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METHODOLOGICAL FOUNDATIONS OF TEACHING PHYSICS IN HIGHER EDUCATION

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ABSTRACT

This article examines the methodological foundations of teaching physics in higher education. It analyses how physics instruction can be organised around the principles of scientific rigour, systematic organisation, continuity and activity-based learning, as well as competency-based, constructivist, problem-based and inquiry-based approaches. It also considers the educational potential of digital technologies, virtual laboratories, visual modelling, interdisciplinary integration, individual learning pathways, gamification and artificial intelligence in physics education. Particular attention is paid to connecting theoretical knowledge with practical activity, strengthening laboratory and research work, and developing students' independent thinking, problem-solving abilities and professional competencies. The article argues that improving the methodology of teaching physics in higher education can contribute to the development of students' scientific outlook, capacity for independent learning and preparedness for future professional practice.

Keywords: physics education; higher education; teaching methodology; competency-based learning; virtual laboratories; interdisciplinary learning; artificial intelligence.

1. INTRODUCTION

Teaching physics in higher education plays an important role in developing future specialists' scientific outlook, helping them understand the nature of physical phenomena, connect theoretical knowledge with practical activity and acquire professional competencies. Physics is not only a fundamental science that explains phenomena occurring in nature; it also provides the theoretical foundations of modern engineering, technology and industry. Progress in engineering, energy, information technology, construction, transport, electronics, mechatronics, telecommunications and many other fields is directly associated with a sound understanding of physical principles. Therefore, organising physics instruction in higher education in a scientifically, methodologically and didactically appropriate manner is an important educational task.

The effectiveness of physics education depends not only on the content of the learning material but also on the methodological approaches used to select, organise, explain, teach, apply and assess that content. Methodology helps determine the general principles of knowledge acquisition, methods of scientific inquiry, and the aims, content, forms and tools of educational practice. In higher education, the methodology of teaching physics is intended to establish a close relationship between the content of physics and students' cognitive activity.

2. DISCUSSION: METHODOLOGICAL FOUNDATIONS OF PHYSICS TEACHING

The principle of scientific rigour should be central to defining the methodological foundations of physics instruction. It requires the subject matter to be presented in accordance with contemporary scientific views, theories, laws, principles and research findings. Students should not merely receive information about physical phenomena as established facts; they should also understand the causes of

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these phenomena, the relationships between them and their practical significance. This approach helps develop scientific reasoning.

Systematic organisation and continuity constitute another important methodological foundation. Concepts in physics form an interconnected system. Moving on to a more complex concept before a preceding one has been properly understood may create gaps in students' knowledge. Learning materials should therefore progress from simple to complex, from the known to the unknown, and from concrete examples to abstract concepts.

An activity-based approach is also methodologically significant. Within this approach, students are not passive recipients of information but active participants who acquire knowledge independently, analyse it, apply it in practical situations and develop new solutions. Active participation can be encouraged through problem situations, experiments, laboratory classes, practical assignments, projects, research tasks, modelling and discussions.

The methodology of physics teaching is closely connected with the competency-based approach. One of the principal aims of contemporary higher education is to prepare specialists who can use their knowledge effectively in a range of practical situations. This approach focuses on students' ability to apply the knowledge and skills they have acquired in real activities. In physics education, it can be implemented through problem-solving, experimentation, analysis of measurement data, construction of physical models, interpretation of graphs and diagrams, and explanation of technical processes on the basis of physical laws.

The constructivist approach also has an important place in the methodological foundations of physics education. From this perspective, knowledge is not simply information transmitted in a finished form; it is constructed through students' prior knowledge, experience, observations and active engagement. In physics classes, students can be encouraged to observe a phenomenon, identify a problem, formulate a hypothesis, test it experimentally and draw conclusions. These activities represent a practical application of constructivist learning.

Problem-based learning offers further opportunities to strengthen students' thinking. Rather than supplying ready-made answers, it encourages students to search for explanations and solutions. Real-life phenomena, technical devices, experimental results and apparently contradictory situations can be used to create problem scenarios. Such tasks can help students develop a deeper understanding of physical principles.

Experimentation and practical activity are particularly important in the methodology of teaching physics. Since physics is an experimental science, the verification of theoretical knowledge through experiments is an important means of developing students' scientific outlook. Laboratory classes enable students to measure physical quantities, use measuring instruments, process experimental data, determine measurement errors and interpret results scientifically.

The introduction of digital technologies into education is adding new dimensions to the methodology of physics teaching. A digital learning environment enables students to model physical phenomena virtually, conduct interactive experiments, access learning materials remotely, complete independent assignments and receive timely feedback on their performance. Virtual laboratories, simulations, electronic textbooks, video lessons, interactive presentations, online testing platforms and mobile learning resources can broaden the possibilities of the educational process.

Visual modelling is another important element of contemporary physics education. Many physical processes cannot be observed directly with the naked eye or occur at extremely small or large scales. Visual models can help explain processes such as the motion of atoms and molecules, the structure of electric fields, the propagation of electromagnetic waves and quantum phenomena. Such

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representations can support the development of students' abstract thinking and conceptual understanding.

An interdisciplinary approach is also important in higher education physics. Physics is directly connected with many natural sciences, technical disciplines and mathematics. Mathematical knowledge is essential for expressing physical laws and solving problems; computer science and information technologies support the modelling of physical processes; and engineering disciplines demonstrate how physical laws are applied in technical devices.

Individualisation and differentiation are further methodological foundations of physics education. Students in higher education differ in their levels of prior knowledge, interests, motivation and ability to work independently. Consequently, assigning exactly the same tasks and applying identical methods to all students may not produce the expected outcomes. A differentiated approach makes it possible to vary assignments according to their level of difficulty and to provide opportunities for students to follow individual learning pathways.

An inquiry-based approach is an important means of preparing students for scientific activity. Inquiry involves identifying a problem independently, formulating a research question, proposing a hypothesis, collecting information, conducting an experiment and analysing the results. Through these activities, students develop scientific reasoning, the ability to evaluate evidence and the capacity to draw independent conclusions.

Assessment in physics education also needs to be reconsidered from a methodological perspective. Traditional assessment often focuses on determining students' theoretical knowledge. In contemporary education, however, assessment should also consider whether students understand knowledge, can apply it in practice, analyse information, solve problems and express independent opinions. Alongside diagnostic, formative, interim and summative assessment, it is therefore appropriate to expand opportunities for self-assessment and peer assessment.

A reflective approach is valuable because it enables students to analyse their own learning and performance. At the end of a lesson, students should be able to identify not only whether they have understood the topic but also what they have learned, which issues they found difficult and what they need to do next. Reflecting on their learning helps students develop the ability to study independently.

A communicative approach is another important methodological component of physics teaching. Students should learn to express their ideas clearly, use physical terminology accurately, explain problems and justify their conclusions. Pair work, small-group activities, discussions, question-and-answer sessions, presentations and project defence can increase students' communicative engagement.

The development of logical thinking and mathematical literacy also deserves particular attention. Quantitative descriptions of physical phenomena require the use of mathematical tools. However, memorising a formula is not sufficient. Students need to understand the physical meaning of the quantities in the formula, the relationships between them and the conditions under which the formula can be applied.

Developments in artificial intelligence are creating new opportunities for the methodology of physics education. AI-based tools can assist in generating individual assignments, explaining learning materials, preparing tests, identifying students' errors and individualising the learning process. At the same time, the use of artificial intelligence should preserve students' independent thinking and academic integrity.

The methodological foundations of physics teaching are also closely related to students' personal and professional development. Through the study of physics, students can develop accuracy, logical reasoning, consistency, responsibility, observational skills and an evidence-based approach.

Recording experimental results, observing measurement accuracy, taking errors into account and drawing evidence-based conclusions all contribute to the development of a scientific work ethic.

3. CONCLUSION

To improve the effectiveness of physics teaching in higher education, methodological approaches should not be applied in isolation but integrated into a coherent system. The combined use of scientific rigour, systematic organisation, continuity, competency-based and activity-based learning, problem-based and inquiry-based instruction, individualisation, digital technologies, interdisciplinary integration and reflection can enrich both the content and the methodological possibilities of physics education.

Overall, the methodological foundations of teaching physics in higher education should focus not merely on students' acquisition of ready-made knowledge but on their ability to acquire scientific knowledge independently, understand and model physical phenomena, test them experimentally, analyse the results and apply them in practical contexts. Contemporary physics education therefore calls for renewed relationships between teachers and students, a stronger role for students as active participants in the learning process, and the thoughtful use of the opportunities offered by digital learning environments.

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