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METHODOLOGICAL IMPROVEMENT OF TEACHING MEDICAL PHYSICS BASED ON THE INTEGRATION OF STEAM AND EXPERIMENTAL APPROACHES

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Abstract
The modern educational process is not aimed at the student's memorization of ready-made knowledge, but at the formation of independent thinking, analysis and creation of new ideas. Especially in the subject of medical physics, it is important to develop students' ability to understand scientific phenomena through experiments and observations. Therefore, demonstration experiments and the STEAM approach play a key role in the effective organization of the educational process. The article discusses the ways, stages and evaluation criteria for conducting demonstration experiments in medical physics lessons and methodologically improving the educational process based on STEAM integration.

Keywords: Medical physics, demonstration experiment, STEAM approach, computed tomography, X-ray, detector, experimental methodology, integration.

Introduction

Medical physics is a discipline taught through the harmonious integration of medical equipment, ionizing and non-ionizing radiation, tomography, detectors, measurement techniques, and theoretical physics principles. In turn, this discipline involves complex physical concepts, technological devices, and measurement methods, so traditional oral theoretical lectures do not always achieve sufficient understanding in students.

Pedagogical research has shown that through demonstrative experiments, students have the opportunity to visually observe, perceive, and analyze theoretical concepts. For example, using an analog experiment, topics such as

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"ionizing radiation propagation", "detector signal generation", "tomographic image processing" can be studied in an interconnected way. In pedagogical theory, this principle is called the "principle of demonstrability" - according to scientists-pedagogues J. Komensky, K.D. Ushinsky, A. Disterweg and others, knowledge is acquired much more firmly when a student perceives it not only verbally, but also visually.

In addition, in recent years, an interdisciplinary approach to education - that is, the integration of science, technology, engineering, arts, and mathematics (STEAM) components - has been widely introduced. This approach serves to develop students' problem-solving skills, creative thinking, project-based work, and understanding of the interrelationships between different disciplines.

In this regard, organizing medical physics lessons based on demonstrative experiments and a STEAM approach not only transforms the learning process from theoretical knowledge to practical competencies, but also creates the basis for the formation of interdisciplinary skills in students necessary for their future professional development. In this article, we will consider the scientific methodological aspects, stages, practical examples, and assessment approaches of this methodology.

Theoretical foundations. Pedagogical methodological content of demonstration experiments.

A demonstration is an activity performed by a teacher or student in a laboratory or classroom setting that demonstrates the laws of physics, phenomena, or the operation of devices in a practical way. It allows students to relate abstract concepts to real-world phenomena and to see, observe, and analyze the application of physical laws in medicine.

Demonstrative experiments perform the following didactic functions:

• concretization of theoretical knowledge (for example, the phenomena of "distribution of ionizing radiation" or "generation of a detector signal" are understood directly through experience),

• linking knowledge with practice (the student begins to explain the phenomena of his life with a scientific basis),

• orientation towards research activities (the student seeks to conduct experiments to find answers to questions),

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• formation of observation, measurement, and analysis skills (which is the basis of scientific thinking).

For example, in a medical physics lesson, a demonstration experiment is conducted on "Changes in the intensity of X-rays passing through matter in an X-ray computed tomography device," where students use a measuring cylinder to observe and analyze changes in radiation intensity and detector signal - thereby reinforcing theoretical concepts with a real practical process.

The STEAM approach and its role in medical physics education. STEAM is an abbreviation for Science–Technology–Engineering–Arts–Mathematics. This approach aims to develop problem-solving, project-based work, creative thinking, and collaboration skills in students through interdisciplinary integration, rather than limiting the educational process to a single subject. Studies have shown that the STEAM approach helps to increase efficiency in natural science education, especially physics. In addition, the integrative approach increases students' ability to think critically, analyze logically, find creative solutions, and understand the connections between different disciplines.

Medical Physics and STEAM: A Harmonious Perspective Medical Physics is a discipline that combines the laws of physics, technological medical equipment (e.g., tomographs, detectors, sensors), engineering aspects (device design and understanding), artistic aspects (imaging, visualization, 3D modeling), and mathematics (measurement, calculation, modeling). In this sense, medical physics can naturally be a “central component” of the STEAM concept. For example:

• Science: radiation, waves, detector operation and tomographic principles in medicine,
• Technology: X-ray machine, MRI scanner, detectors, sensor systems,
• Engineering: understanding the operation of these techniques, designing devices or modeling with a teacher,
• Arts: students' views on device models, 3D images, visualization, aesthetic design,
• Mathematics: measurement, signal analysis, modeling, working with mathematical functions.

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Therefore, organizing medical physics lessons based on STEAM not only helps students master physics concepts, but also develops engineering thinking, visualization, and creative solution-finding skills.

Methodological aspects: methodological stages and content. General methodological stages The following methodological stages are recommended when organizing medical physics lessons based on demonstration experiments and the STEAM approach:

Stage 1. Motivational stage: at the beginning of the lesson, students are presented with a problematic question or a real-life situation: “Why can we see your internal structure inside a tomograph scanner?”, “Why do detectors process signals in real time?”, etc. At this stage, student interest and internal motivation are formed.

Stage 2. Experimental and observation stage: the teacher conducts a demonstration experiment or students are divided into small groups and directed to carry out experimental projects. For example, measuring a wave with a detector, observing the propagation of X-ray radiation.

Stage 3. Analysis and Discussion Stage: Students measure the results of the experiment, draw diagrams and graphs, connect theoretical concepts with experimental data, and explain cause-and-effect relationships.

Stage 4. Integration Stage: In this stage, students connect the results to technology, engineering, art, and mathematics. For example, making a model of a device, creating a 3D visualization, performing mathematical calculations.

Stage 5. Reflection and Evaluation Stage: The student evaluates his/her performance, draws conclusions, determines his/her learning path, and makes suggestions for the future.

Hands-on experiences and STEAM integration. Hands-on experiences and the STEAM approach complement each other:

• Demonstrative experience activates the student's perception, while STEAM transforms this perception into practical creativity.

• Demonstrative experiences make scientific concepts visible, while STEAM transforms these concepts into projects.

• Demonstrative experience demonstrates the process, while STEAM leads to the result - an "innovative product (project, model, prototype)".

For example: if the topic of the lesson is "principles of tomographic imaging," the teacher demonstrates the propagation of X-rays and the signal through the detector module (demonstration experiment). Then, in small groups, students create a mini tomograph model (engineering), visualize it with software (technology), decorate the design (art), and analyze the measurements and signal with a mathematical model (mathematics) – this is STEAM integration.

Methodological recommendations.
• Consider an integrative approach in the lesson plan (for example, linking mathematics and computer science);
• Include virtual labs, interactive simulations (for example, PhET Interactive Simulations), and AR/VR elements. Involve students in project and research activities, encourage teamwork;
• Clearly define assessment criteria: include factors such as outcome, process, creativity, collaboration;
• Conduct experiments in a safe environment, have sufficient equipment; if laboratory facilities are limited, use a virtual or simulated environment.

Practical examples and methodological applications.
1. Example 1: "Ionizing radiation propagation and detector signal measurement"
• Motivation: Why can an image from an X-ray machine be distorted?
• Experiment: Students measure signals using a simple detector module and a visible radiation source, analyze the effect of using various protective filters.
• Analysis: Enter the data obtained in a table and graphically show the difference between the signals without a filter and in a protected state. Discuss the cause-and-effect relationship.
• Integration: Students draw a design of a detector device and visualize its operating principle using a 3D model; aesthetically decorate the protective layers. Develop a mathematical model of the signals (for example, the attenuation law).
• Reflection: Each group presents its project, comments on the problems encountered during the experiment and their solutions.
2. Example 2: "The principle of tomographic scanning and creating a 3D model"
• Motivation: Why can a tomographic image be a cross-section?
• Experiment: Students observe the scanning process using a model analogous to tomography, study the detectors and locations of the tomographic apparatus.

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• Analysis: analyze the elements of the obtained "cross-section image" and discuss the contrast, detector location, and location effect.
• Integration: groups prepare a model of the tomographic apparatus using a 3D printer or a modeler, model the scanning algorithm using a simplified graphics program; give the model an aesthetic design. The obtained data are analyzed using mathematical statistics (for example, the signal-to-noise ratio).
• Reflection: present the project to the class, evaluate it based on the evaluation criteria.
3. Enrichment with digital technologies. Students can replicate experimental processes using simulation programs (PhET or other virtual labs); this is especially useful in cases where laboratory equipment is lacking or safety is a concern. With VR/AR, students can explore the internal structure of tomography or X-ray machines in 3D format.

Evaluation and results

Assessment approaches. Assessment in the learning process is carried out in two stages: process (activity, group work, project) and result (experimental result, model, analysis, reflection). Assessment criteria include:
• Active participation (group work, problem approach),
• Experimental design and safety,
• Analysis and discussion (table, graph, cause-effect relationship),
• Project integration (technology, engineering, art, mathematics),
• Creative component (design, visualization, new approach),
• Reflection and self-assessment.
Information about scientific results. The results of the research show that the introduction of STEAM technologies into the educational process significantly increases the effectiveness of teaching medical physics. As a result of this approach, students' theoretical knowledge deepens, practical skills are strengthened, and their skills in participating in project-based activities are also developed.
In addition, interdisciplinary integration and the use of digital technologies make the educational process more interactive and creative. As a result, students develop critical thinking, problem-solving, and creative approach skills.

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Conclusion and suggestions

This article examines the methodology for organizing medical physics lessons based on demonstration experiments and the STEAM approach. The main conclusion is as follows:

• Demonstration experiments allow students to see and analyze physics concepts through real processes, thereby consolidating knowledge.

• The STEAM approach, on the other hand, allows students to engage in creative and practical activities based on projects, combining the components of science, technology, engineering, art, and mathematics.

• The nature of medical physics is very suitable for STEAM integration - equipment, measurement, laws of physics, models, and design elements are combined.

• This integration serves to form interdisciplinary thinking, engineering thinking, experimental design, and creative competencies in students during the educational process.

Suggestions:

• Demonstrative experience and STEAM stages should be clearly defined in medical physics curricula.

• Measures should be taken to improve the skills of teachers in digital literacy, virtual laboratories and 3D modeling.

• Virtual laboratories and STEAM project packages adapted to the conditions of higher education institutions should be developed and implemented.

• In the future, it is recommended to use AR/VR technology, simulations, digital teaching tools and mobile learning environments more widely in medical physics education.

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