for Economic Co-operation and Development (OECD), Kazakhstan scored 423 points in scientific literacy and ranked 49th out of 81 participating countries, which is significantly below the OECD average score of 485.

The disparity in educational quality between rural and urban schools also remains a pressing issue. Studies based on the 2018 PISA results show an average 31-point gap in scientific literacy between rural and urban students. This inequality is associated with weaker material and technical infrastructure in rural schools, insufficient laboratory equipment, limited access to digital resources, and a shortage of qualified teaching staff. As a result, students' practical skills and their ability to apply scientific knowledge in real-life contexts remain underdeveloped.

Mechanics, a fundamental branch of physics, studies motion, equilibrium, and the nature of forces. Since motion-related phenomena are closely connected to everyday life, teaching mechanics should go beyond theoretical explanations and actively engage

students in cognitive activities. The modern educational paradigm views students not as passive recipients of ready-made information but as active constructors of knowledge. In this context, problem-based learning (PBL) emerges as an effective instructional approach.

Purpose of the Research: The purpose of the study is to experimentally examine the impact of applying problem-based learning technology in teaching the "Mechanics" section of secondary school physics on students' conceptual understanding and their attitudes toward physics.

Research Objectives:

1) To conduct a systematic analysis of domestic and international scientific literature and, on this basis, to investigate the characteristics of teacher–student interaction in teaching mechanics within the framework of problem-based learning.

2) To experimentally determine the effect of applying problem-based learning technology in teaching the "Mechanics" section on students' conceptual understanding.

3) To examine the impact of a short-term pedagogical intervention using problem-based learning on students' attitudes toward physics and to assess differences between groups.

4) To develop a collection of problem-based tasks and an elective course program for the "Mechanics" section, to conduct expert evaluation, and to implement the developed methodological complex into school practice.

Research Methods

Theoretical methods:

– systematic analysis of pedagogical, psychological, and didactic literature to identify the scientific foundations of problem-based learning technology, its potential in teaching mechanics, models of problem-based learning, and features of teacher–student interaction;

– comparative analysis of studies on problem-based learning to identify effective elements and to substantiate the research design;

– theoretical modeling, including the design of a system of problem-based tasks and its alignment with the content of the "Mechanics" section.

Empirical methods:

– identification of the impact of problem-based learning (PBL) on students' conceptual understanding of mechanics and their attitudes toward physics;

– comparative analysis of the results of experimental and control groups;

– evaluation of the effectiveness of the pedagogical intervention based on statistical processing and analysis of experimental data.

Object of the Research

The process of teaching the "Mechanics" section in secondary school using problem-based learning technology.

Subject of the Research

The impact of applying problem-based learning technology on students' conceptual understanding and their attitudes and beliefs about physics.

Provisions Submitted for Defense:

1. The developed structural–facilitative model of problem-based learning for teaching the "Mechanics" section, which includes target, content, activity, and outcome

components, ensures the organization of cognitive conflict between intuitive and scientific conceptions through qualitative problem-based tasks and promotes students' meaningful acquisition of physical concepts.

2. The application of problem-based learning technology leads to a significant increase in students' conceptual understanding. The results of the experimental group were 2.4 times higher than those of the control group.

3. A short-term pedagogical intervention does not have a statistically significant impact on students' attitudes toward physics, as the attitude survey scores in the experimental group increased only from 112.16 to 115.34, and in the control group from 107.77 to 114.30, with no statistically significant differences identified.

Scientific and Practical Significance of the Study

- A structural–facilitative model of teacher–student interaction for implementing the "Mechanics" section within the framework of problem-based learning was developed. The model is aimed at the purposeful organization of cognitive conflict between intuitive and scientific conceptions through specially designed problem tasks.

- Under the conditions of Kazakhstan, the impact of problem-based learning technology on the formation of students' conceptual understanding in the "Mechanics" section was experimentally determined.

- It was established that, under short-term intervention conditions, problem-based learning technology does not have a statistically significant effect on students' attitudes toward Physics.

- A collection of problem-based tasks for the "Mechanics" section and an elective course program entitled "Methodology of Applying Problem-Based Learning Technology in Teaching the 'Mechanics' Section" were developed. The materials underwent expert evaluation at the Regional Methodological Center of the State Institution "Department of Education of Almaty Region," were approved, and subsequently implemented into school educational practice.

Compliance with national strategies and educational programs:

This study was carried out in accordance with the requirements of the State Compulsory Educational Standard approved by Order No. 348 of the Minister of Education of the Republic of Kazakhstan dated August 3, 2022. The Standard emphasizes strengthening the applied nature of knowledge in teaching science subjects, using inquiry-based tasks, and gradually increasing the complexity of the curriculum. Teaching the Mechanics section based on problem-based learning (PBL) technology fully aligns with these requirements.

The research is also consistent with the directions outlined in the Concept for the Development of Preschool, Secondary, Technical and Vocational Education in the Republic of Kazakhstan, approved by Government Resolution No. 249 dated March 28, 2023. This document highlights the need to improve the quality of physics and science education, enhance scientific literacy, and bring instruction closer to practical activities.

Furthermore, the study corresponds to the objectives defined in the National Development Plan of Kazakhstan for 2025–2030, particularly within the national project "Educated Nation," which prioritizes updating the content of science subjects and strengthening laboratory and practical components. The implementation of

problem-based learning in teaching Mechanics supports the development of inquiry-oriented instruction outlined in this national project.

As a result of the study, a problem-based learning workbook was developed as an important instructional tool that supports students in analyzing problem situations, systematically carrying out research activities, and mastering practical tasks. This workbook increases the proportion of applied and hands-on activities in the learning process.

The lesson plans were designed in accordance with the document formats required for teachers, approved by Order No. 130 of the Ministry of Education and Science of the Republic of Kazakhstan dated April 6, 2020. The structure of the documents, the content of tasks, and the assessment components were prepared in compliance with the requirements of this regulation.

As an outcome of the research, an elective course program and a workbook for teaching the Mechanics section through problem-based learning technology were developed and proposed as methodological materials that complement and enrich the content of physics instruction.

Author's Contribution

The author defined the research concept and, based on an analysis of scientific literature, developed a structural–facilitative model for applying problem-based learning technology in teaching the "Mechanics" section. A program for the experimental study was designed, and a pedagogical experiment was organized and conducted. During the research process, instructional and methodological materials and a system of problem-based tasks were developed. The main content of the dissertation, its conclusions, and scientific findings are the result of the author's independent research work.

Approbation of the dissertation. The results obtained in the dissertation have been published, presented, and discussed in scientific publications and at international conferences.

Articles with impact factor included in the international scientific databases Scopus and Web of Science:

1. Sagatbek Amangul, Temitayo Kehinde Oni, Emily Adah Miller, Gulmira Gabdullina, Nuri Balta. *Do High School Students Learn More or Shift Their Beliefs and Attitudes Toward Learning Physics with the Social Constructivism of Problem-Based Learning?* //Education Sciences, 2024, Vol. 14, No. 12, Article 1280. https://doi.org/10.3390/educsci14121280 (WoS: Q1; Scopus CiteScore percentile – 84%).

Scientific articles published in journals recommended by the Committee for quality assurance in the field of education and science of the Ministry of Science and Higher Education:

2. Sagatbek A., Gulmira G. L. *Problems in Forming Students' Competence in Teaching Physics.* //Journal of Educational Sciences, 2024, Vol. 80, No. 3, pp. 200–209. https://doi.org/10.26577/JES2024v80.i3.016

Presentation of Research Results at International Conferences

3. Sagatbek A., Gabdullina G. L. Effectiveness of Problem-Based Learning in Forming Functional Literacy of School Students in Mechanics // MATERIALS

of the International Scientific and Practical Conference «Integration of education and science: problems and prospects as a tool for implementing modern innovative kazakhstani state policy» – Semey: Shakarim University, 2024. – pp. 120–122.

4. Sagatbek A., Gabdullina G. L. Features of Explaining Certain Physical Phenomena Based on Problem-Based Learning // «Modern trends in physics: integration of science and education» materials of the international scientific conference. – Astana: L. N. Gumilyov Eurasian National University, 2024. – pp. 220–222.

Author's Elective Course Program:

An elective course program entitled "Methodology for the Application of Problem-Based Learning Technology in Teaching the Mechanics Section" and a workbook designed for Grade 9 students were developed. The prepared instructional and methodological materials were reviewed and approved by the Expert Council of the Almaty Regional Methodological Center and subsequently implemented in school educational practice.

Structure and Volume of the Dissertation. The dissertation consists of an introduction, four main chapters, a conclusion, a list of references, and appendices. The work includes 16 tables, 4 formulas, 7 figures, and 133 references and is presented on 138 pages.