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Impacts of Artificial Intelligence (AI) on anatomy education

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Abstract

Artificial Intelligence (AI) is transforming anatomy education by redefining traditional teaching methods such as cadaveric dissection, bone maceration, and plastination. Its integration into medical education has the potential to enhance instructional delivery, learning experiences, and assessment strategies. AI tools, including chatbots and virtual assistants, provide personalized learning support, interactive simulations, and virtual dissection experiences that improve student engagement and understanding of anatomical structures. This paper examines the impact of AI on anatomy education, highlighting its applications through teaching case studies, as well as its advantages and limitations. While AI-driven approaches can enhance student performance through personalized assessment and immersive learning, challenges related to curriculum integration, ethical considerations, and technological limitations remain. Adapting anatomy education to evolving technological trends is therefore essential to optimize teaching, assessment, and curriculum design.

Keywords: *Artificial intelligence, Anatomy education, Technological applications, Personalized learning, Simulation, AI models*

1. Introduction

Artificial Intelligence (AI) technology is a wide range of technological applications that are used to artificially generate ideas aimed to support education, information, infrastructure and other developmental and strategic institutions (Ghosh, 2022; Moro, 2023). Even though, AI is built on preexisting natural intelligence, they are trained technologies to simplify life activities for mankind. Studies has shown that the impact of AI generally

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carries both "promises and perils" (Lazarus *et al*., 2022), and these research findings follows the same influential trends of new technology exposure to the society. Over a decade, debates have unavoidably escalated over the use and misuse of technology so as the merit and demerit of its impact on the status quo. New technologies are always a source of ethical issues and challenges in all areas of biomedical research, practice, and public policy, and the science of anatomy is no different. The way forward is to distinguishably study the positive and negative impacts of AI, a strategic way of counter effecting the challenges and limitations that might arise and also providing effective theories to improve education without impending ethical issues (Lige, 2024).

Over decades, human Anatomy has been classified has a basic medical science that delves into exploring the internal structure of the body. It has always been a very fundamental and important aspect of medical science for centuries and is relevant to all health science courses such as nursing, medicine, surgery, radiology, physiology, physiotherapy and others. However, AI has given students the optimum privilege to develop a three dimensional (3D) understanding of the body which includes insight into the topographical relationships between anatomical structures. Formerly, the physical dissecting room has always been used for this purpose before the emergence of virtual dissections and simulations.

Over the years, educational technology has evolved from the simplest innovations such as e-books, video and audio recordings, learning applications and digital simulations practically uprooting the traditional methods of teaching anatomy via physical texts, model and other methods. However, the emergence of these versatile and digital applications couldn't replace the utility of the physical dissecting room. The old technologies can be minutely compared to Artificial intelligence for its digital occurrence but there is a huge significant difference due to the incredible and surplus benefits that has been positively reviewed by educators, such as adaptive ability, real-time feedback, "smart" analytics, continuous improvement abilities, instant simulations, and potential for "intelligent" tutoring (Cornwall *et al*., 2023). The use of AI in the dissection room is thus a greater educational challenge to the ongoing use of body donors than previous technologies because at face value it appears to offer an experience that is more personalized, interactive, and adaptive than other digital resources. However, with the huge visibility of AI's potential on medical education, it ought to be viewed from a practical perspective if the incorporation of AI would disrupt the fundamentals of anatomy for these students. According to studies, it is still unclear whether learning outcomes around anatomical knowledge will be altered by the arrival of AI technology.

It is very crucial to understand that as we hammer on the impact of AI on medical education or education generally, we shouldn't overrule the importance of its presence and position in education and also the status of education without AI today. The incorporation of AI into medical education has not ceased, it's still a gradual and revolutionary process (Arif *et al*., 2023; Dahmen *et al*., 2023). Generating human-like ideas, mutual and interactive conversations, automating time-intensive tasks such as summarizing and evaluating relevant medical knowledge and medical literature with its natural language processing capabilities and advanced algorithms (Butt *et al*., 2023; Mogali, 2023), it has the potential to provide students with detailed and personalized information in medical education and can be paired with other technical software to develop interactive simulations (Li *et al*., 2021; Lazzarus *et al*., 2022). This has definitely created a huge medical educational model by acting as a virtual assistant. In this paper, we aim to analyze in detail the general impacts of AI in medical education, especially in the teaching of anatomy. In addition, we explore the advantages as virtual dissections, diagnostic simulations and medical training.

2. Anatomy in Medicine: Use of Artificial Intelligence

For hundreds of years, anatomy has been a cornerstone of medical education (Singh *et al*., 2015). Anatomy was considered one of the most important and crucial subjects taught in the curriculum when the first medical school in Italy was founded in Salerno in 1235 (Zampieri *et al*., 2013). With the publication of his major works, Vesalius (1543), the father of modern anatomy, ushered in a new age of scientific study of human anatomy. Furthermore, dissection was considered the cornerstone of medical education toward the end of the 20th century (Zampieri *et al*., 2013).

Since anatomy forms the foundation of all clinical medical sciences, it is recognized as the mother of medical education. Physicians have indicated that gross anatomy has the most fundamental significance

when asked about the importance of anatomy (Pabst and Rothkotter, 1997). Several studies have shown that anatomy is highly relevant to both postgraduate students (Turney, 2007) and medical students (Moxham and Plaisant, 2007).

Anatomy is necessary for medical personnel to examine patients. It's also critical to comprehend illness, diagnose it, and communicate with patients and other medical professionals. Anatomical knowledge is necessary for surgical and other invasive procedures. Anatomy is essential for both diagnosis and therapy. Treatment is impacted by knowledge of normal anatomy and alterations caused by disease (Singh *et al*., 2015). A fundamental component of medical education will always involve human anatomy (Turney, 2007). There have been many changes made to anatomy education. Pedagogical and administrative officials at universities have long faced challenges, including a shortage of staff and a time commitment to anatomy instruction. Traditional methods of teaching and learning are followed by few schools, while many have changed their curricula and embraced an integrated approach. Students generally think anatomy courses are boring, uninteresting, and use antiquated teaching methods. According to Wilson *et al*. (2018), there was no one model or teaching strategy that was proven to be more successful than another. However, integrating multimodal methods into the classroom was undoubtedly the most successful strategy (Estai and Bunt, 2016).

The number of publications and citations of linked studies has increased recently, indicating a growing interest in the application and research use of AI in medical education. All facets of medical education, such as curriculum construction, curriculum analysis, learning, and evaluation, can benefit from the use of AI (Savage, 2021). It may be able to assist pupils with specific needs and pinpoint knowledge gaps. Additionally, integrating AI into medical education will boost student interest and increase the quality of instruction (Bayne, 2015; Botrel *et al*., 2015). However, in order to effectively integrate AI into medical education, medical educators will need to possess a solid foundational understanding of the technology. In addition, AI must be included into medical curricula in order for students to gain the necessary abilities and be able to employ AI in their practice.

3. Application of artificial intelligence models in anatomy education

3.1. VirtuaL dissection

3.1.1. Augmented Reality (AR) and Virtual Reality (VR)

The use of virtual 3D models in education has revolutionized the way anatomy is taught. These days, 3D models are used in a wide range of technical applications, particularly in the medical sciences. The delivery of anatomy lectures and practical sessions has been considerably aided by the availability of various digital models as well as the use of virtual reality and simulation. These virtual models are widely employed in the health sciences to provide students with greater insights and individualized learning opportunities regarding anatomical structures through virtual dissection, surgeries, and simulations (Wainman *et al*., 2020).

Cadavers have always been an integral part of anatomy instruction (Albanese, 2010). However, there are drawbacks, including specimen degradation and financial strain on institutions, as a result of their fragility, high cost, and limited availability (McLachlan and Patten, 2006; Nicholson *et al*., 2006; Berube *et al*., 1999). Furthermore, the teaching process is made more difficult by the greater student-to-cadaver ratios brought about by the paucity of cadavers (McLachlan and Patten, 2006). Three-dimensional visualization technology (3DVT) has become more widely used by educators as an additional tool to solve these problems (Codd and Choudhury, 2011; Moro *et al*., 2017; Triepels *et al*., 2020).

Studies demonstrate that interactive modules yield more satisfaction than static text, and they also emphasize the benefits of 3DVT. One example of this is the Educational Virtual Anatomy (EVA) software, which was favored by 75% of students over traditional techniques (Petersson *et al*., 2009; Keedy *et al*., 2011). While 3DVT shows promise, its superiority over conventional approaches is still up for question. Some research (Petersson *et al*., 2009; Keedy *et al*., 2011; Khot *et al*., 2013; Preece *et al*., 2013; Yammine and Violato, 2016; Wainman *et al*., 2018 and 2020) prefer physical models for learning. On the other hand, while the use of high-profile virtual tools replaces the real world by constructing a new one with virtual representations of the human body, virtual educational systems that enrich the learning environment through computer-based simulations.

3.2. The Anatomage Table

For decades, the traditional method of dissection (Cadaveric dissection) has been used for anatomical studies to understand the normal anatomical structures and relation of the human body. However, due to many limitations of cadaveric dissections such as putrefaction, developmental defects, disease or trauma to the cadaver, it might disrupt the normal anatomical structure (Miller *et al*., 2002). Also, in radiology, graphical technology is implemented for these imaging techniques such as X-rays and CT scans. So, having a profound understanding of anatomy might be enhanced using anatomy visualization system (Fredieu *et al*., 2015). Fredieu *et al*. (2015) noted the use of digital 3D anatomic models, such as anatomical visualization systems, and have been reported as an effective tool in enhancing learning and retention in medical and dental students although further examination is still needed. The evolvement of using 2D images to 3D in anatomical education had enhanced and improved the teaching and learning environment into an active one (Tan *et al*., 2012).

The Anatomage virtual dissection table (Figure 1) is a life-size virtual dissection table that displays gross anatomy models reconstructed from cadavers (Custer and Michael, 2015). An internal software in this dissecting table allows the creation of clinical problems from the CT scan and MRI images installed. Anatomy can be presented in 3D format and in coronal, axial, sagittal or other planes.

Figure 1: The Anatomage Table

Source: Ramsey (2019)

3.3. Impacts of the Anatomage on Anatomy Education

3.3.1. Advantages

- The Anatomage table can be utilized in a variety of ways to better demonstrate and learn anatomy and pathology (Cresswell, 2013).
- The Anatomage table enables students to view and manipulate full-body male and female models through the use of three virtual cadavers.
- Ability to better visualize the anatomy and pathology using a 3D format along with different anatomical planes including axial, coronal, sagittal and user defined planes.
- The ability to scroll through the entire body vs. simply seeing subsequent images from a textbook was noted to be very beneficial by Custer and Michael (2015).
- The Anatomage Table is equipped with numerous pre-installed pathological examples which can be used to evaluate and compare normal and abnormal anatomical structures.

- Provides the ability to load real patient data for manipulation and viewing. Students listed the ability to load and view real patient data into the table as a huge advantage.
- The Anatomage Table provides the students and instructors with the ability to perform drill/practice activities along with quizzing and testing (Custer and Michael, 2015).

3.3.2. Disadvantages

- Inability to view Sonography and Positron Emission Tomography (PET) imaging scans on the Table. The Table best displays computed tomography and magnetic resonance imaging scans (Cresswell, 2013).
- The study carried out by Custer and Micheal showed that since the Table was used in the different courses. Several courses began with slow incorporation of the Table by utilizing it for only four times over the course of the semester in one-hour increments. Other courses utilized the Table for several hours each week during the first semester. Overall, the students felt that exposure to the Table from one to three hours per week was optimal (Custer and Michael, 2015).
- Other minor disadvantages involved specific function errors of the Table which can be easily resolved with technical support.

3.4. Students' psychology and performance in relation to the Anatomage Table

Studies has shown that the virtual dissection table has a profound effect on the anatomical knowledge of medical students. Majority of students has shown great performance in their assessments after the introduction of this apparatus. Over time, the Anatomage table also positively influenced the classroom learning experience above 50%. Also, final year medical students acknowledged that use of the Anatomage Table during their educational journey has better prepared them to enter a health care profession. These results were gotten from a study by Custer and Michael (2015).

4. Diagnostic simulation

4.1. Artificial intelligence in medical training and clinical applications

Health care students can practice autonomous decision-making and action without the essential restraints of patient safety thanks to computer-based clinical simulations (Schultz, 1979).

The creation and testing of computer-based clinical simulation models aimed at enhancing the clinical skills of healthcare professionals was first documented in 1978 by the Center for Medical Computing at the University of Wisconsin-Madison. Medical education has traditionally involved reading and discussing analyses of patient case histories as well as practicing on hospital wards and clinics to become involved in ongoing patient cases. Through reading about illnesses or taking part in real patient care, a student learns what steps are proper to take and what they should not take.

However, the possibility of independent, self-directed study is limited by both approaches. Due to the static nature of written information and patient safety standards, the student is not allowed to actively make independent diagnostic decisions based on returning data. An integrated educational and assessment support system that pushes health care students toward autonomous, self-directed decision-making and action has been created to get around these limitations. The method creates an instructional medium that falls between a static case history and an active patient case by using computer-based clinical simulations. A "simulation" of a patient condition can be developed and, more crucially, can be "worked on" by health care providers by adapting real-life patient cases with their varying illness states and test results.

4.2. Disease diagnosis with deep learning: The diagnostic model

The diagnostic simulation approach allows the learner to follow various simulated hospitalized patient problems on their own (Freidman, 1976). This diagnostic simulation model as shown in Figure 2 allows students to independently learn using simulation to study records and solve different medical cases from coded input to printed outputs. As the patient's medical consultant while being treated by "other doctors," the student user's job is to ascertain the patient's underlying issue. The learner receives a brief introduction to the patient from the computer at the start of a visit.

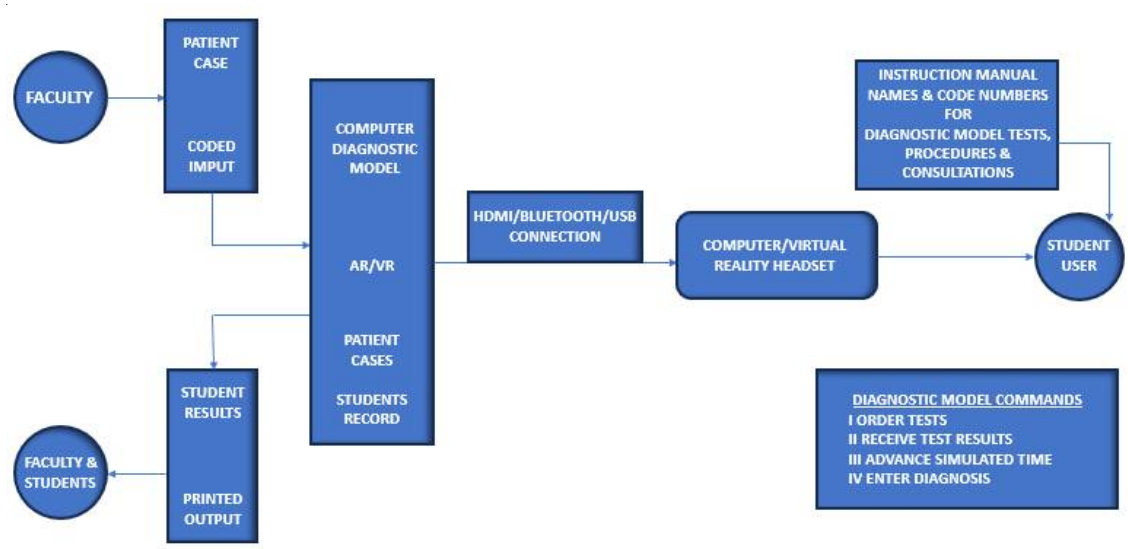

Figure 2: System overview of the diagnostic simulation model used in medical training

Source: Schultz et al. (1979)

The "simulated" day of the week and time of day are also disclosed to the student. Next, he or she can place an order for any of the more than 400 tests, operations, and consultations by using code numbers or free text. The student can try to draw diagnostic conclusions by getting the test results, analyzing them, developing diagnostic hypotheses, and pursuing these hypotheses by ordering additional tests. Given the inclusion of a "time axis" in the model, the state of the patient and the outcomes of any of the 400 ordered or reordered tests, operations, or consultations are subject to variation.

A pupil can try to diagnose the situation accurately at any time during the interaction. To accomplish this, type the diagnosis in a free text statement (e.g., "multiple myeloma" or "tuberculosis" (Schultz *et al.*, 1979). The patient's case is closed if the student is right. Even if no one's safety was endangered, if a student makes a mistaken diagnosis, they will be penalized financially and in terms of time in proportion to the severity of the mistake.

4.3. Medical imaging and diagnostics

The process of identifying a health problem, illness, disorder, or other condition that a person may have been known as disease diagnosis. Diagnosing certain diseases may be quite simple at times, but there may be more difficult cases. There are lots of data sets out there, but the number of tools that can reliably identify patterns and generate forecasts is limited. Traditional disease diagnosis techniques are labor-intensive and prone to inaccuracy. When compared to solely human competence, the use of Artificial Intelligence (AI) predictive approaches reduces detection mistakes and enables auto diagnosis (Kaur *et al.*, 2020). The most difficult process of all is diagnosing an illness, which is crucial for a medical practitioner to do before coming to a diagnosis.

The diagnosis procedure may be quite laborious and intricate. The healthcare professionals gather empirical data to determine a patient's illness in order to reduce the uncertainty in medical diagnosis. If the diagnosis procedure is flawed, the patient may have major health problems and have their proper treatment delayed or neglected. Sadly, not every medical professional is an expert in every area of the field. Therefore, an automated diagnostic system that combines the advantages of human expertise with machine precision was required (Choi *et al.*, 2016). To obtain precise diagnosis results at a lower cost, an appropriate decision support system is required.

AI would assist in identifying and managing these types of instances because it is difficult for human experts to classify diseases based on multiple factors. Currently, the medical industry uses a variety of AI algorithms to effectively diagnose illnesses. Artificial Intelligence (AI) is a crucial component of computer

science that enables computers to learn. Learning is a fundamental requirement for every intelligent system. Furthermore, AI is better able to generate outcomes that are more accurate than they were previously since it is constantly learning. The Internet of Medical Things, which facilitates the use of IOT devices to gather healthcare data, is another important application of AI.

Artificial Intelligence (AI) software senses the symptoms of the disease even before it manifests. In less time than a skilled radiologist, neural networks can be trained to detect lung cancer, breast cancer, and strokes. Doctors may detect certain diseases by just identifying symptoms thanks to a variety of AI algorithms that evaluate medical imagery like MRIs, CT scans, and x-rays. Since several diseases have extremely similar symptoms, diagnosing a disease and determining the best course of therapy are always difficult and complex processes. Physicians can diagnose patients more precisely and recommend the best course of action when they use medical expert systems. Doctors can categorize the various deadly diseases using AI technologies in addition to being able to identify the sickness itself (Kaur *et al*., 2020).

4.4. Trends of diagnostic simulations

Traditionally, medical students have not been allowed to perform any acts on patients for safety reasons; instead, they have only been allowed to study case histories and make their own diagnoses in front of their teachers. Nonetheless, the usage of computer-based clinical simulation dates back to the 1970s, when faculty members at medical schools uploaded student records and patient histories to a computer system for the purpose of assessing students and providing medical education (Freidman, 1976). Their decision-making and autonomous activities regarding diagnosis, imaging, testing, and therapy performed on these virtual patient histories determine the performance outcome. However, the development of virtual realities and more sophisticated computer systems allowed students to interact with virtual patients and perform tests.

5. Lectures and medical training

Human behavior is inexorably shaped by technology, and Artificial Intelligence (AI) has the potential to revolutionize the medical field. Medical precision has increased due to ongoing advancements in monitoring health and disease, but these advancements have also left clinicians perplexed by mounds of healthcare data and rapidly developing medical knowledge that is getting harder and harder to understand and apply. In order to make diagnosis and treatment decisions based on the most recent medical knowledge, medical experts sort through this enormous volume of healthcare data (Kundu, 2021).

In AI, the diagnosis and the treatment choices are called data labels. When healthcare data is labeled in this manner, Artificial Intelligence (AI) can identify patterns in the data and use those to make decisions on new, untrained data in the future. Unlike basic automation, which excels at precise routine activities for which it has been created but lacks the generalization capacity to make decisions in unexpected scenarios, Artificial Intelligence (AI) can generalize and make decisions in unknown circumstances (Benjamens *et al*., 2020).

The rapid growth and increasing complexity of medical knowledge has increased the need for machine-assisted help in the medical field. Although medical knowledge quadrupled over several decades in the middle of the 20th century, estimates based on publication growth show a far shorter doubling time often reported as roughly 73 days highlighting the extent of information overload experienced by trainees and clinicians. According to Alper *et al.* (2004), medical students would require more than 29 hours of study time per week to be up to date with the primary care literature. In actuality, therapeutic specialty is driven by an abundance of knowledge (Kundu, 2021). Compared to 7% in 1951-1960, 88% of internal medicine residents specialize today (Dalen *et al.*, 2017). Second, an individualized approach to treatment is required since individuals who live longer are more prone to have several comorbidities.

Finally, a greater range of tests and drugs are available to physicians, and the introduction of next-generation sequencing, high-resolution imaging modalities, and other technologies has contributed to the unparalleled growth of medical data in electronic medical records. The first year of residency is essentially a school in the art of filtering data, therefore it seems sense that freshly outfitted interns are observed with white coat pockets bursting at the seams with flashcards, rounding notes, fishbone laboratories, and medicine dosing instructions (Kundu, 2021).

Medical students are essential because they train with so many new gadgets. Doctors-in-training could study how to handle patient data by examining the effects of various factors on patient health, including social determinants, clinical diagnosis and care, prompt decisions, and collaboration with other health professionals, while keeping patients at the center of the mission. Training in post-knowledge medicine may move from biology to psychology and sociology, emphasizing empathy and a deeper comprehension of socioeconomic systems. Contrary to popular belief, knowledge-centered or even therapeutic connection has less of an effect on wellbeing (CloudMedx Inc., 2019).

6. General impacts of artificial intelligence on Anatomy education

6.1. Advantages and positive impacts of AI on Anatomy education

6.1.1. Personalized learning experiences and information

Artificial Intelligence (AI) is a sophisticated technology that uses algorithms to mimic human performance in tasks like text recognition, image processing, and speech recognition. As a result of its primary reliance on natural intelligence—which encompasses language processing, machine learning, and neural networks—data—text, videos, and audios—is gathered from many sources, categorized, and made easily readable by algorithms that provide targeted responses. Built on these algorithms, ChatGPT, one of the most effective AIs with over 100 million monthly active users worldwide, offers instant feedback and 24-hour access to any information. This is undoubtedly a smart way to improve the way medical education is delivered (Lige, 2024).

High-profile AI apps, cutting-edge search engines, and chatbots like TeachMe Anatomy, Google Scholar, and ChatGPT have all been extremely effective teaching tools, particularly in the medical sciences by providing access to well-researched medical topic summaries. This strategy can simplify medical courses such as histology, embryology, gross anatomy, physiology, and others by offering clear, concise, and organized summaries that are easier to understand (Rospigliosi, 2023). The application of these AI models has lessened the burden of educational delivery for teachers and provided students with access to individualized instruction. New medical students have also profited from this, since AIs can quickly understand medical intricacies into elementary and literal language. According to Hsiao *et al.* (2010), these AIs also have the ability to track student development and evaluate them, among many other things.

6.1.2. Easy educational delivery and students' progress assessment

Students can now readily track their personal development based on the question and answer supplied by their learning AI model, thanks to the widespread availability of personalized learning. It becomes simple to discover issues and close the gaps. AI chatbots are able to effortlessly offer clinical queries on demand, analyzing anatomical knowledge of the cardiovascular and respiratory systems before providing the answers following an attempt (Rospigliosi, 2023). Not only may the questions be tailored to each student's unique circumstances, but they can also significantly lessen the workload for teachers. Lige (2024) thought ChatGPT was really good after evaluating the anatomy generating questions.

Teachers' time can be saved by using ChatGPT to mark test questions of varying difficulties after inspections, notwithstanding the possibility that it will produce wrong questions (Totlis *et al.*, 2023). Additionally, it can offer other alternate questions as it is formulating the original question (Sallam, 2023). Therefore, by strengthening their capacity to comprehend anatomy-related concepts and produce pertinent questions and distractions for varying levels of difficulty, these AI chatbots and sophisticated web engines have the potential to become a more dependable and valuable tool for anatomy education and exam preparation (Ghosh and Bir, 2023).

6.1.3. Other advantages

Education and technology are engaged in a never-ending race to provide fair and comprehensive access to education, particularly for students with special needs and in times of disaster and emergency (Sousa *et al.*, 2021). Additional benefits of integrating AI technologies into anatomy education include making the subject matter more approachable for students, reducing the need for human resources, promoting self-directed learning, automating gross and clinical anatomy practical sessions, deep learning, minimizing errors, providing real-

world solutions for clinical settings and medical education, divergent learning, storing research repositories, and many more (Abdellatif *et al*., 2022).

6.2. Disadvantages and negative impacts of AI on Anatomy education

6.2.1. Overreliance on artificial intelligence

The use of AI in healthcare carries additional concerns. An over-reliance on AI could make doctors less aware of their surroundings and thus increase their chance of being taken by surprise. Dependence on AI also carries the risk that there will always be a need for specialists in the event that the system malfunctions or is unable to provide the necessary services.

6.2.2. Large Scale Errors

Additionally, because AI systems are always learning from data, they bring a level beyond automation. AI systems have the potential to be extremely beneficial by selecting the finest content using data-driven strategies, but they are also prone to widespread mistakes. Consequently, AI must always be a feedback-driven system, allowing users to flag when judgments made by the AI are erroneous. This way, the model may learn from its mistakes and make better training iterations.

6.2.3. Ethical Issues and Considerations

The application of AI in healthcare raises additional ethical questions. When choosing therapies, patients and doctors frequently have to make trade-offs. One such trade-off is between life expectancy and quality of life. Therefore, there is no such thing as a patient treatment strategy that is one size fits all. The intricacy of multiple-choice situations must be captured by AI systems, yet stakeholders must still be involved when a medical decision requires a trade-off.

6.2.4. Other disadvantages

Additional drawbacks include the expensive price of AI technology models, worries about privacy, quality control, technical difficulties, employment declines, and a decrease in human interaction.

7. Conclusion

Even though 3D visualization technologies and chatbots are still in their early stages of development, Artificial Intelligence (AI) has already had a significant impact on anatomy education. Additional specialized AIs for teaching anatomy, such Anatomage and other virtual apps for 3D anatomy and virtual dissection, are incredibly effective at teaching anatomy. Numerous studies have started to investigate the potential of fully implementing AI in medical education for theoretical purposes. It needs to be continually researched and assessed in order to guarantee its functionality and effective integration.

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