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Methods of Using Educational Methods in Teaching Physics to Future Engineers

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Abstract
This study explores the methodological foundations and effective strategies for using teaching methods in the process of teaching physics to future engineers. The research emphasizes the importance of aligning instructional techniques with the cognitive, practical, and professional needs of engineering students. A combination of theoretical, empirical, and research-based learning approaches is proposed to enhance students' scientific understanding, problem-solving skills, and professional competencies. The methodological model integrates lecture-based reproductive techniques, laboratory-based explanatory–illustrative methods, problem-based learning in practical sessions, and project-oriented independent study. In addition, research-oriented activities within academic circles are shown to promote analytical thinking, experimental skills, and the ability to model and interpret physical processes. The findings suggest that a systematic and competency-based application of teaching methods significantly improves the quality of physics education in technical higher education institutions and contributes to the professional development of future engineers.

Keywords: Physics education; engineering students; teaching methods; methodological model; competency-based learning; problem-based learning; laboratory instruction; project-based learning; research skills; technical higher education.

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Introduction. The rapid development of science and technology in contemporary society places increasing demands on the professional preparation of future engineers. As a result, higher technical education institutions must ensure that students acquire not only theoretical knowledge but also the ability to apply scientific principles to real-world engineering tasks. Physics, as one of the fundamental disciplines in engineering education, plays a pivotal role in shaping students' analytical thinking, scientific reasoning, and problem-solving skills. Therefore, the effective use of teaching methods in physics instruction is essential for developing professional competencies required in modern engineering practice.

The process of teaching physics to future engineers must be grounded in scientifically justified pedagogical approaches that reflect the unity of empirical, theoretical, and research-based cognition. In this context, teaching methods serve as the primary pedagogical tools through which

instructors can structure learning activities, manage students' cognitive engagement, and facilitate the development of engineering-oriented competencies. The selection and appropriate application of teaching methods—such as explanatory–illustrative, reproductive, problem-based, heuristic, project-based, and research-oriented approaches—enable the formation of deep conceptual understanding and practical skills that align with the needs of technical disciplines.

Furthermore, aligning teaching strategies with competency-based education and modern didactic principles ensures a holistic learning experience in which students are actively involved in the process of scientific inquiry. When teaching methods are used systematically and purposefully, they contribute to the development of independent thinking, creativity, and the ability to integrate theoretical knowledge with engineering applications. Thus, the study of effective teaching methods in physics instruction for engineering students is of significant scientific and practical importance, as it enhances the quality of engineering education and ensures the preparation of highly qualified specialists.

Literature Review. The methodological development of physics education for engineering students has been widely discussed in international research over the past three decades. Scholars emphasize that the integration of conceptual understanding, experimental practice, and problem-solving skills forms the core of effective engineering preparation. According to recent studies, physics education in technical universities must transition from content transmission to competency-oriented learning frameworks that incorporate inquiry, modeling, and technology-enhanced instruction.

A significant body of work highlights the role of teaching methods as mediators between theoretical knowledge and engineering practice. For example, explanatory–illustrative and reproductive methods remain essential for introducing theoretical constructs, whereas laboratory-based empirical methods provide opportunities for students to observe natural phenomena and apply measurement techniques. Problem-based learning has been shown to enhance students' analytical reasoning, while heuristic and research-oriented methods foster creativity and experimental thinking—competencies critical to engineering innovation.

International literature also emphasizes the need for interdisciplinary integration. Studies conducted at MIT, TU Delft, and Tokyo Institute of Technology demonstrate that physics learning becomes more impactful when embedded within engineering contexts such as thermodynamics, material science, and mechanical systems. Digital simulations, virtual laboratories, and project-based learning environments further extend the range of methodological tools, enabling students to explore complex physical systems through modeling and algorithmic reasoning.

Overall, existing research underscores that the effectiveness of physics education in engineering curricula depends not merely on content quality, but on the systematic application of diverse teaching methods that address both cognitive and professional dimensions of student development. This review provides the conceptual foundation for the methodological approach proposed in the present study.

Research Methodology. The appropriate selection or combination of teaching methods enables the instructor to address specific didactic tasks while taking into account the individual characteristics of students. Below, we consider several examples of conducting lecture, practical, and laboratory sessions in an active and engaging manner. A problem-based lecture begins with the identification of one or several problems that must be solved using the knowledge acquired throughout the lecture. It should be emphasized that the problems presented in the lecture must correspond to the students' level of difficulty, lie within their zone of proximal development, consider individual abilities, and be pedagogically meaningful for assimilating new material [1].

In recent years, this form of lecture has become increasingly common when multimedia presentations are used, as slides often contain the most essential concepts and may include video-

lectures. It is crucial to remember that we are educating a generation that has grown up during the rapid development of computer technologies.

In binary lectures, problem-oriented instructional content is presented to students through dynamic interaction not only between two instructors, but also between the instructors and the audience. Although rarely used, this form of instruction makes it possible to simulate real professional situations and to discuss theoretical issues from two different perspectives—for example, from the standpoint of a theorist and a practitioner, a proponent and an opponent of a certain viewpoint, and so forth [2].

A less common but highly interactive form of instruction is the lecture with pre-planned errors (lecture-provocation). This format is designed to develop students' skills in quickly analyzing professional situations and acting as experts, opponents, or reviewers, while also fostering critical thinking towards the presented information [3].

During preparation, the instructor deliberately introduces a set of content-related, methodological, or behavioral errors. Students become aware of this list only at the end of the lecture. Moreover, the selected errors must be typical of those commonly made by both students and instructors, yet carefully concealed and not easily noticeable. Such an approach requires the instructor to work through the lecture material thoroughly and thoughtfully, and to possess a high level of lecturing proficiency.

Practical experience shows that lectures incorporating pre-planned errors stimulate high levels of cognitive and emotional activity among students, as they are given the opportunity to apply previously acquired knowledge in practice. During the final analysis of the errors, students' theoretical thinking further develops.

Analysis and results. In a lecture involving the analysis of specific situations, a particular scenario is presented to the audience through a verbal or physical demonstration of an experiment, or through a very short video recording. The presentation must, on the one hand, be brief, and on the other hand, contain sufficient information to allow the evaluation of the phenomenon being demonstrated [4].

When conducting such lectures in physics, it is advisable to begin with the demonstration of a specific physical experiment without explaining its essence, and then, during a discussion with the audience, guide students toward the correct conclusion using leading questions.

During the lecture, students are invited to submit written questions to the instructor on the topic. The questions are formulated 2–3 minutes after the topic is announced, after which the instructor organizes the questions according to their semantic content over the next 3–5 minutes, and only then begins the lecture [3]. It should be emphasized that the instructor does not provide direct answers to individual questions, but instead conducts the lecture in a coherent, logically developing manner that leads students toward forming the appropriate answers. At the end of the lecture, the instructor evaluates the questions as a reflection of the listeners' knowledge and interests.

During lectures, engaging students in cognitive activity is achieved by formulating thought-activating questions and giving learners adequate time to think before answering. This approach enhances attention and enables students not only to ask questions but also to respond competently, defend their viewpoints, justify decisions, navigate challenging communicative situations, and develop tolerance toward alternative opinions [5].

According to the State Educational Standard, "the share of active and interactive learning formats must constitute at least 20% of the instructional process, while lecture-type classes may not exceed 40% of all classroom hours" [1]. This indicates that the time allocated for active and interactive learning is formally regulated.

From a methodological perspective, integrating social networks (Telegram, Facebook, Instagram) into lecture-related activities is advisable. Appointing group moderators from among students allows part of the theoretical work to be shifted outside the classroom, saving in-class time for the most complex and conceptually important elements of the topic. This also supports individualized and differentiated learning, enabling students to revisit lecture material multiple times.

Practical classes may likewise be organized using active learning approaches. These include the project method, which develops students' ability to independently plan and perform increasingly complex tasks; the portfolio method, which serves as a technology for managing and evaluating students' academic progress; game-based learning, which models real-world scenarios and transitions learners from passive knowledge reception to skill formation; training modules, which combine structured exercises to strengthen collaboration and professional competence; and the case method, which develops decision-making under uncertainty and fosters professional reasoning skills (Fig. 1).

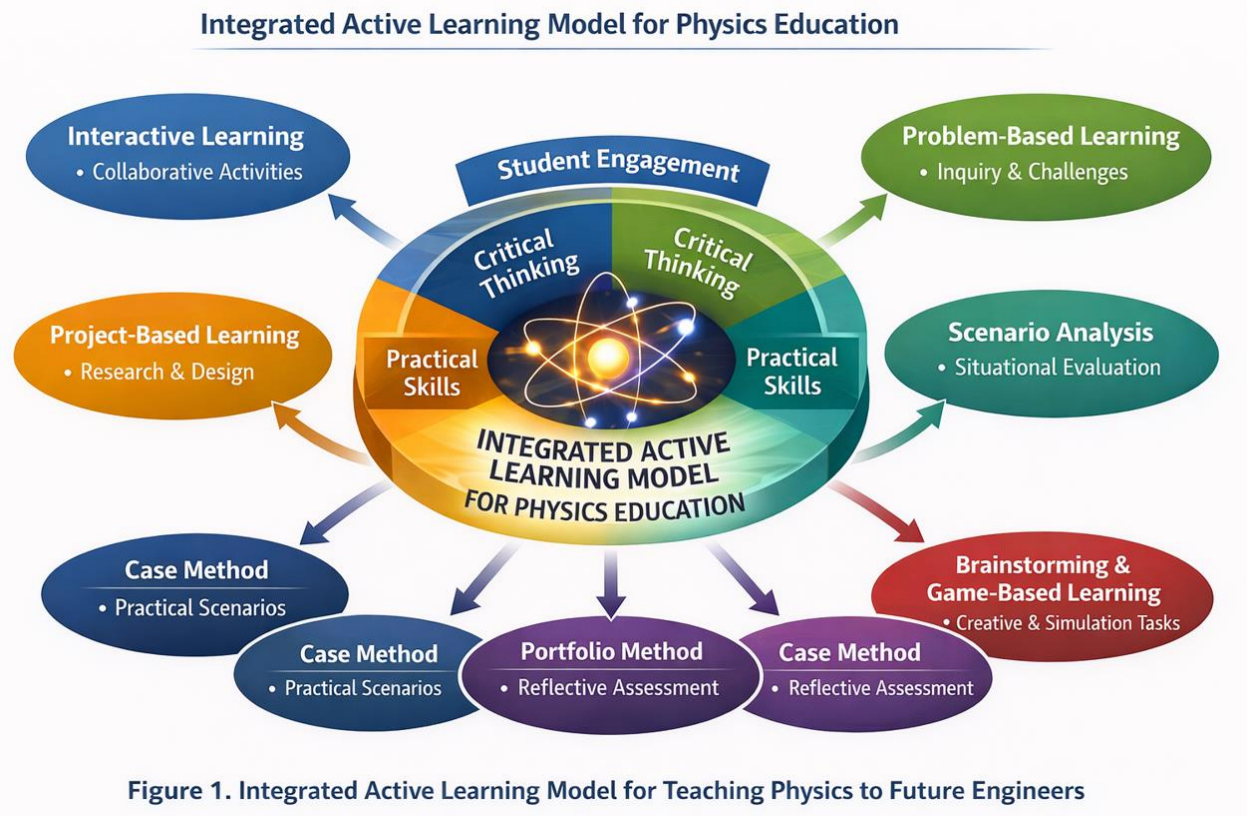

Figure 1. Integrated Active Learning Model for Teaching Physics to Future Engineers

After presenting theoretical material, the lecturer conducts preliminary assessment, followed by individual or pair-based problem solving, with or without analysis of correct solutions. At the end of the practical session, differentiated tasks allow students to choose the level of complexity independently, performing the necessary logical operations required for problem-solving.

Interactive learning differs from other formats. In many interactive courses, instructors prefer using interactive boards and multimedia presentations (approximately 86%). Interactive learning is understood as learning based on reciprocal communication and collaboration among students within a group. Psychologically, interactive learning engages not only perception, memory, and attention but also creativity, behavior, and interpersonal communication [2].

Among interactive strategies, brainstorming is used to generate collective solutions through questioning and analyzing contradictions, while synectics invites analogy-based thinking and deep creative ideation. The case method further strengthens applied decision-making and professional competencies.

Conclusion and recommendations. The study demonstrated that the integrated application of active and interactive teaching methods in engineering physics significantly enhances the effectiveness of the educational process. The combination of active methods (problem-based lecture, project method, game-based learning, training modules) and interactive methods (brainstorming, synectics, case study, portfolio, group discussion) fosters students' cognitive engagement, deepens conceptual understanding, and contributes to the formation of essential communicative and professional competencies.

The findings show that the pedagogically balanced selection of teaching methods, the logical coherence between them, and their step-by-step implementation create favorable conditions for developing students' abilities to solve engineering-oriented problems. Moreover, the integration of digital platforms (Telegram, Facebook, Instagram, LMS systems) into the learning process supports individualized learning trajectories and increases the effectiveness of independent study.

1. It is recommended to apply active and interactive teaching methods within a unified integrated methodological model in the process of teaching physics to future engineers. Such a model ensures the cohesion of lecture, practical, laboratory, and independent learning stages, thereby fostering students' ability to apply theoretical knowledge to practical situations, solve complex problems, and develop professional reasoning and communication skills.
2. It is advisable to incorporate digital learning platforms (interactive boards, multimedia lectures, video-lectures, online portfolios, digital case studies) systematically into engineering physics education. This approach promotes individualized learning, enhances student engagement, supports visualization of complex physical processes, and improves ongoing assessment. Additionally, digital tools strengthen students' independent learning skills and contribute to the development of modern engineering competencies.

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