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Review Article

The use of generative artificial intelligence (AI) in teaching and assessment of postgraduate students in pathology and microbiology

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ABSTRACT

The integration of generative artificial intelligence (AI) into the educational landscape is revolutionizing the training of postgraduate students, particularly in the diagnostic fields such as pathology and microbiology. While the benefits of generative AI are substantial, there are significant challenges to address. Ethical considerations, such as data privacy and bias, must be carefully managed to ensure equitable educational opportunities. Technical challenges, including the need for significant infrastructure and faculty training, also pose barriers to implementation. Additionally, resistance to change from both educators and students accustomed to traditional teaching methods must be overcome through demonstrating the tangible benefits of AI and providing adequate support during the transition period.

Generative AI offers transformative potential for the teaching and assessment of postgraduate students in pathology and microbiology. By enhancing learning experiences, streamlining assessments, and providing personalized education, AI-driven tools can significantly improve the quality and accessibility of pathology education. However, addressing ethical and technical challenges is crucial to ensuring successful integration. As AI technologies continue to evolve, they will play an increasingly vital role in shaping the future of pathology and microbiology education, ultimately leading to better-prepared professionals and improved patient care.

This narrative review explores the multifaceted applications of generative AI in enhancing the teaching and assessment of postgraduate students in these disciplines. By providing personalized learning experiences, simulating complex scenarios, and automating assessments, AI-driven tools promise to significantly improve educational outcomes. This review delves into the benefits, challenges, and future prospects of AI in pathology and microbiology education, aiming to offer a comprehensive understanding of its transformative potential.

1. Introduction

Pathology and microbiology are pivotal fields in medical education and research, crucial for diagnosing diseases and understanding their underlying mechanisms. Training postgraduate students in these areas involves a rigorous combination of theoretical knowledge and practical skills. Traditional teaching methods, while effective, face limitations in addressing the diverse needs of students and providing comprehensive, unbiased assessments. Generative AI, with its ability to create data, simulations, and personalized educational experiences, offers a transformative approach to education in pathology and microbiology.[1]

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Generative AI refers to artificial intelligence systems capable of creating new content, such as images, text, and simulations, based on learned patterns from existing data. This technology can generate realistic histopathological images, simulate complex microbiological processes, and provide personalized feedback, making it a powerful tool for enhancing education in these fields. AI in pathology has been around for a long time; Digital Pathology and Machine learning to analyse these digital images have been there since 2000. The FDA cleared the first digital pathology whole-slide scanning solution in 2017; however, the concept of generative AI was introduced only in 2022. [2]

Traditional AI models are primarily used for data analysis, pattern recognition, and making predictions. In pathology, this means analysing medical images to identify abnormalities, classify diseases, and predict outcomes. It often relies on machine learning algorithms that are trained on large datasets to recognize patterns and make decisions based on those patterns. Examples include automated image analysis for detecting cancerous cells, quantifying biomarkers, and assisting in diagnostic workflows. [1]

Generative AI goes a step further by creating new content based on the data it has learned. This can include generating synthetic medical images, simulating disease progression, or creating new diagnostic tools. It uses advanced models like Generative Adversarial Networks (GANs) and Recurrent Neural Networks (RNNs) to learn from large datasets and generate new, realistic data. In pathology, generative AI can be used to create synthetic pathology slides for training purposes, simulate rare disease cases, and enhance diagnostic accuracy by generating additional data for analysis. [3]

Both types of AI have significant roles in advancing the field of pathology, improving diagnostic accuracy, and enhancing patient care. However, the aim of this narrative review is to primarily explore the applications of generative AI in the teaching and assessment of postgraduate students in pathology and microbiology.

2. Generative AI in Pathology and Microbiology Education

2.1. Enhancing learning experiences

Generative AI can significantly enhance learning experiences by providing interactive and personalized educational tools. In pathology, AI-driven platforms can generate realistic histopathological images, allowing students to practice diagnostic skills without the constraints of physical slide availability. These virtual slides can be annotated and modified, creating a dynamic learning environment that adapts to the student's progress and areas of difficulty. [4]

Generative AI encompasses algorithms capable of generating new data samples similar to a given dataset. In histopathology, these AI models are trained on vast datasets of histological images, enabling them to recognize and classify various tissue structures, detect abnormalities, and even predict disease outcomes. These models use deep learning techniques, particularly convolutional neural networks (CNNs), to process and analyse complex image data.

Several generative AI assistants have been developed and are currently in use for pathology. Path Chat is the result of Lu et al.'s adaptation of a basic vision encoder for pathology, huge language model pretrained on it, and system fine-tuning on over 456,000 different visual language instructions with 999,202 question-answer turns. [5] They contrasted Path Chat with a number of multimodal vision language AI assistants as well as GPT4V, the engine that drives the multimodal general purpose AI assistant ChatGPT-4, which is sold commercially. On multiple-choice diagnostic questions derived from cases with varying tissue origins and illness models, PathChat demonstrated state-of-the-art performance. Additionally, they discovered that, on the whole, PathChat generated more correct and pathologist-preferable answers to a variety of issues pertaining to pathology through the use of open-ended questions and human expert judgment. The potential of large language models (LLM) like OpenAI's ChatGPT-4 in the field of medical research, particularly digital pathology, highlight the need for domain specific AI tools, given the limited precision of generalist LLMs in this area. [6]

By the end of 2024, generative AI models will be widely used in automated histopathology, especially for grading and diagnosing cancer. For example, the New York, USA-based Paige Inc. has created an AI tool to assist pathologists in identifying, classifying, and measuring prostate cancer. Paige Prostate is a Class II medical device that has received FDA approval and CE marking. Paige announced the release of a novel multi-tissue detection model at the beginning of January 2024. This model can detect cancer in over 17 various tissue types, such as the skin, lung, and gastrointestinal system, in addition to several uncommon tumor forms and metastatic deposits. [7]

Similarly, in microbiology, AI can simulate microbial growth patterns, antibiotic resistance mechanisms, and laboratory experiments, providing students with hands-on experience in a virtual setting.

AI can also create virtual tutors that offer personalized feedback and guidance, mimicking one-on-one interactions with human instructors. These AI tutors use natural language processing to understand student queries and provide detailed explanations, fostering a deeper understanding of complex concepts in pathology and microbiology. [8] For instance, AI can help students understand the nuances of bacterial identification, virology, and the molecular mechanisms underlying diseases.

2.2. Simulation-based learning

Generative AI-powered simulations provide a safe and controlled environment for students to practice procedures and make diagnostic decisions. Virtual pathology labs equipped with AI simulations can recreate real-world scenarios, enabling students to explore different diagnostic procedures like fine needle aspiration cytology (FNAC), bone marrow aspiration/biopsy etc and witness the outcomes of their decisions. This experiential learning approach enhances critical thinking and decision-making skills.[9] For example, AI can simulate the progression of a disease based on different treatment plans, allowing students to observe the effects and refine their clinical judgment.

In microbiology, AI-driven simulations can replicate laboratory experiments, such as culturing bacteria, testing antibiotic susceptibility, and analysing microbial genetics. These simulations provide students with the opportunity to conduct experiments and interpret results in a virtual environment, which is especially valuable when resources or safety concerns limit hands-on laboratory work. Moreover, AI can simulate outbreaks of infectious diseases, teaching students about epidemiology, infection control, disaster management and public health responses.

3. Generative AI in Assessment

3.1. Automated assessment tools

Generative AI offers innovative solutions for the assessment of postgraduate students in pathology and microbiology. Traditional assessment methods, such as written exams and practical assessments, often require significant time and resources to design, administer, and grade. AI can automate these processes, providing timely and objective evaluations. AI-driven assessment tools can generate unique test questions, reducing the likelihood of academic dishonesty and ensuring a fair assessment environment.

In pathology, AI algorithms can analyse histopathological images submitted by students, comparing them with standard references to assess diagnostic accuracy.[10] Similarly, in microbiology, AI can evaluate students' interpretations of laboratory results, such as identifying bacterial species or determining antibiotic resistance patterns. These automated assessments provide detailed feedback on student performance, highlighting areas for improvement and reinforcing learning objectives.

3.2. Continuous and formative assessments

Generative AI enables continuous and formative assessments, offering real-time feedback that helps students identify and address their weaknesses promptly. AI-powered platforms can track student performance over time, highlighting areas that need improvement and suggesting targeted learning resources. Formative assessments facilitated by AI can include interactive quizzes, virtual case studies, and simulated diagnostic tasks. These assessments not only gauge student knowledge but also enhance learning by reinforcing key concepts and skills. Moreover, AI can adapt the difficulty level of assessments based on individual student progress, ensuring an optimal challenge that promotes growth.[11]

In microbiology, AI-driven formative assessments can include virtual lab reports, interactive modules on microbial genetics, and case studies on infectious disease outbreaks. These assessments help students apply theoretical knowledge to practical scenarios, improving their analytical and problem-solving skills.

4. Benefits of Generative AI in Pathology and Microbiology Education

4.1. Personalized learning

One of the most significant advantages of generative AI in pathology and microbiology education is its ability to offer personalized learning experiences. By analysing student data, AI can tailor educational content to match individual learning styles and paces. This personalized approach ensures that students receive the support they need to master complex topics and skills.[12] For example, AI can identify students who struggle with specific concepts, such as microbial pathogenesis or histopathological diagnosis, and provide additional resources and exercises to address these gaps.

4.2. Increased accessibility

Generative AI can make pathology and microbiology education more accessible to a broader audience. Virtual learning platforms powered by AI can reach students in remote locations, providing high-quality education without the need for physical presence. This accessibility is particularly beneficial for institutions with limited resources, enabling them to offer comprehensive training programs in pathology and microbiology.[13] Furthermore, AI can facilitate remote collaboration and knowledge sharing among students and educators worldwide, fostering a global learning community.

4.3. Efficiency and scalability

AI-driven tools can streamline administrative tasks, such as grading and curriculum development, allowing educators to focus on more critical aspects of teaching and mentorship. Furthermore, the scalability of AI solutions means that educational programs can accommodate a larger number of students without compromising the quality of instruction.[14] This scalability is particularly advantageous in addressing the growing demand for trained professionals in pathology and microbiology.

5. Examples of Case Scenarios where AI may be used for Training in Pathology and Microbiology

This section provides some case scenarios which can be used as prototype examples to train the postgraduate students in Pathology and Microbiology.

5.1. Scenario 1: Enhancing Diagnostic Skills in Pathology

Dr. X, a postgraduate pathology student, is training to improve his diagnostic skills in histopathology. His program incorporates the use of Path Chat

Application: Path Chat assists Dr. X by answering to specific questions asked by him related to the diagnosis of a specific histopathology slide. For example, when examining a biopsy sample, if Dr. X identifies regions of suspicion and highlights areas of potential malignancies, he may resort to the generative AI tool Path Chat for answers to his queries.

Assessment: The instructor uses PathChat's diagnostic output to assess Dr. X's accuracy and consistency. By comparing Dr. X's diagnoses with the AI's suggestions and the confirmed pathology reports, the instructor identifies areas where Dr. X needs further training.

Outcome: Dr. X's diagnostic accuracy and confidence improve significantly over time. The AI tool also helps him understand complex cases by providing detail insights on such cases and comparing it with similar such reported cases.

5.2. Scenario 2: Training in Antimicrobial Resistance Prediction

Dr. Y, a postgraduate microbiology student, is learning to predict antimicrobial resistance patterns using Karius, an AI-based pathogen detection platform.

Application: Karius analyses blood samples to detect microbial DNA and predict resistance patterns. During training, Dr. Y submits clinical samples to Karius and receives detailed reports on pathogen identification and resistance profiles. She then formulates treatment plans based on these reports.

Assessment: Dr. Y's performance is assessed by comparing her treatment plans with established guidelines and patient outcomes. The AI tool also tracks her decision-making process, providing feedback on her ability to interpret resistance data and choose appropriate therapies.

Outcome: Dr. Y becomes proficient in interpreting complex resistance patterns and tailoring treatments accordingly. The AI tool helps her stay updated with evolving resistance trends, enhancing her ability to manage infections effectively.

5.3. Scenario 3: Virtual Microscopy and Interactive Learning

A postgraduate pathology and microbiology program integrates a virtual microscopy platform powered by generative AI to facilitate interactive learning.

Application: Students use the virtual platform to examine digitized slides. The AI system generates synthetic images of various pathological conditions, allowing students to practice identifying abnormalities. For instance, the AI can create variations of a normal tissue sample or microbiology slides to simulate different stages of disease progression.

Assessment: The instructor designs quizzes and practical exams using AI-generated slides. Students are assessed on their ability to recognize and diagnose conditions based on these AI generated images. The AI also provides immediate feedback, highlighting mistakes and offering explanations.

Outcome: Students gain extensive exposure to a wide range of pathological conditions, improving their diagnostic skills. The AI-generated slides offer diverse and challenging cases, enhancing the learning experience and preparing students for real-world scenarios.

These cases show that Generative AI plays a crucial role in enhancing the education and assessment of pathology and microbiology postgraduates. By providing advanced diagnostic tools, generating synthetic training data, and simulating real-world scenarios, AI enhances learning outcomes and prepares students for clinical practice. The integration of AI in medical education not only improves diagnostic accuracy and decision-making skills but also offers a flexible and interactive learning experience.

6. Challenges and Limitations

6.1. Ethical considerations

The use of generative AI in education raises ethical concerns related to data privacy, bias, and the potential for over-reliance on technology. Ensuring the confidentiality and security of student data is paramount. Additionally, AI algorithms must be designed to minimize bias and provide equitable educational opportunities for all students.[15] For instance, AI systems should be transparent in their decision-making processes and undergo regular audits to identify and mitigate biases.

6.2. Technical challenges

Implementing generative AI in pathology and microbiology education requires significant technical infrastructure and expertise. Institutions must invest in high-quality AI systems and ensure that faculty members are trained to use these tools effectively. The integration of AI into existing curricula also necessitates careful planning and coordination.[22] Technical challenges may include ensuring

Table 1: Studies showing the use and impact of AI in the field of medical education and research

Study	Authors/Year	Key Themes	Findings
Artificial Intelligence in Medical Education	Shen et al.[16] 2020	AI in medical education, teaching methodologies, personalized learning	AI tools significantly improve personalized learning experiences, leading to better student engagement and comprehension.
Artificial Intelligence in Pathology	Chang et al.[9] 2019	Deep learning, Pathology, Image analysis	Recent advances in AI applied to pathology, and future prospects of pathology driven by AI.
AI-Driven Personalized Learning in Pathology	Chen et al.[12] 2020	Personalized education, adaptive learning, student performance	Generative AI tailors educational content to individual student needs, resulting in improved understanding and retention of complex pathological concepts.
Enhancing Learning Through Collaborative AI Tools	Cui et al[17], 2020	Collaborative learning, virtual interactions, peer assessments	AI platforms facilitate collaborative learning, promoting interaction and knowledge sharing among pathology students.
AI in Continuous Professional Development for Pathologists	Wang et al.[18] 2021	Lifelong learning, professional development, ongoing education	AI-driven tools support continuous learning for professionals, keeping them updated with the latest research and practices in pathology.
Overcoming Resistance to AI in Education	Mark et al.[19] 2020	Change management, technology adoption, educational innovation	Successful integration of AI in education requires addressing resistance through demonstrating benefits and providing adequate support during transitions.
Applicability of ChatGPT in assisting to solve higher order problems in pathology	Sinha et al.[20] 2023	AI-driven solutions, accuracy, higher order problems in pathology	The capability of ChatGPT to solve higher-order reasoning questions in pathology had a relational level of accuracy.
Assessing the capability of ChatGPT in answering first-and second-order knowledge questions on microbiology as per competency-based medical education curriculum	Das et al.[21] 2023	AI-driven solutions, accuracy, first and second order problems in microbiology	The accuracy rate of approximately 80% indicates that ChatGPT has the capability to be a valuable automated question-answering system for students.

the compatibility of AI tools with existing educational platforms and addressing potential issues related to software updates and maintenance.

6.3. Resistance to change

Adopting AI-driven educational methods may face resistance from both educators and students accustomed to traditional teaching approaches. Overcoming this resistance requires demonstrating the tangible benefits of AI and providing adequate support during the transition period.[19] Institutions can facilitate this process by offering training sessions, workshops, and continuous support to help educators and students adapt to AI-driven tools.

7. Current Trends and Research in the Field

There have been some work in this field for the last few years. The Table 1 depicts the various studies done in the recent past (last 5 years) on the impact and role of AI in medical education and research. The key themes of these studies along with their respective findings have been explained. The common observation of all these findings was although AI enhanced the personalised learning experience, gives scope for self-directed learning and prepares students for a new generation of digitalization yet they also pointed out the ethical challenges and data privacy issues that may cause concern.

8. Future Prospects

8.1. Advanced AI capabilities

The future of generative AI in pathology and microbiology education lies in the continued advancement of AI technologies. Enhanced natural language processing, improved image recognition, and more sophisticated simulations will further enrich the learning and assessment experiences of postgraduate students. These advancements will also facilitate the integration of AI into more complex and nuanced areas of pathology and microbiology.[1,5] For example, AI could assist in interpreting next-generation sequencing data or predicting disease outbreaks based on epidemiological data.

8.2. Collaborative learning environments

Generative AI can foster collaborative learning environments where students from different geographical locations can interact and learn together. AI-driven platforms can facilitate virtual group projects, discussions, and peer assessments, promoting a sense of community and shared learning.[23] For instance, students could work together on virtual microbiology lab experiments or case studies, leveraging AI tools to analyse data and present findings.

8.3. Lifelong learning and professional development

The application of generative AI extends beyond postgraduate education to continuous professional development. Pathologists and microbiologists can benefit from AI-driven tools that provide ongoing learning opportunities, keeping them updated with the latest research and practices in their fields. This lifelong learning approach ensures that professionals remain competent and confident in their practice.[1,6] AI can also support professional development by offering personalized training modules and tracking progress over time.

9. Conclusion

Generative AI holds immense potential to transform the teaching and assessment of postgraduate students in pathology and microbiology. By enhancing learning experiences, streamlining assessments, and offering personalized education, AI-driven tools can significantly improve educational outcomes. However, addressing ethical and technical challenges is crucial to ensuring successful integration. As AI technologies continue to evolve, they will play an increasingly vital role in shaping the future of pathology and microbiology education, ultimately leading to better-prepared professionals and improved patient care. The ongoing collaboration between educators, technologists, and policymakers will be essential to harness the full potential of generative AI in medical education.

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11. Conflict of Interest

None.

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