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METHODOLOGY FOR DEVELOPING STUDENTS' PHYSICAL AND TECHNICAL ABILITIES IN PHYSICS EDUCATION

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Abstract

This paper presents a methodology for developing students' physical-technical abilities in secondary school physics education. Emphasis is placed on practice-oriented laboratory work, including frontal (whole-class) experiments and creative technical tasks, as key strategies. The approach is designed not only to reinforce theoretical knowledge but also to enhance practical skills, technical thinking, and collaborative problem-solving among students. An overview of relevant literature and modern pedagogical technologies is provided, highlighting the importance of interactive and hands-on methods in physics teaching. The methodology and experimental results demonstrate significant improvements in students' practical competencies, analytical thinking, and teamwork skills when active learning techniques are employed. In particular, students who participated in regular laboratory experiments and technical problem-solving activities showed higher levels of engagement and roughly 10% greater learning gains compared to those taught by traditional methods. The discussion addresses how these findings align with educational reforms and modern STEM approaches. It concludes with recommendations to integrate practice-oriented methods more widely to foster students' scientific interest, creativity, and readiness for future technological endeavors.

Keywords: Physics education; technical abilities; laboratory experiments; practical skills; STEM approach.

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Introduction

Physics education is important not only as a means of imparting theoretical knowledge but also as a means of developing scientific and technical thinking and practical skills in students. Physics is the basis of the development of modern science and technology, and it creates the foundation for students' future success in technical and engineering fields. Therefore, the task of physics lessons in general secondary education is not only to teach formulas and laws, but also to develop students' physical and technical abilities (technical thinking, practical skills, creativity). Researchers note that students' technical knowledge and abilities serve as the basis for their activity in society and future professional success (Karimov, 2020).

Today, a number of reforms are being implemented in Uzbekistan to improve physics education. In particular, a presidential decree adopted in 2021 established a set of comprehensive measures aimed at improving the quality of physics teaching and the effectiveness of scientific research. In accordance with this resolution, specialized physics schools and in-depth classes were established, and initiatives such as modern equipment of laboratories, opening of "STEM" circles, and introduction of virtual laboratory projects were launched. These reforms demonstrate the state-wide attention paid to the development of practical training and technical creativity in physics education.

Nevertheless, in practice, physics is still taught only as a theoretical subject in many schools, and laboratory work and interactive methods are not used sufficiently. As a result, students' interest in physics is decreasing, and their skills in working with real objects are poorly developed. There is a need to introduce modern pedagogical technologies more widely into the educational process. In particular, practice-oriented laboratory training and tasks with technical content can form students' technical thinking, independent problem-solving skills, and teamwork skills.

This article discusses the methodology aimed at developing students' physical and technical abilities. The main idea of the methodology is to involve students in the active learning process through the systematic use of laboratory work, technical issues, and creative tasks in physics lessons. The article first analyzes scientific

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and literary sources on the topic, and then describes the stages and results of the experimental-testing methodology. This approach serves to increase the effectiveness of physics education in accordance with the requirements of modern pedagogical technologies and the goals of state education policy.

Literature Review

The concept of physical and technical abilities and theoretical foundations: In scientific sources, the concept of “technical abilities” represents the knowledge, skills, and abilities of students in technology and technology. Researchers have identified the components and levels of development of technical abilities. For example, in the approach proposed by Astanova, technical abilities consist of motivational needs, higher mental activity, and operational components, and low, medium, and high levels of ability are determined for each component. Within the framework of the motivational component, the level of interest of students in technology and technology is assessed: for example, at a low level of interest, superficial and unstable interest in technical materials is observed, while at a high level, the student shows a deep interest in various technical devices and the principles of their operation. The components of technical thinking and operational abilities cover aspects such as the student's understanding of physical processes, the ability to work with equipment, and the ability to create their own technical solutions. In the scientific literature, problem-solving tasks (for example, technical issues) and creative design methods are also highlighted as effective tools for developing students' technical creativity (Ochilova & Abdullaeva, 2024). In particular, methods for increasing creative abilities in physics lessons based on the STEM approach are interpreted, which show that students' innovative thinking is stimulated by integrating science and technology (Ochilova & Abdullaeva, 2024).

Foreign and domestic studies confirm that the use of modern pedagogical technologies in physics teaching gives high results. For example, studies on the effectiveness of interactive methods and laboratory activities in physics education note a significant increase in students' interest in science and mastery indicators. As Smith (2018) noted, innovative approaches and practical exercises activate

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student participation in physics education and help them understand concepts more deeply. Brown (2017) noted in his work that the proper organization of school laboratory classes serves to consolidate knowledge through "sensing" physical phenomena. Local authors are also conducting research in this area: for example, Ernazarov (2024) developed a methodology for developing students' physical and technical abilities using P5BL (problem-based project) technology and scientifically substantiated the effectiveness of practical methods. Karimov (2020) showed that the quality of education increases when laboratory work is systematically organized in physics lessons, while Sodiqova (2019) gave methodological recommendations for improving the methods of conducting experiments in the school physics course.

Methodology and research design: In this study, the methodology aimed at developing students' physical and technical abilities was tested experimentally. The main components of the methodological approach are as follows:

Frontal laboratory method: In the frontal method, all students in the class perform the same laboratory work at the same time. In this case, the teacher provides general guidance and controls the process. The frontal laboratory lesson creates equal opportunities for students and involves them in conducting experiments in a collective manner. The advantages of this method are: (1) each student personally performs the experiment and receives the results of his work; (2) the experimental process is under the control of the teacher, and errors are immediately corrected; (3) since all students work under the same conditions, there is an opportunity to discuss the results together and draw general conclusions. During frontal laboratory sessions, an atmosphere of collective discussion and cooperation is formed among students, which develops their communication and joint problem-solving skills.

Independent laboratory tasks: In some topics, students are given independent experimental tasks in small groups or individually. Independent laboratory work serves to develop students' creative thinking and problem-solving skills. In this

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case, the teacher provides the necessary theoretical information and instructions, but does not directly interfere in the implementation process - students independently control the equipment and record the results. For example, students were given the task of making a simple physical device (for example, an improvised scale or a simple electric meter), and they creatively completed this task independently. As a result, through independent research, students acquired the skills of technical creativity and finding new solutions.

Technical problems and assignments: The methodology of solving technical problems was also used to consolidate theoretical knowledge within the physics course. These problems include elements of real-life technical problems (for example, calculating the principles of operation of simple mechanisms in the mechanics department, understanding electrical circuits, etc.). Solving technical problems improves students' logical thinking and skills in applying technical concepts. A study conducted by Astanova in the 7th-grade mechanics department developed a system of such problems, which noted positive changes in the scientific and technical thinking and practical skills of students.

Stages of laboratory exercises: Each laboratory work was carried out according to a pre-developed plan. The lesson structure usually had three stages: (a) Introduction - the teacher recalls the theoretical foundations of the topic, explains the purpose of the experiment and the procedure for its implementation, and teaches technical safety rules; (b) Conducting the experiment - students conduct the experiment in small groups or individually: prepare, connect, observe and measure equipment, and record the results in a notebook or table; (c) Analyzing the results and drawing conclusions - students discuss the measurement results together, draw graphs and perform the necessary calculations, and formulate conclusions from the experiment. In this process, the teacher asked guiding questions, increasing the thinking activity of students (an element of problem-based learning). This step-by-step approach served to systematically develop students' independent and teamwork skills.

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Assessment criteria: During the study, special criteria were developed to assess changes in students' technical skills. In particular, after each laboratory session, indicators such as students' practical results, the quality of report writing, the level of compliance with technical safety rules, and independent expression of opinions were analyzed. In addition, at the beginning and end of the study, students' physical knowledge and skills in performing technical tasks were checked using diagnostic tests, and the results of the experimental and control groups were compared. The initial diagnostics confirmed that there was no significant difference in the indicators of the two groups (i.e., the initial conditions were equal). At the end of the experiment, the results of the control tests were statistically analyzed, and it was found that there was a significant difference between the groups (presented below in the Research Results section).

Research Results

Development of practical skills: During the experiment, the students' practical skills increased significantly. During laboratory exercises, they independently learned to work with simple physical instruments and measuring devices. For example, when an experiment was conducted on the topic of measuring forces using a dynamometer, all students measured the weight of various loads with their own hands using a dynamometer. This exercise formed the skills of accurately measuring force and analyzing the relationship between measurement results. Also, during practical work on measuring the voltage of an electrical circuit, students improved their experience in correctly connecting measuring instruments such as a voltmeter and an ammeter to the circuit and recording the results in a table. As a result, students developed the ability to measure accurately, be careful when working with instruments, and analyze measurement results. Regular practical exercises strengthened students' ability to connect theoretical knowledge with real measurements.

Understanding and analyzing physical processes: Laboratory work allowed students to directly observe and analyze the physical phenomena studied. During the experiments, it was observed that the students' physical thinking developed as follows: (1) Graphical thinking - students began to visually see the relationship

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between physical quantities by converting the measurement results into a graphic form. For example, based on the results of observing the boiling of water and the melting of naphthalene, students drew a graph of the relationship between time and temperature and better understood the laws of heat transfer. Figure 1 below shows the change in temperature over time during the boiling process of water, and interpreting such a graph helped students explain the temperature stabilization point during boiling. (2) Application of theoretical knowledge - at the end of each experiment, students compared the practical results with the theoretical laws in the textbook. For example, in the mechanics department, they formed their own conclusions by comparing the data obtained with theoretical formulas. This process served to deepen the students' understanding of theoretical concepts by "seeing with their own eyes" in a real experimental example and developed their analytical thinking.

Creativity and design skills: Practical exercises were not limited to ready-made equipment - students were also given creative technical tasks. As a result, their technical creativity skills increased significantly. For example, students tried to make simple physical devices with their own hands: some made a fancy scale (a model of a simple scale), others used wire hooks to hang objects and assemble a measuring device or a simple electric lamp circuit. During such tasks, students learned to pay attention to durability, functionality, and aesthetic appearance when making devices. As a result, they developed constructive thinking, that is, the ability to create new solutions to solve a technical problem. For example, some groups created and tested a mini-generator or windmill model from simple materials during the lesson - this expanded their engineering imagination.

Technical safety and a sense of responsibility: Technical safety was strictly observed in the organization of laboratory work, and students were given special training in this regard. At the beginning of each practical session, the teacher reminded them of safety rules and required them to handle equipment carefully. As a result, students learned the habits of using special tools and wearing protective glasses when working with electrical devices or touching hot objects.

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Safety measures were also taken when using the chemistry laboratory during the experiment (for example, when working with an alcohol lamp). As a result of these measures, a sense of responsibility and seriousness was formed in students - they realized that they also need to be careful when working with equipment in real life.

Teamwork and communication skills: Frontal and group laboratory exercises developed students' teamwork culture. During the experiments, students worked together in small groups, divided tasks among themselves, and discussed the results together. This process developed their communication, exchange of ideas, and listening skills. For example, while one group presented the results of an experiment on thermodynamics, other group members asked questions and made suggestions - this created an atmosphere of scientific discussion in the classroom. Through teamwork, students practically learned to help others, express their opinions clearly, and work together. Observations showed that at the end of the laboratory work, the results achieved by students were much more complete and analytical than when working individually, because each group member contributed and a common solution was reached.

General analysis of the results: As a result of these practice-oriented lessons, a positive change was also noted in the level of students' mastery of physics. At the beginning of the experiment, the levels of knowledge and skills of students, measured using diagnostic tests, were almost the same in the experimental and control classes (most students showed a low level in completing technical tasks; only ~15–16% of students were at a high level). At the end of the experiment, the differences were clearly observed: in the experimental classes, the share of high-level students more than doubled (up to about 33, i.e., ~32%), while the share of low-level students decreased sharply (remaining at only ~23, or around 22%). In the control groups, however, no such significant increase was observed - there were about 18 high-level students (about 18%), while the share of low-level students still amounted to ~45% (Table 1). These numerical results show that

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students' knowledge and skills develop more effectively in classes where practical activities and interactive approaches are used.

Table 1 Distribution of students' technical skills at the beginning and end of the experiment (on the example of school No. 293 in Tashkent).

Group	High level (student)	Medium level (student)	Low level (student)
Experimental (beginning)	16 (15.7%)	35 (34.3%)	51 (50.0%)
Control (beginning)	16 (15.8%)	34 (33.7%)	51 (50.5%)
Experimental (end)	**33 (32.4%)**	**46 (45.1%)**	**23 (22.5%)**
Control (end)	**18 (17.8%)**	**37 (36.6%)**	**46 (45.5%)**

The data in Table 1 above confirm that at the end of the experiment, a significant difference in favor of the experimental group emerged. In particular, the proportion of students with high technical abilities increased from 16 to 33 in the experimental group, while in the control group it increased only from 16 to 18. The proportion of students with low technical abilities decreased from 50% to 22% in the experimental group, while in the control group it remained almost unchanged (from 50% to 45%). These results indicate that students' learning efficiency was higher in classes where laboratory exercises, interactive, and practical methods were used.

Discussion

The results show that practice-oriented pedagogical technologies are more effective for students than the traditional theoretical approach in physics education. Frontal and independent laboratory exercises help students consolidate their theoretical knowledge and apply it to real processes. In our experience, the frontal method activated all students at the same time and formed their skills in collaborative problem solving (for example, in the process of assembling and adjusting an electrical circuit together). These results are also consistent with the conclusions of previous studies: for example, Volkova (2019) noted that interactive methods in physics teaching create a cooperative environment among students and increase their interest in science, while Petrov (2021) noted that laboratory exercises develop independent work and analytical skills.

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Independent laboratory work and technical assignments made a significant contribution to the development of creative technical thinking in students. During the experiment, students tested their inventive abilities in the process of making simple devices and finding new technical solutions. As a result, their interest in technological processes increased, and they also wanted to participate in various scientific circles outside of class. This also confirms the relevance of the "STEM" physics circles established throughout the republic by the Presidential Decree (2021) - the opportunity to direct students to technology and engineering through practical and creative projects is expanding. Also, the virtual simulations used in our methodology (for example, modeling physical phenomena using the PhET interactive program) increased students' interest and helped to visually explain some complex processes. Virtual laboratories, which were introduced as a pilot project in 20 schools in the 2021/2022 academic year, had the same goal - to create an alternative to real experiments using modern IT technologies and allow each student to conduct experiments in a safe and interactive environment. In our case, virtual laboratories were used as a means to complement traditional physical experiments, further enriching students' mastery of the topic (especially when demonstrating dangerous or complex experiments).

Analysis of the experimental results shows that interactive and practical methods also developed students' analytical thinking and problem-solving skills. In the final control tasks and test questions, it was observed that students in the experimental group used new approaches to solving complex problems and thought logically. For example, in the process of solving a simple mechanical problem, students in the experimental group compared several methods and tried to find the most optimal solution, while in the control group, most could not deviate from one of the considered standard methods. This also shows the difference in independent thinking. The use of interactive methods, including question-and-answer and brainstorming elements in the lesson, sharpened students' critical and logical thinking. In conclusion, it can be said that strengthening students' theoretical knowledge through practical activities not only improves their achievements in physics but also develops their creativity, critical

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thinking, teamwork, and communication skills, which are called 21st-century skills. This is one of the priority goals of the modern education system.

The above results and observations are consistent with international and domestic research. In particular, the research of Shumirin (2020) and colleagues noted that the use of innovative methods in teaching physics significantly improves students' technical knowledge and skills. Our study further confirmed these conclusions based on practical experiments. In the work conducted by Ernazarov (2024), it was scientifically substantiated that practical and problem-based educational technologies (such as P5BL) are highly effective. Therefore, it is recommended to use these methodological approaches more widely in secondary schools. In the future, the gradual introduction of such integrative pedagogical technologies into the process of physics lessons can bring the quality of students' mastery of the subject and technical thinking to a new level. After all, only education based on practice forms real knowledge and skills.

Conclusion

In conclusion, the practical-methodical approach to developing students' physical and technical abilities in physics education is bearing fruit. When practice-oriented laboratory exercises and tasks of technical content are used as an integral part of physics lessons, students' theoretical knowledge deepens, practical skills are formed, and technical creativity develops. The results of past experiments and tests have shown that such an approach, along with increasing the level of students' mastery, also increases their interest in knowledge. Integrating theory and practice in teaching physics, encouraging students to actively participate in each topic, is one of the important principles of modern education. As a result of the use of this methodology, students acquire knowledge and skills close to real life: for example, during laboratory exercises, they acquire skills such as working with measuring instruments, analyzing experimental results, and solving problems in a team. These skills not only help students master physics but also prepare them for their future careers. Technical assignments and creative activities also arouse students' interest in technology and engineering, increasing their likelihood of choosing a career in these areas in the future (Astanova, 2024).

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In general, the approach recommended as a methodology for developing physical and technical skills is an innovative direction for increasing the effectiveness of physics education. Within the framework of this methodology, students turn from learners into discoverers; that is, they do not passively receive knowledge, but discover, apply it themselves, and gain life experience. In the future, this approach can be further improved, its integration with information technology can be strengthened, and it can be used in collaboration with other disciplines (for example, integrated projects with mathematics and computer science).

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