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РЕАЛІЗАЦІЯ ПРИНЦИПУ МІЖДИСЦИПЛІНАРНОЇ ІНТЕГРАЦІЇ ПРИ ПІДГОТОВЦІ МАГІСТРІВ МЕДИЦИНИ ЯК ПЕДАГОГІЧНА ПРОБЛЕМА

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INTERDISCIPLINARY INTEGRATION IN THE TRAINING OF MASTER'S STUDENTS IN MEDICINE AS A PEDAGOGICAL CHALLENGE

Анотація. У статті обґрунтовано актуальність і доцільність реалізації принципу міждисциплінарної інтеграції в освітньому процесі підготовки магістрів медицини як одного з ключових напрямів підвищення якості професійної освіти. Розглянуто терміни «інтеграція» та «міждисциплінарна інтеграція» в загальнонауковому контексті й підкреслено, що міждисциплінарна інтеграція виступає сучасною дидактичною концепцією, що забезпечує цілісність освітнього процесу, високий науковий рівень викладання та є ефективним засобом формування професійних знань і практичних навичок здобувачів освіти. У статті детально проаналізовано ключові компетенції, які формує навчальна дисципліна «Медична фізика», зокрема розвиток логічного мислення, здатності до синтезу та аналізу інформації, а також умінь правильно формулювати завдання та знаходити шляхи їх розв'язання, що є необхідними для практичної діяльності майбутніх лікарів.

Висвітлено значення медичної фізики для розвитку сучасних методів діагностики і лікування, у тому числі застосування ультразвукової, магнітно-резонансної та рентгенівської томографії, лазерних і радіологічних технологій, що не можуть ефективно використовуватися без розуміння фізичних принципів їх роботи. Проаналізовано особливості реалізації інтеграційних зв'язків між медичною фізикою та іншими навчальними дисциплінами, включаючи клінічні, що дозволяє студентам сформувати системне бачення медичних процесів та комплексний підхід до діагностики і лікування. Наведено приклади фізичних методів і приладів, які стали основою для хірургічних, терапевтичних та неінвазивних діагностичних методик, а також обґрунтовано педагогічні та методичні аспекти застосування міждисциплінарного підходу в підготовці магістрів медицини.

Таким чином, у статті підкреслено, що інтеграція медичної фізики з іншими дисциплінами вищої медичної освіти сприяє підвищенню наукового рівня викладання, формуванню компетентностей, необхідних для майбутніх лікарів, та розвитку здатності до практичного застосування отриманих знань у клінічній практиці, що є ключовим чинником підготовки висококваліфікованого медичного фахівця в умовах сучасної медицини.

Ключові слова: міждисциплінарна інтеграція; магістр медицини; медична фізика, клінічні дисципліни.

Abstract. This article substantiates the relevance and feasibility of implementing the principle of interdisciplinary integration in the educational process for training Master's students in Medicine, highlighting it as a key approach to enhancing the quality of professional education. The terms "integration" and "interdisciplinary integration" are analyzed in a general scientific context, emphasizing that interdisciplinary integration represents a modern didactic concept that ensures the coherence of the educational process, a high scientific standard of instruction, and serves as an effective tool for developing students' professional knowledge and practical skills. The article provides a detailed analysis of the core competencies developed through the academic course Medical Physics, including the enhancement of logical thinking, analytical and synthetic abilities, as well as the capacity to accurately formulate tasks and identify strategies for their resolution, all of which are essential for the practical activities of future physicians.

The significance of Medical Physics in advancing modern diagnostic and therapeutic methods is highlighted, including the application of ultrasound, magnetic resonance, and X-ray tomography, as well as laser and radiological technologies, which cannot be effectively utilized without an understanding of the underlying physical principles. The article examines the implementation of integrative links between Medical Physics and other courses, including clinical subjects, enabling students to develop a systemic understanding of medical processes and a comprehensive approach to diagnosis and treatment. Examples of physical methods and instruments that have formed the basis for surgical, therapeutic, and non-invasive diagnostic techniques are presented, along with the pedagogical and methodological rationale for employing an interdisciplinary approach in the training of Master's students in Medicine.

Thus, the article emphasizes that the integration of Medical Physics with other courses in higher medical education contributes to elevating the scientific quality of instruction, fostering competencies essential for future physicians, and enhancing the ability to apply acquired knowledge in clinical practice. This interdisciplinary approach is a key factor in preparing highly qualified medical specialists capable of meeting the demands of modern Medicine.

Key words: interdisciplinary integration; Master of Medicine; Medical Physics; clinical courses.

Introduction. The preparation of a competent and highly skilled Master of Medicine, equipped not only with the theoretical foundations required for health maintenance, disease prevention, and treatment, but also with the ability to apply this knowledge effectively in clinical practice, represents a central goal of modern medical education. During the course of training, students develop an integrated body of knowledge across multiple courses outlined in the medical curriculum, which creates the need for teaching approaches and organizational models that ensure a high level of educational quality and professional readiness. Within this framework, the adoption of the principle of interdisciplinary integration in the educational process plays a particularly significant role.

The theoretical and practical dimensions of interdisciplinary integration in the training of medical professionals at higher medical education institutions have been explored in the works of S. Bukhalska, N. Shamro, M. Karpets, N. Voloshchuk, B. Palasiuk, E. Yu. Rozhdestvenskyi, A. Shulhai, among others. The relevance of interdisciplinary integration as a pedagogical issue is evidenced by the wide range of scholarly studies addressing its various aspects.

Within the general scientific framework, the concept of integration is commonly understood as the unification of separate parts, elements, or components into a coherent whole (Proshkin, 2010). In the context of education, interdisciplinary integration is defined by scholars (Palasiuk, 2022) as a process of coordinating the content of academic courses in order to reflect unified, continuous, and holistic phenomena of professional activity. This process involves the deliberate strengthening of interdisciplinary links while maintaining the theoretical and practical integrity of individual courses.

Emphasizing interdisciplinary integration as a modern didactic concept underlying a holistic educational process in higher education, M. Karpets interprets curriculum integration as both a process and an outcome of constructing coherent academic courses through the synthesis of scientific knowledge. This synthesis is based on fundamental laws governing the development of science and is shaped by the didactic representation of natural relationships and interconnections, thereby fostering meaningful inter-subject links. Other researchers (Lysachenko, 2012) highlight the role of interdisciplinary integration in the development of students' clinical thinking, while also examining issues of horizontal interdisciplinary integration within competence-based (Kyrvas & Sytnykova, 2016) and problem-based learning models (Shulhai, Fedoniuk, Mudra & Oleshchuk, 2018).

Interdisciplinary integration provides a conceptual foundation for addressing shared educational objectives through a holistic and worldview-based synthesis of knowledge. The implementation of interdisciplinary links facilitates the development of curricula that emphasize the interconnection of academic courses at various stages of the educational process. While this approach overcomes the limitations of isolated subject teaching, it preserves the relative autonomy of individual courses, as well as their logical structure and sequential organization of learning content.

In this way, interdisciplinary integration ensures a high level of scientific rigor in instruction and is regarded as one of the most effective methodological tools for fostering the professional knowledge and practical skills of students.

The aim of this article is to analyze the specific features of implementing integrative links between the academic course Medical Physics and other subjects taught at medical higher education institutions.

Theoretical framework. Medical Physics and its related research fields are currently among the most promising areas within the natural sciences, as evidenced by the active integration of cutting-edge scientific achievements, particularly those of physics, into clinical medical practice. Medical Physics focuses on exploring the potential application of a wide range of physical agents and physic and mathematical methods for studying the human body, with the aim of developing and implementing innovative diagnostic techniques and therapeutic interventions.

According to scientific sources (Rozhdestvenskiy, 2009), under contemporary conditions the primary objective of the educational process in higher medical institutions is to foster the professional development of physicians capable of effectively perceiving, independently acquiring, and practically applying relevant information, as well as solving complex clinical problems. Consequently, the knowledge gained through the study of the academic course Medical Physics contributes significantly to the formation of essential general and professional competencies in future medical specialists. These include the development of logical thinking skills, the ability to accurately formulate professional tasks, and the capacity to identify effective solutions to a wide range of clinical and professional challenges.

In modern Medicine, a wide range of physical methods and instruments serve as the foundation for diverse medical techniques in surgery, therapy, and non-invasive diagnostics. For instance, ultrasound diagnostic imaging (US) has become possible due to advances in contemporary acoustics, as well as nonlinear and Doppler ultrasonography. The use of electronic and proton accelerators for sterilizing medical equipment has also become routine in global medical practice.

Synchrotron radiation from charged particles in accelerators is employed in high-resolution X-ray transmission tomography, complementing conventional X-ray radiography and computed tomography. Advances in radiation physics have paved the way for the safe and effective application of radionuclides, gamma cameras for radiodiagnostics, and a variety of radiotherapy devices, including the so-called “cyberknife”. In this context, methods such as single-photon and positron emission tomography, nuclear magnetic resonance imaging, high-frequency electroencephalography, laser technologies, and various radiation sources have become feasible, largely due to the contributions of Medical Physics.

Analyzing the conceptual foundations of integrating natural science knowledge with professional and practical training for future physicians, scholars emphasize that “a solid grounding in natural sciences and the corresponding skills of medical students provides an objective basis for the development of professional competencies” (Paykush, 2015).

In higher medical education, when teaching Medical Physics, it is advisable to organize the curriculum according to the professional context of the future physician. In other words, the subject should be presented in a way that enables students, as future doctors, to perceive the concept of “the human body as an object of physical study” through the following integrated components:

a) the physical principles underlying processes in the human body at different levels: cell, tissue, organ, organ system, and whole organism;

b) the physical foundations of medical diagnostic and therapeutic methods;

c) the physical principles of scientific research in medical practice.

Biological forms of material motion differ qualitatively from other forms but cannot exist independently of them. Simple forms of matter movement, physical and chemical, are ultimately governed by the primary biological form. Biological physics, which differs from classical physics and physiology, employs specialized methods of investigation. From a biophysical perspective, these methods are distinct from classical approaches in that they allow for precise measurement of biological parameters, mathematically describe the physical and physical and chemical foundations of biological processes, and create quantitative models of life-sustaining processes. For future physicians, this provides a foundation for a comprehensive understanding of both normal and pathological indicators of the human body.

Medical and Biological Physics enables students to understand phenomena that a physician must observe and evaluate during physical examination. It examines sound vibrations, considering both objective characteristics: frequency, intensity, sound pressure, harmonic spectrum and subjective characteristics: pitch, timbre, and loudness. It also explains the principles and specific features of sound propagation in elastic and gaseous media, thereby providing a methodological basis for sound-based clinical techniques such as auscultation, percussion, and phonocardiography. Students should appreciate that changes in tissue elasticity, a physical property altered by pathological processes, lead to corresponding changes in the quality of sound (Mykytiuk, 2019).

The percussion method is based on the principle of resonance. During thoracic percussion, a percussive strike generates impulses both in depth and laterally. The region through which these sound waves propagate is referred to as the percussion field.

Different organ sounds are audible during percussion, depending on their air content. In tissues lacking air, resonance does not occur. For example, percussion of the thigh produces a dull sound, whereas a hollow organ yields a resonant, loud tone. The pitch of the sound depends on the tension of the organ walls: higher tension produces higher-frequency sounds, while lower tension results in lower-frequency tones.

When studying respiratory pathologies, students develop the skills not only to distinguish variations in percussion sounds associated with changes in the elasticity and firmness of lung tissue, formation of cavities, or accumulation of fluid or air in the pleural spaces, but also to understand the underlying mechanisms of these changes. This knowledge enables a more in-depth analysis of the dynamics of pathological processes (Lysachenko, 2012).

Thus, the knowledge acquired during the study of Medical Physics enables students to identify the physical basis of sound changes over specific organs. This, in turn, allows clinicians to detect potential pathologies even before performing radiography or other advanced instrumental examinations. An understanding of the physical principles underlying sound variations or palpatory phenomena, learned in Medical Physics courses, can be critically important for providing timely emergency care. These diagnostic skills are particularly valuable in field conditions or emergency settings, where access to X-ray or specialized equipment may be limited.

Specifically, the medical and biological physics curriculum provides students with foundational knowledge of acoustics, which underlies the technique of auscultation – listening to the sounds produced by internal organs. The first device for auscultation was the stethoscope, a simple tube applied to the body to detect organ-generated sounds. Unlike the stethoscope, the phonendoscope incorporates a stretched membrane that amplifies sounds. Today, combined devices known as stethophonendoscopes are commonly used, and the physician's task is to recognize and interpret sounds from different organs. For example, during lung auscultation, the presence of additional sounds, such as rales, crepitation, or pleural friction rubs, superimposed on normal breath sounds indicates pathological changes, and the ability to interpret these findings is essential for physicians across all medical specialties.

As is well known, the human circulatory system represents a complex physiological process, which is fundamentally physical in nature. It involves the flow of fluid (hemodynamics, an example of hydrodynamics), the propagation of vibrations through blood vessels (wave and oscillation theory), the mechanical work of the heart (mechanics), and the generation of cardiac bio-potentials (electricity).

Hemodynamics studies the movement of blood within the vascular system. Understanding the principles of blood flow is crucial for diagnosing a wide range of cardiovascular diseases. Knowledge acquired in medical and biological physics courses regarding hydrodynamics and hemodynamics allows students to better comprehend the mechanisms underlying heart sounds. According to hydrodynamic theory, blood flow can be laminar or turbulent. Laminar flow does not produce audible vibrations, whereas turbulent flow generates sound phenomena due to particle oscillations during abrupt changes in flow, which are perceived clinically as heart murmurs.

During medical and biological physics classes, students also study the origin and dynamics of cardiac bio-potentials throughout the cardiac cycle. The field utilizes the concept of the heart's electrical vector, defined as the resultant dipole moment of all current dipoles present in the cardiac muscle at a given moment. The excitation wave propagating through the myocardium causes continuous changes in the heart's electrical vector and its spatial orientation. At specific phases of the cardiac cycle, the heart vector describes three closed loops in space, representing atrial excitation, the ventricular complex, and ventricular relaxation following the ejection of blood into the aorta.

Another example of interdisciplinary integration is the primary method for studying cardiac function, electrocardiography (ECG). The role of medical and biological physics is to identify the origins of cardiac bio-potentials and explain their dynamics throughout the cardiac cycle, while the role of cardiology is to detect pathological conditions based on ECG analysis.

Many such examples can be provided to illustrate the implementation of interdisciplinary links between Medical Physics and clinical courses. What distinguishes interdisciplinary integration is that the educational content is not merely repeated across subjects; rather, it is applied in students' learning activities to achieve a deeper understanding of the underlying principles and mechanisms of physiological phenomena and clinical processes.

In contrast to traditional teaching methods, which often lead to fragmented understanding, where students may succeed in individual subjects but struggle to apply knowledge across different areas of study, interdisciplinary integration enables students to develop the ability to establish connections between diverse scientific fields. This approach enhances critical thinking skills and fosters the capacity to synthesize information. It not only improves academic performance but also effectively prepares students to address the complex, multifaceted challenges they will encounter in their professional practice.

In this context, it is important to emphasize that the successful implementation of interdisciplinary links in the training of Master's-level medical students requires the use of problem-based, learner-centered, and interactive teaching approaches, as well as computer-assisted and simulation-based technologies, including tests, case studies with integrated content, and virtual reality. Incorporating other innovative educational technologies and strengthening interdisciplinary approaches within the curriculum are also essential. Given the rapid pace of development in medical science, teaching materials and student assessment methods must be continuously updated and refined to maintain educational effectiveness.

Conclusions and prospects for further research. As a fundamental science, Medical Physics plays a critical role in the development of modern diagnostic and therapeutic methods. Its integration into the curricula of higher medical education institutions enhances students' understanding of the underlying processes in medical technologies, thereby improving the quality of medical training.

Diagnostic tools such as ultrasound (US), magnetic resonance imaging (MRI), laser systems, and other medical devices cannot be used effectively without a solid understanding of the physical principles that govern their operation.

Moreover, the advancement of emerging technologies – including nanotechnology and artificial intelligence relies on an interdisciplinary approach that combines Physics, Biology, and Medicine. Therefore, integrating Medical Physics with other courses represents an essential step toward enhancing the training of future physicians and creating more effective and innovative healthcare systems.

Educational program reforms should address these challenges by providing students not only with foundational knowledge but also with opportunities to apply it in practice through the strengthening of interdisciplinary approaches in the learning process. Given that the issues discussed in this article lay the groundwork for exploring a wide range of interdisciplinary connections between Medical Physics and other, particularly clinical, courses in higher medical education, further research may focus on improving curriculum content and implementing innovative technologies, such as simulators and virtual reality, to enhance the interdisciplinary approach in medical education.

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