UDC 616-091:378.147:004

https://doi.org/10.52058/2786-6025-2025-1(42)-485-495

Sheremeta Ruslan Oleksandrovych PhD, assistant of the department of Pathological Anatomy, National Pirogov Memorial Medical University, Vinnytsya, Vinnytsia, tel.: (0432) 55-39-10, https://orcid.org/0009-0007-4243-3399

INTERACTIVE TECHNOLOGIES IN TEACHING PATHOLOGICAL ANATOMY: IMPACT ON THE QUALITY OF MEDICAL STUDENT TRAINING

Abstract. The paper investigates the impact of interactive technologies on the quality of medical students' training in pathological anatomy. The article is devoted to modern approaches to teaching, which contribute not only to better mastering of the educational material, but also to the formation of professional competencies necessary for future clinical practice. The main attention is focused on assessing the effectiveness of innovative educational methods in comparison with traditional forms of training. The study considers the implementation of such methods as simulation classes, virtual laboratories, interactive electronic platforms, case methods and group discussions. It is noted that the interactive approach not only develops students' ability to think critically, but also contributes to an in-depth analysis of morphological changes in tissues and organs based on real clinical examples. Particular attention is paid to the adaptation of educational materials to modern educational needs, which includes the creation of multimedia content, modular programs and testing in digital format. The aim of the study is to identify ways to increase the effectiveness of the educational process by integrating innovative technologies into the traditional training system. The paper analyzes the results of a survey of medical students conducted to assess the impact of interactive methods on their motivation, perception of the material, and confidence in applying the acquired knowledge in practice. The results obtained indicate that interactive approaches increase students' interest in learning, improve communication skills, and develop the ability to make reasoned decisions. The authors proposed new strategies for integrating innovative technologies, such as combining lectures with practical classes in a virtual environment, using simulations to practice complex pathological cases, and using distance platforms to consolidate knowledge. The study confirms the feasibility of using interactive methods in medical education aimed at improving the professional level of graduates. The data obtained may be useful for developing and improving educational programs in pathological anatomy, as well as other fundamental disciplines taught in medical institutions of higher education.

Keywords: pathological anatomy, interactive technologies, medical education, quality of student training, innovative teaching methods.

Шеремета Руслан Олександрович асистент кафедри патологічної анатомії Вінницького національного медичного університету ім. М. І. Пирогова, м. Вінниця, тел.: (0432) 55-39-10. https://orcid.org/0009-0007-4243-3399

ІНТЕРАКТИВНІ ТЕХНОЛОГІЇ У НАВЧАННІ ПАТОЛОГІЧНОЇ АНАТОМІЇ: ВПЛИВ НА ЯКІСТЬ ПІДГОТОВКИ СТУДЕНТІВ-МЕДИКІВ

Анотація. У роботі досліджено вплив інтерактивних технологій на якість підготовки студентів-медиків у межах вивчення патологічної анатомії. Стаття присвячена сучасним підходам до викладання, які сприяють не лише кращому засвоєнню навчального матеріалу, а й формуванню професійних компетенцій, необхідних для майбутньої клінічної практики. Основна увага зосереджена на оцінці ефективності інноваційних освітніх методів у порівнянні з традиційними формами навчання. У дослідженні розглянуто впровадження таких методів, як симуляційні заняття, віртуальні лабораторії, інтерактивні електронні платформи, кейс-методи та групові дискусії. Зазначено, що інтерактивний підхід не лише розвиває здатність студентів до критичного мислення, а й сприяє поглибленому аналізу морфологічних змін у тканинах і органах на основі реальних клінічних прикладів. Особливу увагу приділено адаптації навчальних матеріалів до сучасних потреб освіти, що включає створення мультимедійного контенту, модульних програм і тестувань у цифровому форматі. Метою проведеного дослідження є виявлення шляхів підвищення ефективності навчального процесу за рахунок інтеграції інноваційних технологій у традиційну систему підготовки. У роботі проаналізовано результати анкетування студентів-медиків, проведеного для оцінки впливу інтерактивних методів на їхню мотивацію, сприйняття матеріалу та впевненість у застосуванні отриманих знань на практиці. Отримані результати свідчать, що інтерактивні підходи підвищують інтерес студентів до навчання, покращують комунікативні навички та розвивають здатність до аргументованого прийняття рішень. Автори запропонували нові стратегії інтеграції інноваційних технологій, такі як комбінування лекцій із практичними заняттями у віртуальному середовищі, використання симуляцій для відпрацювання складних патологічних випадків і застосування дистанційних платформ для закріплення знань. Проведене дослідження підтверджує доцільність використання інтерактивних методів у медичній освіті, спрямованих на підвищення професійного рівня випускників. Отримані дані можуть бути корисними для розробки та вдосконалення освітніх програм

з патологічної анатомії, а також інших фундаментальних дисциплін, що викладаються у медичних закладах вищої освіти.

Ключові слова: патологічна анатомія, інтерактивні технології, медична освіта, якість підготовки студентів, інноваційні методи навчання.

Statement of the problem. Modern medical education is in a transformation phase, which is associated with new requirements for the level of training of graduates, who must be able to quickly adapt to the constantly changing conditions of clinical practice. At the same time, high-quality training of medical students is impossible without a deep understanding of fundamental disciplines, such as pathological anatomy. This is one of the key disciplines that provides the formation of basic knowledge about the morphological foundations of diseases necessary for diagnosis and treatment. However, traditional teaching methods, based mainly on the lecture format and standard practical classes, often turn out to be insufficiently effective in the conditions of modern educational and professional challenges. Among the main problems that arise in the process of teaching pathological anatomy, one can single out insufficient active participation of students in the educational process, a low level of interactivity of classes and limited opportunities for applying knowledge in practice. The traditional form of training often boils down to passive perception of material, which negatively affects the level of knowledge acquisition and the development of professional competencies. In particular, students have limited experience in analyzing clinical cases, discussing complex pathological processes, and modeling real-life situations, which complicates their preparation for future practical activities.

Another important problem is the lack of effective approaches to the use of modern digital technologies in teaching pathological anatomy. Despite the availability of numerous tools for interactive learning, such as virtual laboratories, simulation programs, and electronic learning platforms, their application in the educational process is still limited. This is explained both by the insufficient technical training of teachers and the lack of clear strategies for integrating such tools into traditional forms of education.

The problem is also exacerbated by the increase in the number of students in groups, which limits the possibility of individual work with each of them. In this context, interactive technologies become a promising tool that allows you to increase the efficiency of the educational process, provide an individual approach to each student, and contribute to the formation of deeper knowledge and skills.

Therefore, there is an urgent need to develop and implement new approaches to teaching pathological anatomy that would meet modern requirements for medical education. The integration of interactive technologies into the educational process has the potential to solve many of the above problems, but requires systematic analysis, justification and adaptation to the specifics of this discipline.

Analysis of recent research and publications. In recent years, the role of interactive technologies in teaching pathological anatomy has noticeably increased, allowing to change the approach to teaching and make the learning process more flexible and accessible. The scientific literature already widely covers examples of the use of such technologies to facilitate the assimilation of complex material and improve the level of student training. One of the first such approaches was the use of virtual laboratories, which allows students to access materials without having to be in a classroom or laboratory. Marchevsky and his colleagues demonstrate the effectiveness of web technologies for self-study through the creation of so-called "virtual pathology laboratories". Such initiatives not only change the traditional learning environment, but also help students better learn the material through interactive research [1]. The use of new technologies to improve the process of teaching pathology is not limited to virtual laboratories. Khoo points to successful examples of the implementation of innovative approaches to teaching pathology, in particular by integrating various technological tools that significantly increase the level of student involvement in the process. Such approaches allow for greater emphasis on individualized learning, which is an important aspect in the training of future medical professionals [2].

The use of virtual pathology in the context of distance learning has become equally important. The role of digital platforms and their importance for learning is growing. Virtual slides and digital images allow for the creation of educational materials that are accessible to students at any time and in any place. Interactive resources, such as electronic textbooks, have already become a familiar element of the educational process and are actively used in practice. Digital pathology technologies greatly facilitate the learning process, making it more accessible, convenient and diverse [3].

Another significant step in the development of interactive learning is the use of wiki tools. Using a collaborative platform not only improves communication between students and teachers, but also contributes to a deeper understanding of the material through joint editing and discussion of educational topics. Wikis help students create shared resources, which allows them to better understand complex concepts in genetics and computer science, and also promotes the development of critical thinking [4].

The introduction of digital resources has become an important step in the modernization of pathology education. Hassell and colleagues describe how virtual pathology has changed approaches to learning, noting that this process has already become an important part of educational practice in many medical schools. The transition to virtual resources allows students to work with modern tools that bring them as close as possible to real-world practice [5].

The use of screencasts and interactive slides for teaching pathology is also an interesting topic, which has become popular among teachers. In particular, it has

been found that the use of screencasts with embedded slides significantly increases the effectiveness of learning, ensuring better integration of theoretical and practical knowledge [6]. This allows students not only to view the slides, but also to interact with them, which provides a deeper understanding of the topic.

The use of virtual microscopy in the learning process is an important step in the development of digital technologies in pathology. Hamilton et al. emphasize that virtual microscopy is a tool that allows students to perform in-depth analysis of pathological specimens without the need for physical microscopes. This approach significantly saves time and resources, allowing students to focus on learning theoretical aspects and practical skills [7]. According to the studies of Dee and Meyerholz, virtual microscopy opens up new opportunities for learning, which is especially important in conditions of limited access to traditional laboratories. They indicate that this technology allows students to work with large volumes of material and increases the efficiency of the educational process, and also allows for online learning [8]. An important aspect of modern digital education is the integration of spatial and visual dimensions into the learning process, which allows to significantly improve the understanding of complex anatomical and pathological concepts. For example, Wan and colleagues describe how the integration of visual-spatial aspects into digital pathology contributes to better assimilation of the material by students. This allows for an effective combination of anatomical structure with pathological changes, which gives students the opportunity to interpret pathological specimens with greater accuracy [9]. The use of digital tools for interactive study of structures and their changes significantly simplifies the learning process, as students are able to better navigate the three-dimensional structures and relationships of organs and tissues. In addition, an approach is relevant in which interactive technologies are used for a blended form of learning, which combines traditional methods and the latest digital resources. The importance of integrated online systems for teaching pathology is explored, with two examples of how such systems can be used to create modular courses where each student can integrate theoretical knowledge with practical skills using digital tools. They also emphasize the importance of a feedback system that helps teachers assess student progress and adjust the learning process [10].

Studies aimed at evaluating different teaching methods have compared three different pathology teaching methods, including traditional lectures, practical classes, and the use of digital platforms. The results of the study showed that interactive digital tools significantly increase the efficiency of material acquisition and contribute to a deeper understanding of complex pathogenetic processes. The use of digital platforms helped students to perform tasks more successfully and acquire practical skills, which in turn had a positive effect on their overall level of training [11].

Particular attention should be paid to the use of modern online tools for learning in African countries, where the lack of access to traditional laboratories is

a significant problem. A positive experience of using a technology-based approach in Nigeria, where medical students used digital resources to learn pathology, was established. Thanks to this, they were able to significantly improve their skills in interpreting pathological specimens, even without having the opportunity to work with physical microscopes. This approach significantly expands access to quality medical education in resource-limited countries [12]. Finally, an important role in the development of pathology education is played by modern digital slides, which are used not only for teaching, but also for consulting and quality control. Rocha and colleagues draw attention to the importance of such digital tools for ensuring quality medical education. They emphasize that the use of digital slides allows for improved access to educational material, provides higher diagnostic accuracy, and allows students to work with real pathological specimens without the limitations inherent in traditional teaching methods [13].

The purpose of the article – to investigate the impact of interactive technologies on the quality of medical student training within the study of pathological anatomy.

Presentation of the main material. Due to the need to adapt medical education to modern requirements, in particular in the context of technological innovations, interactive technologies have become an important element of the educational process. In particular, the study of pathological anatomy - a discipline that is the basis for understanding various pathological processes in the human body - requires the use of new, technology-oriented approaches to improve the quality of training of future medical professionals. Interactive technologies allow you to create a more dynamic and effective learning environment that meets modern standards of medical education. One of the main areas in which interactive technologies need to be implemented is the use of virtual laboratories. Students can perform virtual autopsies, analyze pathological samples, observe the development of diseases in interactive 3D models, and also interact with educational programs that simulate real situations that they may encounter during their professional activities. Virtual laboratories allow students to work with pathological materials without the need to use physical specimens, which is especially important in conditions of limited access to real materials or in cases where traditional teaching methods are not effective enough. In addition, virtual laboratories allow students to work at a time convenient for them and at a pace that meets their individual learning needs.

Also, an important element of interactive learning is the use of virtual microscopy. Virtual microscopes allow students to view histological samples, conduct their detailed analysis, and compare samples of healthy and pathological tissues. Virtual microscopes allow you to reproduce different levels of magnification, which provides a deeper understanding of the structural organization of tissues and organs. Such training provides high quality training, as it makes it possible to work with a large number of samples and conduct their analysis without the limitations characteristic of traditional laboratories.

Another important interactive technology is the use of digital slides. Digital slides are images of histological specimens obtained using digital microscopes and allow teachers and students to interact with virtual specimens, make notes, sign structures, mark areas of pathology, etc. This allows for the creation of individual learning trajectories where each student can independently study the material, complete tasks and receive feedback.

Another direction is the use of mobile applications and programs for studying pathology. Modern applications can include interactive maps that display various pathological conditions, as well as video lessons that demonstrate anatomical structures and their changes in various diseases. The use of mobile applications contributes to the development of learning mobility, which is especially convenient for students who are on internships or practical training.

Interactive videos and animated educational programs also play an important role in teaching pathological anatomy. Animations allow you to visualize complex processes, for example, the development of a pathological process in organs or changes at the cellular level, which helps students better understand and remember important aspects of pathology. Videos can be supplemented with interactive tests that allow students to test their knowledge in real time, receiving instant feedback.

Equally important is the role of social media and online platforms in supporting the learning process. The use of resources such as forums, blogs or video conferencing windows allows students to discuss complex pathology issues together, share their observations and experiences. Video conferencing platforms allow for online classes where the teacher can demonstrate the material, conduct tests and answer students' questions in real time.

An important point in the implementation of interactive technologies is the need to train teachers, who must be ready for changes in the learning process. Teachers must not only master new technologies, but also adapt their teaching methods to digital tools. Since interactive technologies have a wide range of capabilities, it is important that teachers have a clear idea of how to effectively use these tools to achieve educational goals.

For the successful implementation of interactive technologies in the teaching of pathological anatomy, it is also necessary to take into account some organizational aspects. In particular, it is important to create the necessary technical infrastructure in educational institutions, as well as provide access to appropriate resources for students and teachers. This includes providing computer classes with appropriate software, access to Internet resources, as well as databases with pathological specimens, digital slides, 3D models of organs and tissues used in the educational process. In addition, the integration of such technologies should be organized in such a way as to ensure the continuity of the educational process, since many of these technologies require the presence of special platforms on which educational materials are stored. Monitoring and evaluation of their effectiveness play a

significant role in the implementation of new technologies. The use of interactive technologies requires a systematic assessment of student learning outcomes. This can be done through regular testing and analysis of the achieved results using software tools that allow tracking the progress of each student. Evaluation of the effectiveness of interactive technologies should be comprehensive, including feedback from students and teachers, as well as comparison of learning outcomes using traditional and interactive methods.

Of particular importance is the creation of integrated courses that combine different types of interactive technologies and allow students to develop both theoretical and practical skills in the context of pathological anatomy. Such courses can combine theoretical lectures using multimedia resources, such as presentations, animations and interactive tests, with practical classes using virtual laboratories, where students can study real histological specimens and conduct their analysis. It is important that these courses are flexible and allow for individual adjustment of the learning process according to the pace and level of knowledge of the student.

No less important is the creation of interdisciplinary courses that combine pathological anatomy with other medical disciplines. For example, the integration of pathological anatomy with physiology, clinical medicine and other sciences allows students to gain a more holistic understanding of pathological processes, their impact on the body, as well as methods of diagnosis and treatment. For this, modern software solutions can be used that allow the integration of different types of educational materials (for example, videos of surgical interventions, animations of disease development processes, digital slides with histological samples).

One of the main advantages of interactive technologies is their ability to provide students with flexibility in learning. Students can study the material at a convenient time and at a convenient pace, which is important for those who combine study with practical activities or have other responsibilities. Mobility of learning makes it possible to avoid unnecessary interruptions in the educational process, which often occur when using traditional teaching methods. Also, such flexibility allows students to better assimilate the material, since they can return to difficult topics or undergo additional training.

We should also not forget about the importance of student motivation, which is a key factor in the successful implementation of interactive technologies. Given that medical students are often faced with a large amount of theoretical knowledge, it is important to make the learning process not only effective, but also interesting in order to stimulate interest in the discipline. Interactive technologies allow you to create learning scenarios that include various forms of activities: from participation in games and simulations to performing real practical tasks. This allows not only to improve the level of knowledge, but also to develop students' analytical abilities, the ability to self-study and make decisions in complex clinical situations.

Therefore, interactive technologies in teaching pathological anatomy can significantly improve the quality of student training, making the learning process

more flexible, accessible and effective. Thanks to the introduction of modern digital tools, such as virtual laboratories, microscopy, digital slides and mobile applications, students can gain a deeper understanding of pathology and effectively apply knowledge in practice. However, the successful integration of such technologies into the educational process requires not only technical training, but also constant evaluation of effectiveness, flexibility of training courses, as well as the creation of conditions for interaction between students and teachers through the latest platforms. The introduction of interactive technologies will not only improve the teaching of pathological anatomy, but will also provide students with the necessary skills for a successful career in the medical field. Interactive technologies in teaching pathological anatomy have great potential to improve the quality of medical education. They make learning more accessible, flexible and effective, and also enable students to receive high-quality training using modern digital tools. The successful implementation of such technologies will help prepare qualified medical professionals who will be able to work effectively with modern medical information systems and technologies, which is an important aspect in the development of the medical industry.

Conclusions. The introduction of interactive technologies into the teaching of pathological anatomy has significant potential to improve the quality of medical student training. The adaptation of virtual laboratories, digital slides, 3D models and mobile applications allows combining theoretical knowledge with practical skills, contributing to a deeper understanding of the material and the development of students' analytical abilities. Interactive technologies provide flexibility in learning, which is important for medical university students who combine study with practical activities. These technologies also provide the opportunity to independently study histological specimens, analyze them through digital slides and receive feedback through interactive platforms, which improves students' professional skills. For the effective integration of new technologies, support is needed, including teacher training, the creation of integrated courses and continuous assessment of effectiveness. Feedback from students and teachers will help to improve the implementation of these technologies in the educational process. In general, interactive technologies in teaching pathological anatomy contribute to the creation of a more dynamic and effective learning environment, which increases the level of student training and forms competent specialists who are able to effectively apply their knowledge in practical activities.

References:

1. Marchevsky, A. M., Relan, A., & Baillie, S. (2003). Self-instructional “virtual pathology” laboratories using web-based technology enhance medical school teaching of pathology. *Human pathology*, *34*(5), 423-429. https://doi.org/10.1016/S0046-8177(03)00089-3

2. Khoo, U. S. (2014). Innovative use of technologies to enhance the teaching of pathology. *Pathology*, *46*, S31. https://doi.org/10.1097/01.PAT.0000454190.27913.d5

3. Chiu, B. K., Solez, K., & Sergi, C. M. (2014). Digital pathology for e-learning and digital education-a review. *Journal of Information Technology and Application in Education, 3*(4), 164-168. https://doi.org/10.14355/jitae.2014.0304.09

4. Park, S., Parwani, A., MacPherson, T., & Pantanowitz, L. (2012). Use of a wiki as an interactive teaching tool in pathology residency education: Experience with a genomics, research, and informatics in pathology course. *Journal of Pathology Informatics, 3*(1), 32. https://doi.org/10.4103/2153-3539.100366

5. Hassell, L. A., Absar, S. F., Chauhan, C., Dintzis, S., Farver, C. F., Fathima, S., ... & Bui, M. (2023). Pathology education powered by virtual and digital transformation: now and the future. *Archives of Pathology & Laboratory Medicine, 147*(4), 474-491. https://doi.org/10.5858/arpa.2021-0473-RA

6. Wong, M., Frye, J., Kim, S., & Marchevsky, A. M. (2018). The use of screencasts with embedded whole-slide scans and hyperlinks to teach anatomic pathology in a supervised digital environment. *Journal of pathology informatics, 9*(1), 39. https://doi.org/10.4103/jpi.jpi_44_18

7. Hamilton, P. W., Wang, Y., & McCullough, S. J. (2012). Virtual microscopy and digital pathology in training and education. *Apmis, 120*(4), 305-315. https://doi.org/10.1111/j.1600-0463.2011.02869.x

8. Dee, F. R., & Meyerholz, D. K. (2007). Teaching medical pathology in the twenty-first century: virtual microscopy applications. *Journal of veterinary medical education, 34*(4), 431-436. https://doi.org/10.3138/jvme.34.4.431

9. Wan, K. L., Sen, A., Selvaratnam, L., Naing, M. I. M., Khoo, J. J., & Rajadurai, P. (2022). Visual-spatial dimension integration in digital pathology education enhances anatomical pathology learning. *BMC medical education, 22*(1), 587. https://doi.org/10.1186/s12909-022-03545-x

10. Kainulainen, M., Helle, L., Kronqvist, P., Vincken, K. L., Pawelka, F., Korpinen, K., & de Leng, B. (2023). Towards an integrated online learning system for microscopic pathology: Two teaching examples. In *Proceedings of the Technology-Enhanced Learning in Laboratories workshop* (pp. 16-27). CEUR.

11. Kashif, A. W., Dagar, V. K., Mahato, H. K., Paliwal, G., Datta, K., Patrikar, S., ... & Sen, A. (2024). Teaching pathology differently: Comparision between three diverse teaching learning methods. *Medical Journal Armed Forces India, 80*(6), 667-674. https://doi.org/10.1016/j.mjafi.2023.07.003

12. Vhriterhire, R. A., Orkuma, J. A., Jegede, O. O., Omotosho, A. J., & Adekwu, A. (2016). Technology-Enhanced Pathology Education: Nigerian Medical Students Perspectives. *Journal of Education and Practice, 7*(35), 103-108.

13. Rocha, R., Vassallo, J., Soares, F., Miller, K., & Gobbi, H. (2009). Digital slides: present status of a tool for consultation, teaching, and quality control in pathology. *Pathology-Research and Practice, 205*(11), 735-741. https://doi.org/10.1016/j.prp.2009.05.004

Література:

1. Marchevsky, A. M., Relan, A., & Baillie, S. (2003). Self-instructional "virtual pathology" laboratories using web-based technology enhance medical school teaching of pathology. *Human pathology, 34*(5), 423-429. https://doi.org/10.1016/S0046-8177(03)00089-3

2. Khoo, U. S. (2014). Innovative use of technologies to enhance the teaching of pathology. *Pathology, 46*, S31. https://doi.org/10.1097/01.PAT.0000454190.27913.d5

3. Chiu, B. K., Solez, K., & Sergi, C. M. (2014). Digital pathology for e-learning and digital education-a review. *Journal of Information Technology and Application in Education, 3*(4), 164-168. https://doi.org/10.14355/jitae.2014.0304.09

4. Park, S., Parwani, A., MacPherson, T., & Pantanowitz, L. (2012). Use of a wiki as an interactive teaching tool in pathology residency education: Experience with a genomics, research, and informatics in pathology course. *Journal of Pathology Informatics, 3*(1), 32. https://doi.org/10.4103/2153-3539.100366

5. Hassell, L. A., Absar, S. F., Chauhan, C., Dintzis, S., Farver, C. F., Fathima, S., ... & Bui, M. (2023). Pathology education powered by virtual and digital transformation: now and the future. *Archives of Pathology & Laboratory Medicine, 147*(4), 474-491. https://doi.org/10.5858/arpa.2021-0473-RA

6. Wong, M., Frye, J., Kim, S., & Marchevsky, A. M. (2018). The use of screencasts with embedded whole-slide scans and hyperlinks to teach anatomic pathology in a supervised digital environment. *Journal of pathology informatics, 9*(1), 39. https://doi.org/10.4103/jpi.jpi_44_18

7. Hamilton, P. W., Wang, Y., & McCullough, S. J. (2012). Virtual microscopy and digital pathology in training and education. *Apmis, 120*(4), 305-315. https://doi.org/10.1111/j.1600-0463.2011.02869.x

8. Dee, F. R., & Meyerholz, D. K. (2007). Teaching medical pathology in the twenty-first century: virtual microscopy applications. *Journal of veterinary medical education, 34*(4), 431-436. https://doi.org/10.3138/jvme.34.4.431

9. Wan, K. L., Sen, A., Selvaratnam, L., Naing, M. I. M., Khoo, J. J., & Rajadurai, P. (2022). Visual-spatial dimension integration in digital pathology education enhances anatomical pathology learning. *BMC medical education, 22*(1), 587. https://doi.org/10.1186/s12909-022-03545-x

10. Kainulainen, M., Helle, L., Kronqvist, P., Vincken, K. L., Pawelka, F., Korpinen, K., & de Leng, B. (2023). Towards an integrated online learning system for microscopic pathology: Two teaching examples. In *Proceedings of the Technology-Enhanced Learning in Laboratories workshop* (pp. 16-27). CEUR.

11. Kashif, A. W., Dagar, V. K., Mahato, H. K., Paliwal, G., Datta, K., Patrikar, S., ... & Sen, A. (2024). Teaching pathology differently: Comparision between three diverse teaching learning methods. *Medical Journal Armed Forces India, 80*(6), 667-674. https://doi.org/10.1016/j.mjafi.2023.07.003

12. Vhriterhire, R. A., Orkuma, J. A., Jegede, O. O., Omotosho, A. J., & Adekwu, A. (2016). Technology-Enhanced Pathology Education: Nigerian Medical Students Perspectives. *Journal of Education and Practice, 7*(35), 103-108.

13. Rocha, R., Vassallo, J., Soares, F., Miller, K., & Gobbi, H. (2009). Digital slides: present status of a tool for consultation, teaching, and quality control in pathology. *Pathology-Research and Practice, 205*(11), 735-741. https://doi.org/10.1016/j.prp.2009.05.004