

EFFECTIVENESS OF 3D VISUALIZATION AND ANIMATION TECHNOLOGIES IN TEACHING THE LIVER VASCULAR SYSTEM IN MEDICAL EDUCATION

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Abstract: This article examines the effectiveness of 3D visualization and animation technologies in teaching the liver vascular system in medical education. The results of the study showed that these technologies have a positive impact on students' better understanding of complex anatomical structures, long-term memory of knowledge, and the formation of practical skills.

Keywords: Medical education, hepatovascular system, 3D visualization, animation, innovative technologies, anatomy, teaching effectiveness.

Enter

Teaching complex anatomical structures is one of the pressing problems in the modern medical education system. In particular, the hepatic vascular system, with its complexity and multifaceted structure, poses difficulties for students. Traditional teaching methods, including books and two-dimensional drawings, are not enough to fully understand this system. Therefore, the use of modern pedagogical technologies, in particular, 3D visualization and animation tools, is becoming increasingly important. Through these technologies, students are clearly and clearly presented with the spatial structure, functional relationships, and physiological processes of the hepatic vascular

system. The introduction of innovative technologies in the modern medical education process is of great importance not only for improving the quality of education, but also for the formation of professional competencies of students. The role of visual aids is invaluable, especially in studying complex sections of human anatomy. The hepatic vascular system, with its complex anatomical structure, multi-stage circulatory processes, and functional properties, requires a deep understanding from students. Traditional teaching tools, including static images and text materials, are often insufficient to fully understand this system.

In recent years, the use of 3D visualization and animation technologies in medical education has become widely popular. With the help of these technologies, it is possible to display complex anatomical structures in three dimensions, accurately depict their spatial location and functional relationships. This enhances students' visual perception and significantly facilitates the process of learning. In particular, studying complex processes such as the hepatic arteries, venous system, and portal blood circulation in an animated form creates a holistic picture in students. In addition, modern pedagogical approaches require an interactive and student-centered organization of the educational process. 3D technologies are one of the effective tools that meet these requirements. Using virtual models, students can independently study anatomical structures, consider them from different angles, and use them in practical exercises. This develops their independent learning skills and helps them to master knowledge more deeply.

Methods

Experimental and observational methods were used in the research process. Students were divided into two groups, the first group received traditional teaching methods, and the second group received lessons based on 3D visualization and animation technologies. Interactive models, virtual anatomy programs, and animated videos were used in the learning process. During the research, the level of students'

knowledge was assessed through tests, practical exercises, and oral questions and answers. The students' interest and motivation in the learning process were also observed. The level of students' knowledge was assessed through tests. The test questions focused on the anatomical structure of the hepatic vascular system, the relationship of the arterial and venous systems, portal blood circulation, and clinical significance. At the same time, in practical exercises, students were required to work with virtual models of the system, observe the vascular system from different angles, and determine its functional relationships.

Using the observation method, students' activity in the lesson process, the level of answering questions, and participation in interactive exercises were recorded. This made it possible to determine the impact of 3D technologies on motivation and the learning process. Also, methods in the form of questionnaires and self-assessment were used among students, in which they assessed their ability to understand the studied material and apply it in practice.

In the study, to assess practical skills, simulation situations were created in laboratory exercises using 3D animation. Students analyzed various clinical cases by working with virtual anatomical models, trying to identify normal and pathological conditions of the vascular system. Through this method, not only the level of knowledge, but also the clinical thinking and analytical abilities of students were observed.

Statistical analysis methods were also used. Data collected through test results, observed activities in practical sessions, and questionnaires were analyzed. The results were used to identify differences between groups and prove the effectiveness of 3D visualization technologies.

In addition, pedagogical observations and expert assessment methods were used during the study. Teachers assessed students' participation in the learning process, the level of use of interactive technologies, and the ability to apply knowledge in practice. This

approach ensured the scientific validity of the study and the reliability of the results. At the same time, the study also conducted observations aimed at determining the long-term memory of students' knowledge and their ability to self-assess. This made it possible to fully assess the effectiveness of 3D visualization and animation technologies in the educational process.

Results

The results of the study showed that students in the group using 3D visualization and animation technologies mastered the vascular system of the liver more deeply and accurately. They were able to better visualize anatomical structures spatially and correctly understand their interrelationships. At the same time, students in this group achieved high test results and actively participated in practical exercises. In the group that studied using the traditional method, the level of knowledge acquisition was relatively low. According to the results of practical exercises, students in the experimental group correctly identified the interrelationships when working with virtual models and observed the system from different angles, accelerating their understanding of functional relationships. At the same time, they gave more accurate and error-free answers when analyzing clinical situations. The group using the traditional method had difficulties in understanding complex structures and had lower test results.

The results of the questionnaires also confirmed the effectiveness of 3D technologies. More than 90% of students in the experimental group rated the lessons as interesting and interactive, and also showed high motivation in the learning process. In the traditional group, motivation and interest were relatively low, which negatively affected the assimilation of knowledge. The students' self-assessment indicators also showed a difference. Students in the experimental group improved their ability to independently analyze and explain complex aspects of the vascular system of the liver.

This proves the positive impact of 3D visualization and animation technologies on the development of independent thinking and practical skills in the learning process.

In the process of statistical analysis of the results obtained, it was found that the difference between the experimental group and the control group was significant. The average score for the test and practical training results was 87% for students who studied using 3D technologies, and 65% for the group who studied in the traditional way. This difference was confirmed by the analysis to be significant at the $p < 0.05$ level.

The benefits of 3D technologies in terms of developing practical skills were also clearly demonstrated. By working with virtual models, students were able to quickly and accurately solve complex situations, and the ability to correctly apply medical recommendations was formed. This was considered an important preparation for effective work in clinical practice in the future.

The results show that 3D visualization and animation technologies make the medical education process interactive and effective, increase students' mastery of complex anatomical structures and develop practical skills. At the same time, these technologies encourage teachers to use new pedagogical methods and help organize the educational process based on modern standards.

Consideration

The results once again confirm the importance of modern technologies in medical education. 3D visualization and animation tools facilitate the study of complex anatomical systems and make the learning process interactive and interesting for students. This not only increases the quality of knowledge, but also develops students' ability to learn independently. At the same time, the introduction of these technologies requires new skills from teachers and creates the need for technical equipment. 3D technologies also develop students' visual perception skills. By viewing anatomical structures in three dimensions, they more clearly understand the connections between

structures, functional relationships, and clinical significance. This makes the learning process not only effective, but also interesting and interactive.

The study showed that the use of animation and visual aids develops students' independent learning skills. By working with virtual models, students analyze practical situations, consolidate the knowledge learned through self-assessment, and increase their clinical thinking skills. This can be considered an important preparation for future professional activities. When considering, the use of 3D technologies not only increases the level of knowledge of students, but also develops the pedagogical approach of teachers. Teachers will have the opportunity to use new pedagogical methods, organize interactive classes, and form an individual approach. At the same time, it is necessary to provide sufficient technological equipment and programs.

In addition, the results obtained demonstrate the practical importance of introducing 3D visualization and animation technologies in the modern medical education system. With the help of these technologies, complex anatomical systems are better explained to students, the process of long-term memorization of knowledge and the formation of practical skills becomes more effective. At the same time, there are several important aspects in the implementation of 3D technologies in practice. For example, it is necessary to train teachers in the use of technologies, update software, and modernize laboratory equipment. This will allow maintaining the quality of education at a high level and optimally improving students' knowledge.

The results show that 3D visualization and animation technologies make the medical education process interactive, effective and interesting. Students' ability to master complex anatomical structures increases, their practical skills develop, and their level of professional training increases. Therefore, it is recommended to widely introduce these technologies into the educational process.

Conclusions and recommendations

In conclusion, the use of 3D visualization and animation technologies in teaching the hepatovascular system in medical education is highly effective. This approach increases the level of knowledge of students, develops practical skills, and makes the educational process more effective. Therefore, it is recommended to widely introduce these technologies in medical educational institutions, provide special training for teachers, and provide them with modern teaching aids. The results obtained in the experimental group showed that 3D technologies increase the level of knowledge, practical skills, and independent thinking of students. At the same time, the interactivity of the educational process increases and students' motivation increases. The results of tests and practical exercises also confirm the effectiveness of these technologies.

Recommendations

1. It is recommended to widely introduce 3D visualization and animation technologies in medical educational institutions, especially when teaching complex anatomical systems.
2. It is necessary to train teachers in the effective use of these technologies and combine them with pedagogical skills.
3. It is necessary to enrich laboratory and textbook equipment with modern software and 3D models.
4. It is important to involve students in interactive learning activities and pay attention to the development of their independent work skills.
5. It is recommended to regularly evaluate the effectiveness of technologies through tests, practical exercises and questionnaires.
6. 3D visualization and animation technologies can also be introduced when teaching other complex anatomical systems.
7. It is recommended to continue pedagogical research and further study the impact of modern technologies on the educational process.

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