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# DEVELOPING PROFESSIONAL COMPETENCE OF FUTURE ENGINEERS THROUGH THE APPLICATION OF COMPUTER TECHNOLOGIES IN PHYSICS

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| A B S T R A C T | K E Y W O R D S |
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| Physical sciences play a fundamental role in modern engineering education. The application of computer technologies in the process of teaching physics, particularly modeling, simulation, and digital analysis tools, serves as an effective means of developing students' professional competence. This article examines the pedagogical and scientific effectiveness of computer technologies in physics education based on the analysis of scientific sources indexed in the Scopus database. The research results indicate that computer modeling and simulation approaches enhance students' analytical thinking, problem-solving abilities, and digital literacy. Additionally, the theoretical foundations for developing the professional competence of future engineers through interdisciplinary integration are identified. | Physics education, computer technologies, professional competence, future engineers, modeling, simulation, interdisciplinary integration. |

## INTRODUCTION

Modern engineering education requires students to develop not only theoretical knowledge but also practical skills and professional competencies. Physics is a fundamental component of engineering, encompassing complex concepts and processes. Therefore, effective physics teaching is an important tool in developing future engineers' **analytical thinking, problem-solving, and digital literacy** skills (Caballero & Odden, 2024; Voogt et al., 2018).

In recent years, **computer technologies,** particularly **simulation, modeling, and digital analysis** tools, have been widely used in physics education. These approaches allow students to visualize complex processes, integrate theoretical knowledge with practice, and solve problem situations (Kozma, 2019; Hsu et al., 2020). Additionally, interdisciplinary integration of physics and engineering knowledge serves to more effectively develop students' professional competence. From this perspective, the purpose of this article is to identify the theoretical foundations for developing future engineers' professional competence through the application of computer technologies in physics and to analyze the scientific literature in the Scopus database. This field is known as Computational Materials Science and Computational Physics.

The research encompasses the following main tasks:

1. Analyzing the pedagogical effectiveness of computer technologies in physics education;
2. Assessing the impact of modeling and simulation approaches on professional competencies;
3. Developing a theoretical model and determining conceptual foundations through interdisciplinary integration.

The aim of the article is to determine the theoretical foundations for developing the professional competence of future engineers through the use of computer technologies in physics.

**Literature review**

**2.1.Computer modeling and simulation methods.**

In recent years, computational modeling and simulation-based learning have been widely used in physics education. Studies show that computer modeling helps students understand complex processes in a visual and interactive way (Caballero & Odden, 2024; Voogt et al., 2018).

**Molecular and macroscopic models** - allow predicting physical phenomena and enable students to perform experiments in a virtual environment.

**Simulation software** - helps to quickly analyze processes and display results in the form of graphics and tables.

**2.2 The concept of competence.**

Professional competence encompasses not only the theoretical knowledge of future engineers but also their ability to think analytically, solve problems, and effectively use technological tools (OECD, 2020). Studies show that through computer modeling and simulation in physics, students can develop:

1. Analytical and critical thinking skills;
2. Digital literacy;
3. Problem-solving strategies;
4. The ability to apply interdisciplinary approaches is developed.

**2.3 Interdisciplinary integration**

The integration of physics and engineering sciences, as well as modeling carried out using computer technologies, prepares students for real engineering processes. This approach enhances the professional competence of future engineers by combining scientific and practical skills (Kozma, 2019; Caballero, 2024).

**Methods (Methodology)**

This research was conducted based on theoretical-analytical and conceptual approaches. The research process consisted of three stages: systematic analysis of scientific literature, development of a conceptual model, and application of interdisciplinary integration principles to the practical research process. This method serves to identify the theoretical and scientific foundations for developing the professional competence of future engineers.

### 3.1 Literature analysis

As the first stage of the study, a systematic analysis of selected articles from international indexed databases such as Scopus, ScienceDirect, SpringerLink, and IEEE Xplore was conducted. At this stage, work was carried out based on the following criteria:

- Availability of empirical and theoretical works on the research topic;
- Effectiveness of computer modeling and simulation tools in developing students' professional competence;
- Application of interdisciplinary integration approaches and digital technologies in physics and materials science education;
- Scientific reputation of publications (peer-reviewed and Scopus-indexed articles).

As a result of this systematic analysis, a total of 20 articles were studied in depth. The analysis methodology, main results, and pedagogical recommendations were integrated as a scientific foundation.

### 3.2 Development of a theoretical conceptual model

Based on the literature analysis, a conceptual model for developing the professional competence of future engineers through the integration of computer technologies into physics and materials science education has been developed. The model consists of the following components:

1. Computer technologies: Modeling, simulation, virtual laboratories, and interactive visualization tools.
2. Physics and Materials Science Knowledge: Theoretical concepts, physical processes, material properties, and their mathematical analysis.
3. Professional competencies: Analytical and critical thinking, systematic problem-solving, digital literacy, creative thinking, and the development of technological solutions.
4. Interdisciplinary integration: Harmonizing knowledge in physics, materials science, and engineering; preparing for real engineering processes; developing practical competencies.

This model enables the structuring and assessment of students' professional competence and serves as a conceptual basis for laboratory classes, virtual simulations, and modeling work.

### 3.3 Interdisciplinary Integration and Assessment

The third stage of the model focuses on interdisciplinary integration and theoretical assessment of competencies. The following skills of students were evaluated using modeling and simulation approaches:

- Digital literacy: The ability to process and visualize data in digital formats.
- Analytical thinking: Analyzing physical and materials science processes using mathematical and computer models.
- Problem-solving: Applying theoretical knowledge to real engineering tasks.
- Interdisciplinary integration skills: Solving complex problems by integrating knowledge from physics, materials science, and engineering.

The theoretical conceptual model and interdisciplinary integration approach provide a structural, systematic, and scientific foundation for the research. Additionally, this methodology establishes guidelines for planning future empirical studies, laboratory exercises, and virtual simulations.

**Results**

**Discussion**

The research results demonstrated that approaches based on the use of computer technologies and modeling in physics education significantly enhance the professional competence of future engineers [1-20]. The results are discussed from several aspects:

1. Pedagogical effectiveness of computer modeling and simulation: Modeling exercises using computer technologies allow students to visually comprehend complex physical processes. Additionally, this approach improves students' ability to apply theoretical knowledge practically and analyze experimental results [2,4,6,12,14]. For instance, the PhET Interactive Simulations platform enables students to conduct virtual laboratory experiments without experimental errors and model real-world problems [20].
2. Analytical thinking and problem-solving abilities: Analyses have shown that modeling exercises serve to strengthen students' analytical thinking and systematic problem-solving skills [3,5,7,12,15]. This is particularly crucial in interdisciplinary integration tasks, as students learn to apply physical laws within an engineering context [13,16,18].
3. Digital Literacy and Technological Skills: Modeling and simulation approaches enhance students' digital literacy, specifically their ability to analyze data on computers and present it in graphical and visual forms [1,3,10,15]. Additionally, these skills are considered essential practical competencies for future engineers, as they enable the effective application of technological tools in real projects [4,6,12].
4. The role of the interdisciplinary integration approach: Interdisciplinary integration allows students to harmonize their knowledge of physics and engineering. Research results have shown that students' ability to solve complex engineering problems significantly improves through interdisciplinary activities [3,13,16,18]. Furthermore, this approach serves to develop students' creative thinking and reinforce their practical skills [7,12,14,17].
5. Practical significance of the theoretical model: The theoretical model developed in this study provides a conceptual foundation for cultivating the professional competence of future engineers. The model encompasses four key components: computer technologies, physics knowledge, professional competencies, and interdisciplinary integration. Research findings indicate that when these components are integrated, students' analytical thinking, problem-solving abilities, digital literacy, and interdisciplinary integration skills are optimally developed [1-20].

**Scientific and practical conclusions:**

The results demonstrate that the application of computer technologies in physics not only reinforces theoretical knowledge but also enables comprehensive development of professional competence in future engineers. Moreover, this approach establishes a theoretical foundation for conducting empirical research, virtual laboratory sessions, and interactive simulations [2,5,6,12,14,20].

**Conclusion**

The application of computer technologies in physics proves highly effective in developing the professional competence of future engineers. The research findings indicate that:

1. Students integrate theoretical knowledge with practical exercises and visualize complex processes.

2. Analytical thinking, digital literacy, and problem-solving skills are enhanced through the use of MATLAB, Python, and multiphysics simulations.
3. Interdisciplinary integration enhances students' ability to solve real engineering problems and prepares them for the modern engineering environment.
Thus, educational approaches based on computer technologies comprehensively develop both theoretical and practical competencies of future engineers, thoroughly preparing them for their future professional activities.

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