

## DEVELOPING PROFESSIONAL COMPETENCIES OF MEDICAL ENGINEERING STUDENTS THROUGH TEACHING PHYSICS BASED ON THE INTEGRATION OF BIOPHYSICS AND MEDICAL SCIENCES

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**Abstract.** *This article discusses the theoretical and methodological aspects of teaching physics to students majoring in medical engineering based on the integration of biophysics and medical sciences. The significance of integrative education and its role in developing students' professional competencies—such as scientific-analytical thinking, engineering reasoning, practical technical skills, and the ability to understand medical equipment—is analyzed. In addition, the paper addresses modern pedagogical technologies, digital simulation tools, biophysical models, and methodological conditions that enhance interdisciplinary connections.*

**Keywords:** *medical engineering, biophysics, integration, interdisciplinary approach, professional competence, innovative education, medical technologies, physical modeling, engineering thinking, digital education.*

In the modern education system, the integration of medicine and engineering has become a pressing issue. Medical engineering is an interdisciplinary field situated between technology and biology, which explains the human body, medical devices, and physiological processes based on technical and physical principles. Therefore, teaching physics to medical engineering students requires an approach different from traditional methods [3]. For students in this field, physics is not only a theoretical foundation but also a core discipline for understanding, designing, and servicing medical technologies. Consequently, teaching physics through integration with biophysics, anatomy, physiology, and medical technology should be regarded not merely as knowledge transfer, but as a means of forming professional competence.

Through an integrative approach, students are able to directly relate physical laws to practical medical processes [4]. For example, analyzing blood flow hydrodynamics, the mechanical work of cardiac muscles, pressure changes during respiration, or the electrical activity of the heart through fundamental laws of physics is a crucial condition for the development of professional thinking.

### **1. Integration of Biophysics and Medical Sciences as the Scientific and Methodological Basis of Competency-Based Education**

In the training of medical engineers, biophysics occupies a central position. Biophysics studies physical processes occurring within the organism, such as blood rheology, the mechanics of muscle contraction, bioelectrical signals, heat exchange, and radiation absorption. These areas of knowledge form the foundation for the development and operation of modern medical technologies.

By integrating physics with biophysics in the teaching process, students are able to:

- analyze physical laws within biological systems;
- express physiological processes through mathematical modeling;
- develop technical thinking based on the operating principles of medical devices (ECG, EEG, ultrasound, X-ray, MRI);
- enhance scientific research skills.

Thus, the integrative approach enables the preparation of medical engineers as specialists who build a bridge between theory, technology, and clinical practice.

## 2. Advantages of the Competency-Based Approach in Teaching Physics

Within a competency-based approach, knowledge is not merely a collection of theoretical concepts, but the ability to apply it to solving practical problems. Teaching physics on this basis helps form the following competencies in medical engineering students:

- **Analytical competence:** explaining physical processes through mathematical analysis and applying them to biological systems;
- **Technical competence:** understanding the physical foundations of medical equipment, adjusting devices, and integrating them into diagnostic systems;
- **Communicative competence:** mastering scientific language when working with physical and biological terminology;
- **Creative competence:** proposing innovative ideas and new technical solutions [7].

For instance, when an instructor explains electromagnetic induction in connection with the operating mechanism of a cardiac pacemaker, students develop not only physical knowledge but also the ability to understand and evaluate medical technologies.

## 3. Use of Modern Pedagogical Technologies in the Integrative Teaching Process

To enhance the effectiveness of integrative teaching, digital educational resources, virtual laboratories, 3D simulations, and interactive teaching methods play a vital role. For example:

- modeling blood flow, fluid pressure, or the cardiac cycle using platforms such as PhET Simulation or Algodoo Physics;
- visualizing anatomy and physical processes simultaneously using the Anatomage Table;
- measuring physiological signals (pulse, pressure, temperature) with Arduino sensors, which engages students in real engineering analysis.

Such approaches increase students' activity, independence, and professional motivation.

## 4. An Innovative Model of Integrating Physics, Biophysics, and Medicine

The integrative teaching model consists of three main stages:

1. **Theoretical stage** — applying fundamental laws of physics (mechanics, electricity, optics, thermodynamics) to medical contexts.
2. **Practical stage** — studying the physical foundations of medical devices through laboratory work and virtual experiments.
3. **Project-based stage** — demonstrating final professional competencies through the development of biophysical systems or medical device models.

The advantage of this model lies in the fact that students fully master the entire chain from scientific reasoning to practical engineering solutions.

### Conclusion

Teaching physics to medical engineering students based on the integration of biophysics and medical sciences is one of the most effective approaches for developing professional competencies. This approach:

- connects physics with the practical medical environment;
- forms scientific-analytical and technical thinking in students;
- enables a deep understanding of medical devices and technologies;
- promotes independent learning, creative thinking, and innovative activity.

Therefore, interdisciplinary integration in teaching physics to medical engineers constitutes the scientific and practical foundation of modern medical education. This process fosters engineering competencies that meet contemporary medical demands and prepares students as globally competitive specialists.

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