Review Article

# Role of Artificial Intelligence in Teaching Pathology to Medical Students

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## Abstract

The applications of artificial intelligence (AI) have swiftly forayed into medical education. This study aimed to decipher the role of AI in teaching pathology to medical students, enlisting its potential benefits which include improved diagnostic accuracy, personalized learning experiences, and effective feedback mechanisms. It also brings into the light challenges and ethical considerations associated with incorporating AI in pathology education. This article provides a comprehensive idea about the current as well as prospects of AI in pathology in the long run.

**Keywords:** Artificial intelligence, pathology, teaching

## Introduction

### Illuminating the crucial role of pathology in medical education

Pathology is an integral component of medical education helping students in understanding the pathogenesis of disease and its clinical manifestations. At present, traditional pathology education relies on textbooks, lectures, and practical hands-on experience in microscopy, which is quite limited at the moment. Artificial intelligence (AI) technologies are going to revolutionize the current methods and bring about a tsunami of changes through its interactive and novel approaches. This will benefit the learners as well as the teachers massively.[1]

### Unleashing the technology: Embarking on the journey of artificial intelligence

The main intent of AI is to develop innovations by which machines can simulate human intelligence. This includes machine learning, deep learning, and natural language processing. AI develops algorithms that can process data, identify patterns, and predict outcomes on the basis of gathered knowledge.[2]

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## Artificial Intelligence Applications in Pathology Education

### Digital pathology and image analysis

#### *Digital pathology*

Digital pathology involves the digitization of glass slides. This provides access and examination of slides remotely, and AI algorithms produce automated interpretations. Such interpretation can be useful in diagnosing a disease. Such digitized slides can be stored and give exposure to postgraduate students and budding pathologists to various pathological diseases.[3,4]

#### *Image analysis*

Pathology images, tissue patterns, and biomarkers can be assessed using AI algorithms. Medical students can process the information and draw a logical inference using these digital images, which in turn will help in better clinic pathological correlation.[5,6]

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## Virtual reality and augmented reality

### *Virtual reality*

Virtual reality (VR) can be very effective in bringing out an experience that can be very visual, dynamic, and interactive yet virtual for medical students. It is fascinating to imagine a technology like this that will help students maneuver virtual microscopic images, virtually displayed gross organs. The students will be able to zoom in or zoom out the images to understand the pathology of the organ in a better fashion.

#### Interactive learning

This interactivity promotes active engagement because students can investigate and explore specific regions of interest and concentrate on topics pertinent to their learning objectives. In addition, they can simulate various disease scenarios and observe the dynamic changes, thereby augmenting their knowledge of disease progression and its impact on organ systems.[4,7,8]

#### Realistic simulations

VR technology permits the construction of simulations of clinical scenarios and procedures that are realistic. As they would in an actual laboratory, students can participate in virtual surgeries, execute biopsies, and analyze digital pathology slides. These simulations provide a safe and controlled environment for students to practice and hone their skills without the inherent dangers of working with actual patients. In addition, it allows students to learn from their errors, receive immediate feedback, and repeat procedures as necessary to boost their proficiency and confidence.[4,7,8]

#### Collaborative learning and remote access

VR enables collaborative learning in which students can interact with their peers and teachers in a shared virtual environment. They can discuss cases, exchange insights, and collaborate on duties requiring problem-solving. This collaborative aspect encourages learners' collaboration, communication, and sense of community.[4,7,8]

#### Enhanced engagement and retention

VR facilitates students in grasping and understanding the nitty-gritty of pathology. This will also help in amplifying knowledge retention in students and create an impactful learning experience in comparison to traditional methods of learning.[4,7,8]

#### Research and exploration

VR technology offers humongous avenues for research and exploration in pathology. Researchers can create virtual models, apply interventions on them, and generate ground-breaking results which can be helpful in the treatment of diseases.[4,7,8]

Overall, VR application in pathology education can be instrumental in building medical graduates who understand the pathogenesis of diseases and can develop clinical skills that will eventually improve patient care.

### *Augmented reality*

Augmented reality (AR) is an effective instrument for enhancing pathology education by superimposing digital information on the actual world. It permits information overlay in real time, interactive learning experiences, spatial context and visualization, simulation and training, remote collaboration, and gamification. By incorporating AR technology into pathology education, medical students can access dynamic and interactive learning experiences, thereby enhancing their comprehension, diagnostic skills, and patient care skills.[6,9,10]

#### Remote collaboration and consultation

By utilizing AR-enabled devices, users can share their live view of a digital pathology slide or specimen with individuals in various locations. Multiple users can simultaneously observe and discuss cases, share insights, and engage in real-time interactions, enabling remote collaboration. AR technology promotes interdisciplinary collaboration in pathology education and consultation by enhancing communication and the sharing of knowledge.[6,9,10]

#### Gamification and engagement

Using AR technology, pathology education can be made more engaging and pleasant for students. Students can actively implement their knowledge, solve problems, and receive immediate feedback using interactive challenges, assessments, or virtual case studies. Elements of gamification can improve motivation, retention, and knowledge transfer, thereby enhancing the interactivity and immersion of the learning process.[6,9,10]

#### Real-time information overlay

AR technology creates a conducive environment for medical students to spread virtual elements into actual reality. This can be done using electronic devices such as tablets and smartphones, where students can see virtual images and then see actual slides on their microscopes and draw a correlation. This will improve their capabilities to interpret and benefit their learning process.[6,9,10]

#### Interactive learning experiences

AR provides a firsthand explicit experience in pathology education. Students get the liberty of seeing organs that have a pathology virtually and then can see the actual physical specimen and integrate their learning curve. They get to actively zoom virtual organs and understand the details, which facilitates a better grasp of anatomical relationships and pathological processes.[6,9,10]

#### Spatial context and visualization

The concept of spatial context and visualization has been brought about with the advent of AR. Students can observe the spatial relationships, sizes, and positions of structures and, hence, get the opportunity of understanding the finer aspects of the disease they intend to study.[6,9,10]

#### Simulation and training

AR technology can be instrumental in helping medical students to practice interventions and procedures virtually. Such hands-on experience can help our students in harnessing their

skills before they start doing these procedures on real patients. The best part of this technology is that simultaneously it will provide the student with feedback and guidance on how the procedure could have been performed better.[6,9,10]

Hence, in a nutshell, it can be said that AR can be instrumental in integrating and passing on digital information into reality and providing one-of-its-kind learning experiences for medical students.

### Intelligent tutoring systems

Intelligent tutoring systems (ITSs) powered by AI can revolutionize pathology education by personalizing the learning experience for each student. An ITS makes use of AI to provide personalized instructions as per the sensibilities of the learner. This system can bring about a learning experience for medical students, which will be completely based on their choices, needs, and intellect. It will also provide constructive feedback to the students.[11-13]

#### *Personalized learning*

This dimension of ITS will cater to the specific needs and preferences of the students and accordingly personalize the contents as per their sensibilities. It will collect and analyze the data on students by collecting and analyzing data based on students' accomplishments and execution of assignments and tutorials and then accordingly develop the educational content as per their requirements. This system keeps in mind the weaknesses of the students while coming up with personalized content.[11-13]

#### *Adaptive instruction*

Another facet of ITSs is to identify the pitfalls and difficulties faced by the students and correspondingly adapt and develop the educational content appropriately.[11-13]

#### *Real-time feedback*

This aspect can assess pupil's responses, identify errors or misunderstandings, and provide immediate feedback to correct or reinforce learning. This feedback mechanism assists students in comprehending their errors, reinforcing correct comprehension, and modifying their approach. Through guiding students in self-assessment and self-correction, timely and specific feedback promotes a deeper understanding of pathology concepts and metacognitive skills.[11-13]

#### *Knowledge assessment and progress tracking*

Throughout the learning process, ITSs can assess students' knowledge and monitor their development. By assessing performance data and comparing it to predefined learning objectives or benchmarks, the system can reveal an individual's strengths, shortcomings, and improvements. Students and educators can use assessment data to monitor progress, identify areas requiring additional attention, and accordingly take necessary decisions.[11-13]

#### *Interactive and engaging learning environment*

ITSs integrate engaging and interactive learning environments to increase student's motivation and engagement. This system frequently employs multimedia elements, such as videos, interactive exercises, virtual case studies, and gamified elements, to make learning more engaging and interactive. ITSs can enhance student engagement, knowledge retention, and long-term motivation by establishing an immersive and stimulating learning environment.[11-13]

#### *Continuous learning and adaptation*

ITSs can perpetually learn and adapt based on the data gathered from the interactions and performance of students. Over time, the system can refine its models, algorithms, and instructional strategies to enhance the tutoring experience. By utilizing machine learning techniques, the system can adapt to changes in student requirements, emergent trends in pathology, or advancements in educational best practices, ensuring that the instructional content remains current and pertinent.[11-13]

In gist, ITSs in pathology education offer personalized, adaptive, and interactive learning experiences. The system provides individualized instructions, adaptive feedback, real-time assessment, and tracking. By leveraging AI techniques, ITSs enhance the effectiveness of pathology education, promoting student engagement, knowledge acquisition, and skill development.

## Benefits of Artificial Intelligence in Pathology Education

### Improved diagnostic accuracy

Incorporating AI technologies into pathology education can substantially enhance diagnostic accuracy. AI algorithms can assess enormous quantities of data and identify patterns that may not be readily apparent to humans. Using AI in the analysis of digital pathology specimens and image recognition, students can receive automated interpretations and accurate guidance in disease detection and classification. The algorithms can provide evidence-based recommendations and reduce diagnostic errors, thereby improving diagnostic aptitude and self-assurance.[14-16]

### Enhanced learning efficiency

Pathology education tools based on AI offer numerous learning-related benefits that can improve one's efficiency. Students can engage in self-directed, at-their-own-pace learning, where they have access to learning materials anytime, anywhere. The immersive learning experiences provided by digital pathology slides, AR, and VR technologies enable students to visualize complex anatomical structures and disease processes in a more interactive and engaging manner. These technologies encourage active learning, retention of knowledge, and a deeper comprehension of pathology concepts. In addition, AI algorithms can provide students with immediate, personalized feedback, concentrating on areas for development and recommending additional resources or interventions. This real-time feedback mechanism enables

students to quickly address knowledge deficits, thereby reinforcing their learning and promoting continuous improvement.[14-16]

### Objective assessment and feedback

Traditional assessment techniques in pathology education frequently rely on subjective evaluations, which can introduce bias and variability. Standardized and objective assessments can be generated by AI algorithms, facilitating equitable comparisons between students. By assessing student performances and identifying areas of vulnerability, AI algorithms can provide targeted feedback and suggest relevant learning resources to assist students in enhancing their pathology knowledge and skills. By assessing patterns in student's performance data, these systems can identify trends and patterns that can help in building curriculum development, instructional strategies, and assessment design.[17-19]

## Challenges and Ethical Considerations

### Algorithm bias and accuracy

The potential for algorithmic biases and accuracy concerns presents a significant obstacle to the incorporation of AI in pathology education. The quality and representativeness of the data used to train AI algorithms are crucial. Inaccurate or unreliable results may result from the use of biased or unrepresentative training data, particularly when diagnosing rare diseases or conditions. It is essential to ensure diversity and unbiased representation of pathological conditions in training datasets to minimize algorithmic biases and maximize diagnostic accuracy.[20-22]

### Loss of human interaction and clinical skills

The incorporation of AI technologies necessitates cautious consideration of privacy and security concerns, especially regarding patient information. It is a mandatory prerequisite to protect patient information and assure compliance with data protection regulations.[20-22]

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## Conclusion

The future holds immense scope for AI and its role in teaching pathology and other subjects to medical students. AI can be beautifully integrated with traditional methods of teaching. This association will bring about a paradigm shift in students' understanding of the subject and improve learning outcomes, diagnostic accuracy, and personalized education. In the future, AI-integrated research will become the epicenter from where a lot of data will be generated, which in the long run will help in improving student learning, clinical decision-making, and patient outcomes.[23-25]

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### Conflicts of interest

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