**Application of Modern Pedagogical Technologies in Teaching the Mechanical Properties of Solid Bodies in General Education Schools**

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**Abstract.** This article explores the application of modern pedagogical methods in teaching the mechanical properties of solid bodies in general education schools. The primary objective is to enhance students' understanding of this fundamental concept in physics by structuring lessons in an engaging and effective manner. The study emphasizes the importance of utilizing diverse educational resources and methodologies to develop students' knowledge and practical skills at a higher level. Additionally, the article provides recommendations on selecting appropriate teaching materials and strategies that facilitate a more comprehensive grasp of the subject. Special attention is given to the assessment process, where students are encouraged to share their personal opinions and reflections on the topic. This approach not only fosters active participation but also enables teachers to evaluate students' comprehension through discussions and collaborative analysis. Furthermore, the study examines the integration of traditional and innovative teaching methods, highlighting their impact on students' learning efficiency. The findings suggest that a well-balanced combination of these approaches significantly improves students' engagement, critical thinking, and overall academic performance in physics.

**INTRODUCTION**

On January 28 and April 5 of this year, the President of the Republic of Uzbekistan, Shavkat Mirziyoyev, held videoconference meetings on the development of school education. During these meetings, it was repeatedly emphasized that the future of the country, as well as the success of various sectors and projects, depends on educated specialists.

The future of the nation and the success of all fields and projects are directly linked to the knowledge and competence of its people. Therefore, over the past four years, significant efforts have been made to improve the quality of education and enhance the status of teachers. Now, Uzbekistan is entering a new era. The Development Strategy of Uzbekistan for 2022-2026 identifies the fourth priority direction as the development of the education sector and human capital. The President considers this issue a matter of great importance, stating:

“We have no right to delay reforms in this area. We must strengthen the foundation of school education starting today. We will mobilize all our attention and resources for this. We are choosing a difficult path, but this is the path that will solve the existing problems.” [1]

The Role of Educational Reforms in School Development

During the meeting on January 28, 2022, the President emphasized that improving the material and technical base of schools and enhancing the quality of education should not be the sole responsibility of the Ministry of Public Education. Instead, it must be a collective effort involving all ministries and agencies, local authorities, scientific institutions, intellectuals, and the broader public. “It was noted that while advanced teaching methodologies have been implemented in Presidential schools, specialized schools, and private schools, traditional teaching methods still dominate in most other schools. Moreover, there has been a lack of initiatives to introduce modern educational approaches in these schools. In response, the President instructed officials to develop a national education strategy in collaboration with international organizations and to adopt a comprehensive school education development program.”[2]

At present, improving the quality of education must become a shared responsibility of the Ministry of Public Education, all relevant government bodies, research institutions, and civil society. The outdated teaching methodologies in most schools must be addressed to ensure that modern pedagogical approaches are adopted nationwide. As part of this effort, the School Education Development Program is being developed, which will incorporate best practices from international education systems.

**MODERN PEDAGOGICAL APPROACHES IN PHYSICS EDUCATION**

To improve physics education in schools, various didactic materials should be incorporated into lessons, including:

* Visual aids such as **posters, videos, and diagrams** that illustrate complex physics concepts not covered in textbooks.
* Interactive **educational films and digital simulations** to enhance conceptual understanding.
* Laboratory equipment and demonstration tools to facilitate hands-on experiments.

The principle of educational alignment requires that physics lessons be adapted to students' intellectual, physical, and age-related characteristics. In addition, theoretical knowledge in solid-state physics should be reinforced through problem-solving exercises, hands-on activities, laboratory experiments, and project-based learning. The integration of virtual laboratory simulations in physics education can significantly enhance students' understanding by providing interactive experiences that combine theoretical knowledge with practical applications.” [3, 4, 5, 6, 7, 8, 9]

**LITERATURES ANALYSIS**

Scientific research on the use of modern pedagogical technologies in teaching physics, particularly the mechanical properties of solid bodies, indicates that traditional teaching methods alone are not sufficient to ensure the effective assimilation of knowledge by students. Modern educational methodologies, on the other hand, foster independent thinking, facilitate the connection between theoretical knowledge and practical application, and enhance students' interest in the subject.

Furthermore, integrating innovative teaching strategies, such as interactive simulations, problem-based learning, and digital laboratory experiments, has been shown to significantly improve students' comprehension and retention of complex concepts. These methods encourage active participation, critical analysis, and creative problem-solving, which are essential skills for mastering physics.

By implementing advanced pedagogical approaches, educators can create a more engaging and effective learning environment, enabling students to develop a deeper understanding of solid-state mechanics and its real-world applications.

**METHODOLOGICAL APPROACHES TO TEACHING THE MECHANICAL PROPERTIES OF SOLID BODIES**

Research in pedagogy and physics-mathematics education has demonstrated the critical importance of enhancing the role of experimental activities in teaching the mechanical properties of solid bodies (Vygotsky, 1986; Bransford et al., 2000). Practical experiments not only provide students with hands-on experience but also help them develop a deeper conceptual understanding of the subject. These activities allow learners to observe, analyze, and draw conclusions based on real-world physical phenomena, thereby strengthening their problem-solving and critical-thinking skills.

It is recommended that the teaching of these topics be conducted using a constructivist approach, which emphasizes active learning and the construction of knowledge based on students' experiences (Piaget, 1952). In this model, students are not passive recipients of information but rather active participants in the learning process. They engage in inquiry-based learning, perform experiments, and apply theoretical concepts to practical scenarios, enabling them to develop a more profound and intuitive grasp of solid-state mechanics.

Furthermore, integrating modern pedagogical technologies, such as interactive simulations, digital laboratories, and real-time data collection tools, enhances the effectiveness of the learning process. These tools allow students to visualize complex physical principles, test hypotheses, and explore different variables in a controlled environment, making abstract concepts more tangible and easier to understand.

By adopting a student-centered methodology that includes collaborative learning, guided discovery, and project-based approaches, educators can significantly improve students' engagement and retention of knowledge. Encouraging discussions, problem-solving tasks, and cross-disciplinary applications of physics also fosters deeper comprehension and motivates learners to explore the subject beyond the classroom.

Ultimately, a well-structured methodological approach that combines theoretical knowledge with hands-on practice ensures that students develop both the conceptual understanding and practical skills necessary for mastering the mechanical properties of solid bodies.

**MODERN PEDAGOGICAL TECHNOLOGIES AND THEIR EFFECTIVENESS**

Research conducted by scholars such as Pajares (1992) and Slavin (1994) on the application of modern pedagogical technologies has shown that interactive teaching methods, particularly collaborative and experiential learning approaches, play a crucial role in increasing students' engagement and interest in the subject matter. These methods not only enhance comprehension but also foster critical thinking and problem-solving skills.

Among the most effective modern teaching approaches is Project-Based Learning (PBL), which actively involves students in solving real-world problems related to their field of study. According to Thomas (2000), this method significantly enhances students' analytical thinking by encouraging them to explore concepts in depth, conduct research, and apply theoretical knowledge to practical scenarios. PBL provides a student-centered learning environment, where learners work on meaningful projects, collaborate with peers, and develop essential skills such as creativity, communication, and decision-making.

Additionally, incorporating technology-enhanced learning tools, such as virtual simulations, augmented reality (AR), and interactive digital platforms, further improves the effectiveness of modern pedagogical strategies. These tools help visualize complex concepts, enable hands-on experimentation in a risk-free environment, and provide immediate feedback, making the learning process more dynamic and engaging.

Overall, the implementation of modern pedagogical technologies fosters a deeper understanding of the subject, promotes active participation, and prepares students for real-life applications of their knowledge. By utilizing innovative teaching methodologies, educators can create an effective and stimulating learning environment that aligns with the needs of contemporary education.

STEAM Education and Experimental Learning in Teaching the Mechanical Properties of Solids

STEAM education (Science, Technology, Engineering, Arts, and Mathematics) plays a crucial role in explaining the mechanical properties of solids by integrating multiple disciplines to provide a holistic and interdisciplinary learning experience (Yakman, 2008). This approach enables students to understand complex physical concepts by relating them to real-world applications, fostering creativity, problem-solving skills, and innovation. The inclusion of art (A) in STEAM enhances visualization, design thinking, and conceptual understanding, making abstract topics more accessible and engaging for learners.

The Role of Experiments and Laboratory Work in Physics Education

Hands-on experiments and laboratory sessions are essential for reinforcing theoretical knowledge by allowing students to observe, analyze, and interact with physical phenomena in a controlled environment. According to Hofstein & Lunetta (2004), laboratory-based learning enhances students' scientific inquiry skills and deepens their conceptual understanding by providing tangible experiences that bridge the gap between theory and practice.

By incorporating real-life mechanisms and structural models into lessons, educators can help students visualize and comprehend the mechanical properties of solids more effectively. For instance, using engineering structures, mechanical systems, and material testing setups enables learners to explore stress, strain, elasticity, and deformation in a meaningful way.

Moreover, the integration of modern digital tools, such as virtual laboratories, augmented reality (AR), and computer simulations, further enriches the learning process by allowing students to conduct interactive experiments, test hypotheses, and receive immediate feedback. These innovative methods ensure higher engagement, retention, and practical application of physics concepts.

By combining STEAM education with hands-on experimentation, educators can create an immersive and effective learning environment that not only enhances students' understanding of solid mechanics but also prepares them for future careers in STEM fields.

**THE USE OF MULTIMEDIA AND DIGITAL TECHNOLOGIES IN PHYSICS EDUCATION**

In modern physics education, virtual laboratories, simulations, and modeling technologies are widely utilized to enhance student engagement and comprehension. These digital tools provide interactive and visually appealing learning experiences, making complex physics concepts more accessible and easier to understand.

One of the most effective tools in this regard is PhET Interactive Simulations (Wieman & Perkins, 2005), which allow students to experiment with various physical phenomena in a virtual environment. These simulations provide real-time feedback and facilitate a deeper understanding of abstract concepts such as motion, forces, and electromagnetism. Similarly, Arduino-based experiments enable students to apply theoretical knowledge through hands-on activities, fostering practical problem-solving skills and technical proficiency.

Moreover, digital learning platforms and online textbooks play a crucial role in enhancing students' interest in physics. These resources offer high-quality visual aids, interactive content, and real-world applications, making learning more engaging and effective (Mayer, 2009). By integrating multimedia elements such as videos, animations, and augmented reality (AR) applications, educators can create a more immersive and student-centered learning experience.

The incorporation of multimedia and digital technologies in physics education not only improves conceptual understanding but also promotes self-directed learning and scientific inquiry, preparing students for the digital era and STEM-related careers.

**PURPOSE OF THE RESEARCH**

The primary objective of this research is to examine the possibilities of applying modern pedagogical technologies in the teaching process of the mechanical properties of solid bodies in secondary school physics education and to analyze their impact on students’ knowledge acquisition. Additionally, an important goal of the study is to enhance students’ interest in physics and develop their practical skills through innovative teaching methods. By incorporating modern educational approaches, the research aims to improve the effectiveness of physics instruction and facilitate better student engagement and comprehension.

**THE OBJECT OF THE RESEARCH**

The object of this research is the teaching process of physics, specifically the mechanical properties of solid bodies, in secondary schools. Within the scope of the study, the effectiveness of traditional and modern teaching methods will be compared, and the impact of pedagogical technologies on the learning process will be examined.

**SCIENTIFIC NOVELTY OF THE RESEARCH**

* New methodological approaches are proposed for applying modern pedagogical technologies in teaching the mechanical properties of solid bodies.
* The effectiveness of Project-Based Learning (PBL), STEAM education, and virtual laboratories in physics teaching is identified.
* Recommendations are developed for organizing the teaching process by integrating modern pedagogical technologies with traditional methods.
* The impact of practical activities and experiments on students' learning processes in physics lessons is studied.

**METHODOLOGY OF RESEARCH**

The following methods were used in the research:

Theoretical analysis – A review of existing literature and scientific sources on pedagogy and physics teaching methodologies.

Experimental research – Analyzing changes in students' knowledge and skills through the application of modern pedagogical technologies in general education schools.

Surveys and questionnaires – Assessing the effectiveness of new teaching methods based on surveys conducted among teachers and students.

Observation of the educational process – Evaluating students' engagement and interest in physics through the implementation of modern teaching approaches in lessons.

Statistical analysis of results – Analyzing the outcomes of experimental research using mathematical methods.

The findings of the study contribute to improving physics education in schools and enhancing the effectiveness of pedagogical methods.

**ANALYSIS & RESULTS**

The Necessity of Teaching Complex Scientific Topics and Abstract Concepts in a Comprehensive Education System

One of the primary challenges facing modern education is the effective teaching of complex scientific topics and the development of students' analytical thinking skills. In particular, many students encounter difficulties in learning physics due to the abstract nature of certain concepts. This, in turn, negatively affects their interest in the subject and their ability to grasp the material effectively.

Teaching Complex Scientific Concepts in Physics: The Case of Solid Mechanics

Certain topics in physics, such as the mechanical properties of solids, electromagnetism, and quantum mechanics, are considered complex and difficult for students to grasp. For example, when teaching the mechanical properties of solids, concepts such as plastic and elastic deformation, yield strength, and viscosity may be perceived as abstract. If these topics are not explained with concrete examples from everyday life, students' interest in the subject may decline.

Transforming Abstract Concepts into Concrete Understanding

To facilitate the understanding of abstract concepts in physics, it is essential to connect them with real-life examples. In teaching the mechanical properties of solids, the following methods can be employed:

Experiments and Real-Life Examples:

Conducting experiments with different materials such as metal, plastic, and rubber to demonstrate their resistance levels.

Illustrating elastic and plastic deformation with real-world examples (e.g., stretching and restoring a spring).

Using video demonstrations to explain the concept of yield strength by analyzing construction materials.

Visual and Interactive Teaching Methods:

Utilizing simulations and virtual laboratories to demonstrate the mechanical properties of materials.

Modeling deformation and strength laws using computer programs.

Applying the STEAM Approach:

Integrating physics with technology, engineering, and art to encourage students to develop innovative solutions.

Explaining the mechanical properties of solids by relating them to engineering and construction fields.

Limitations of Traditional Teaching Approaches

The mechanical properties of solids are often taught using traditional methods. However, these methods have been found to be less effective. In a conventional approach, teachers verbally explain the topic and provide theoretical examples. However, modern research has shown that this method alone does not yield high learning outcomes, as it fails to fully address students’ difficulties in understanding abstract concepts. Consequently, students may struggle with comprehension, leading to misconceptions and a lack of clarity.

Moreover, understanding the mechanical properties of solids requires sufficient visualization. If the teacher relies solely on theoretical explanations, students may not fully grasp the topic, and their learning outcomes may decline. Concepts such as elasticity, deformation, and strength, when taught through theory alone, can reduce students' engagement.

The Importance of Modern Pedagogical Technologies

For this reason, incorporating modern pedagogical technologies in lessons on the mechanical properties of solids is crucial. These technologies help students form clear mental representations of physical concepts, develop independent thinking skills, and gain a deeper understanding of the subject. For example:

• Through interactive teaching methods, students have the opportunity to discover concepts on their own through experiments.

• Virtual laboratories and simulations allow students to visually observe physical phenomena.

• Collaborative work and problem-based learning techniques enable students to independently explore topics and apply their knowledge in practice.

The teacher should not merely provide information but should actively engage students in the learning process. If an innovative approach is integrated into the pedagogical process, students' interest in the subject will increase, and their level of knowledge will improve. Therefore, the use of modern pedagogical technologies in teaching the mechanical properties of solid materials is one of the most pressing issues today.

"In the process of teaching topics related to solid-state physics in general education schools, improving the quality and effectiveness of education and ensuring that students acquire knowledge independently require teachers to not only master their professional subject matter but also have a deep understanding of modern pedagogical technologies and teaching methods. They must also thoroughly comprehend the principles of effectively utilizing these methods in classroom instruction. The use of virtual laboratories (PhET) and the 'SchoolEducation' platforms in teaching topics related to solid-state physics contributes to students acquiring deeper knowledge, fostering creative thinking, and enhancing their cognitive development." [10, 11, 12, 13, 14, 15, 16]

In particular, traditional approaches in teaching the mechanical properties of solid bodies often do not yield sufficient results. Relying solely on theoretical explanations and examples can make it difficult for students to grasp complex concepts. For instance, concepts such as elasticity, deformation, and strength may not be fully understood by students if they are not explained using real-life examples.

Therefore, the use of modern pedagogical technologies in lessons on the mechanical properties of solid bodies is of great importance. Such approaches help increase students' interest in the subject, develop their independent thinking skills, and enable them to gain a deeper understanding of the topic. Some effective methods of utilizing modern technologies include the following:

• Interactive Methods: Students independently acquire knowledge through experiments and practical exercises.

• Virtual Laboratories and Simulations: Provide an opportunity to understand physical phenomena through models that closely resemble real-life scenarios.

• Problem-Based Learning and Collaborative Work: Help students develop scientific research skills and learn to work effectively in teams.

By applying modern pedagogical technologies, students can connect theoretical knowledge of the mechanical properties of solids with practical applications, leading to a deeper understanding of the subject. The teacher should not only act as a knowledge provider but also as a facilitator who ensures active student participation in the learning process. Therefore, the use of innovative approaches in teaching physics is one of the most effective methods for improving the quality of education today.

Nowadays, the use of various pedagogical methods in teaching physics has become a primary goal. The application of new teaching methods by educators makes the subject more engaging and comprehensible. From this perspective, organizing lessons based on the demonstration of experiments is an effective approach to studying the mechanical properties of solids.

Demonstration is a Latin word meaning "to show" or "to prove." The main purpose of using this method is to increase students' interest in knowledge, make the learning process more dynamic, and clearly explain the essence of the topic in physics. Explaining the topic through experiments and introducing students to physics instruments contribute to achieving highly positive results in their understanding of the subject.

"Students cannot explain the physical meaning of an experiment without acquiring the necessary knowledge, skills, and competencies during the learning process. Therefore, the teacher should explain each topic as engagingly as possible, using practical experiments as the basis for instruction." [17, 18, 19, 20, 21, 22] For example, conducting various mechanical experiments while studying the properties of solid bodies, such as elasticity, deformation, and strength, enhances the effectiveness of the lesson.

When explaining the topic of "Mechanical Properties of Solid Bodies" in physics, it is also important to focus on the historical development of scientific discoveries. For example, ancient Greek scientists studied the strength properties of solid bodies, while Archimedes identified the principles of equilibrium between liquids and solids. Additionally, modern scientific research has precisely defined the limits of plasticity and elasticity of solid materials, serving as the foundation for their applications in various materials.

By applying modern pedagogical technologies, students' theoretical knowledge of the mechanical properties of solid bodies is connected to practical applications. This helps them gain a deeper understanding of the subject. The teacher should not merely be a provider of knowledge but rather a guide who ensures active student participation in the learning process. Therefore, utilizing innovative approaches in teaching the mechanical properties of solid bodies is one of the most effective methods for improving the quality of education.

In this approach, the teacher does not merely introduce the topic to students through verbal explanations but also provides an in-depth understanding using various experiments. This pedagogical method helps enhance students' knowledge, enables them to grasp the subject more deeply, and allows them to analyze their learning.

When studying the mechanical properties of solid bodies, demonstrating real-life, experience-based visual experiments and asking related questions significantly improve lesson effectiveness. If students' attention is not directed toward the topic through such questions, they may struggle to fully comprehend the material.

For example, when studying the elasticity and deformation properties of solid bodies, demonstrating the stretching experiment using rubber or metal wires can be effective. Similarly, testing various materials under pressure or force to determine their strength makes the lesson more engaging. Students independently analyze experimental results and learn to apply physical laws to real-life examples.

Thus, with the help of modern pedagogical technologies, the teacher plays not only the role of an explainer but also a leader who encourages students' scientific research. This approach develops students' independent thinking skills and increases their interest in physics.

In the classroom, students engage in discussions to explore the essence of various physical laws and strive to prove the principles they define through experiments. This process further enhances their enthusiasm for physics.

For instance, when studying the mechanical properties of solid bodies, the teacher can present objects made of different materials and ask students questions about their deformation characteristics. Students predict how these objects will change under applied force and try to explain their ideas using diagrams and written descriptions. Then, experiments are conducted, and students compare their predictions with practical results.

Such an approach fosters independent thinking skills and helps students develop scientific inquiry abilities. Additionally, lessons organized using modern pedagogical technologies create favorable conditions for students to gain a deeper understanding of the subject.

**Table 1.** Students' Responses to the Control Question on the Learned Topic

|  |  |  |
| --- | --- | --- |
| **№** | **Question Given to Students: What phenomena occur when an external force is applied to a solid object?** | **Number of Responses** |
| **1** | The object retains its shape under external force, and no changes occur. | 6 |
| **2** | The object undergoes plastic deformation and does not return to its original state. | 5 |
| **3** | The object undergoes elastic deformation and returns to its original state after the force is removed. | 8 |
| **4** | The object breaks or fractures when the strength limit is exceeded. | 5 |
| **5** | The object develops small internal cracks due to internal stress, but no visible external changes occur. | 3 |
| **6** | The object's dimensions change, but the type of deformation depends on the material properties. | 12 |

This table can be used to assess students' understanding when studying the mechanical properties of solid bodies. If necessary, it can be improved or adapted by adding other indicators.

The teacher listens to students' individual opinions and allows them to compare their thoughts with those of their peers. The teacher poses several questions related to the topic and collects students' responses accordingly (Table 1).

The use of modern pedagogical technologies in studying the mechanical properties of solid bodies helps increase students' interest in the topic and develop their independent thinking skills. Through discussions and debates, students analyze various mechanical phenomena, reinforcing their knowledge in the process.

Additionally, during the lesson, the teacher provides students with opportunities to conduct experiments on deformation, elasticity, plasticity, internal stress, and the strength limit of solid bodies. This pedagogical approach not only strengthens theoretical knowledge but also helps develop students' scientific reasoning skills.

**CONCLUSIONS**

Based on the knowledge gained from the lesson, students conduct experiments to study the mechanical properties of solid bodies. They compare their conclusions with the results of their own experiments, verifying the accuracy of the given ideas and forming final conclusions.

After explaining the topic, the teacher engages students and assesses their level of understanding by asking the following questions:

"How do solid bodies deform?"

"How is the elasticity limit of solid bodies determined?"

"How do we use the mechanical properties of solid bodies in everyday life?"

"How can the strength limit of materials be tested experimentally?"

"What factors influence the deformation of a solid body?"

Students express their personal opinions based on the results of their experiments. Each student has the opportunity to discuss their thoughts with the class. They are encouraged to justify their understanding through simple experiments.

Students reinforce their theoretical knowledge through practice, strive to justify their opinions in discussions, and defend their viewpoints. This approach helps achieve high effectiveness in the learning process using modern pedagogical technologies.

Observations show that reinforcing students' knowledge depends on following the teacher's instructions, assisting classmates, considering different perspectives, engaging enthusiastically in experiments, and gaining a deeper understanding of physical laws.

If students learn to overcome difficulties in analyzing experimental results and draw independent conclusions, they will be able to provide clear and scientifically grounded answers to given questions. This, in turn, develops their ability to independently solve real-life problems they may encounter.

**SUGGESTIONS**

Creating the necessary conditions for students to conduct experiments related to the lesson topic (laboratory equipment, demonstration materials).

Directing students' attention to the topic by asking questions based on real-life experiences related to the studied material.

Providing students with the opportunity to demonstrate their acquired knowledge.

Organizing the lesson using modern pedagogical methods.

Reviewing the existing curriculum and textbooks for physics education and making necessary modifications to ensure effective teaching and higher learning outcomes.

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