



Educating the next generation of radiologists: a comparative report of ChatGPT and e-learning resources

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ABSTRACT

Rapid technological advances have transformed medical education, particularly in radiology, which depends on advanced imaging and visual data. Traditional electronic learning (e-learning) platforms have long served as a cornerstone in radiology education, offering rich visual content, interactive sessions, and peer-reviewed materials. They excel in teaching intricate concepts and techniques that necessitate visual aids, such as image interpretation and procedural demonstrations. However, Chat Generative Pre-Trained Transformer (ChatGPT), an artificial intelligence (AI)-powered language model, has made its mark in radiology education. It can generate learning assessments, create lesson plans, act as a round-the-clock virtual tutor, enhance critical thinking, translate materials for broader accessibility, summarize vast amounts of information, and provide real-time feedback for any subject, including radiology. Concerns have arisen regarding ChatGPT's data accuracy, currency, and potential biases, especially in specialized fields such as radiology. However, the quality, accessibility, and currency of e-learning content can also be imperfect. To enhance the educational journey for radiology residents, the integration of ChatGPT with expert-curated e-learning resources is imperative for ensuring accuracy and reliability and addressing ethical concerns. While AI is unlikely to entirely supplant traditional radiology study methods, the synergistic combination of AI with traditional e-learning can create a holistic educational experience.

KEYWORDS

Artificial intelligence, ChatGPT, digital case studies, educational videos, radiology education

Rapid advances in technology have revolutionized medical education, changing the way healthcare professionals share, access, and assimilate information.¹ This change is particularly evident in radiology, which relies heavily on advanced imaging techniques and visual data.² Continuous technological advancement has led to a significant change in approach, altering traditional teaching methods and introducing new resources that are transforming the educational environment.³

Electronic learning (e-learning) resources, including digital case studies and educational videos, are now essential sources of information.⁴⁻⁶ Radiology, as a primarily visual discipline, has benefited significantly from these multimedia resources.⁷ E-learning platforms, with their ability to present complex details through high-quality images, animations, and videos, provide radiologists with a powerful and thorough learning experience.^{4,8} These digital resources also promote self-directed learning, giving professionals the flexibility to manage their educational journey based on their personal and professional commitments.⁹ This independence promotes improved comprehension and retention, establishing e-learning as a fundamental aspect of modern radiology education. Table 1 summarizes common radiology e-learning resources and their characteristics.

The incorporation of artificial intelligence (AI)-powered tools, such as Chat Generative Pre-trained Transformer (ChatGPT), has introduced a dynamic, stimulating, and customized method of radiology education. OpenAI's ChatGPT is an ideal example of how chatbot technology can create tailored and effortless learning journeys.¹⁰ Unlike standardized learning resources,

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es, these chatbots adapt to individual users, providing responses and guidance in real time, mimicking the experience of a personal tutor.¹¹ This provides learners with an unprecedented combination of immediacy and personalization, breaking down complex radiological ideas into manageable chunks of information and encouraging active participation. In the current literature, there is a noticeable gap in comparing AI tools, such as ChatGPT, directly with traditional e-learning platforms for radiology education. The lack of a direct comparison is significant because it misses an opportunity to evaluate their respective educational impacts, potential synergies, and the ways they could be tailored to improve radiologists' learning experiences. The existing focus on separate evaluations of e-learning platforms and AI tools without a comprehensive comparison within radiology education indicates a critical void in the literature, which may lead to biases in understanding the full potential and shortcomings of each educational technology in this specialized field.^{8,12-14} The purpose of this review is to analyze the ChatGPT tool and compare it with e-learning resources for medical education, with a specific focus on radiology. Through an exhaustive review of empirical studies, surveys, and expert opinions, this paper elucidates the relative strengths and weaknesses of these tools in areas such as personalization, interactivity, visual learning,

Main points

- Chat Generative Pre-Trained Transformer (ChatGPT) utilizes machine learning algorithms to provide a distinctive form of educational engagement. This allows for immediate and personalized feedback based on individual learner needs. Electronic learning (e-learning) platforms, despite their interactivity, may not offer the same level of real-time personalization.
- E-learning tools hold an advantage in teaching visually complex concepts. These tools may require fees and may not be as up-to-date. However, costs associated with these tools can potentially be reduced with ChatGPT, providing an accessible artificial intelligence (AI)-driven learning experience.
- Utilizing ChatGPT in radiology education presents challenges, such as data dependency and potential biases. To ensure precise and unbiased instruction, it is imperative to integrate ChatGPT with expert-curated resources, peer-reviewed content, and practical case studies. Collaboration between AI developers and medical specialists is essential to uphold the integrity, accuracy, and ethical standards of information dissemination.

complex concept presentation, accessibility, user experience, learning curves, and cost-effectiveness. This analysis is particularly relevant, as the global shift to distance learning, accelerated by the coronavirus disease-2019 (COVID-19) outbreak, requires a reassessment of educational tools.

Methodology

A comprehensive search was undertaken in traditional medical databases to discern relevant articles focusing on the use of e-learning platforms and ChatGPT in radiology education (Figure 1). The databases inspected include PubMed, Scopus, and Web of Science. Additionally, preprint servers, such as arXiv, bioRxiv, and medRxiv, were explored to capture the most recent and evolving literature on the subject. The search, conducted between January 2023 and October 2023, utilized keywords such as “e-learning in radiology,” “ChatGPT in radiology,” “ChatGPT in education,” “AI-tools in radiology,” and “AI-tools in education.” The inclusion criteria were articles and preprints that investigated the deployment of e-learning platforms in radiology education, highlighting their advantages, disadvantages, and inherent features, as well as those that examined the application of ChatGPT in radiology teaching, emphasizing its potential, merits, and demerits.

The exclusion criteria encompassed articles that did not address e-learning platforms or ChatGPT in the context of radiology education and those that were duplicates of previously recognized articles. Each study was independently evaluated by two reviewers in terms of the inclusion and exclusion criteria, with any discrepancies resolved through discussion or with a third reviewer if necessary. Throughout the review procedure, the authors collaborated intensively. They teamed up for numerous tasks, including article selection, quality assessment, and the consolidation of findings. This cooperative methodology enables a thorough examination of the articles and ensures that the final review encapsulates a mutual agreement among the researchers. The data were synthesized from the selected articles using narrative methods by organizing them to identify common themes and divergent views on the use of e-learning platforms and ChatGPT in radiology education. These were presented descriptively and structured around the advantages, disadvantages, and educational outcomes reported by the studies.

E-learning resources in radiology education

The introduction of the internet has had a profound impact on various industries,

Table 1. Websites related to radiology education, including video resources name description		
Radiopaedia (https://radiopaedia.org/)	A collaborative radiology resource offering a vast collection of educational articles, cases, and quizzes	
AuntMinnie (https://www.auntminnie.com/)	A comprehensive radiology website featuring news, case studies, webinars, and forums for radiology professionals	
Radiology Assistant (https://radiologyassistant.nl/)	An educational resource for radiology residents, featuring illustrated articles, case studies, and quizzes	
LearningRadiology (http://www.learningradiology.com/)	Provides radiology lectures, podcasts, and case studies for medical students, residents, and technologists	
MedCram - Radiology (https://www.youtube.com/@Medcram)	Offers a collection of video lectures and courses on radiology topics, aimed at medical students, residents, and healthcare professionals	
RadiologyEducation.com (https://radiologyeducation.com/)	A digital library of radiology resources, including textbooks, journals, and teaching files	
Radiology Video Lectures (https://www.youtube.com/@RadiologyVideo)	A YouTube channel with video lectures on various radiology topics, aimed at medical students and radiology residents	
Radiology Channel (https://www.youtube.com/@RadiologyChannel)	A YouTube channel that offers a series of video lectures, case studies, and tutorials related to radiology	
Imaios (https://www.imaios.com/en)	A platform that provides e-learning courses in radiology and other medical disciplines	
FreitasRad (https://www.freitasrad.net/)	A radiology education website that offers various learning resources, including articles, webinars, and case studies	

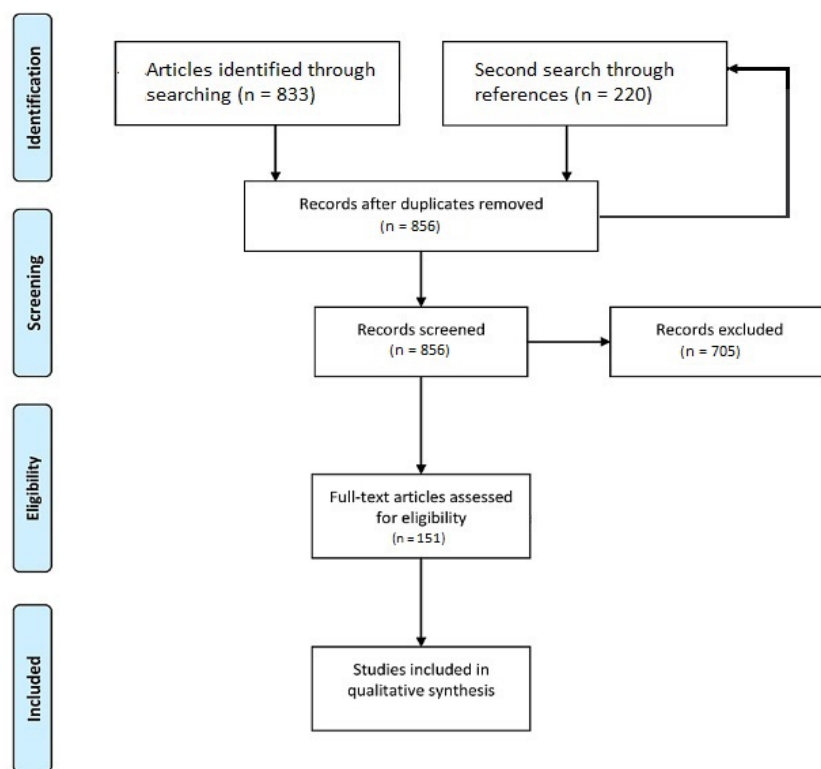


Figure 1. Selection process of articles used in this study. Adopted from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

including medical education. Radiology education, in particular, has undergone significant transformation due to digital advancements at all levels of medical training.¹⁵ This transformation goes beyond a mere change in format and addresses critical limitations inherent in traditional teaching methods. For example, e-learning resources overcome geographical and time limitations, presenting a broader range of case studies for examination.¹⁶

Traditionally, the teaching file has been the foundation of radiology education, containing a carefully curated set of cases that emphasize important diagnostic features. The emergence of the internet has elevated this concept by introducing online databases of expert-reviewed radiological images that function as lively, globally accessible learning resources.¹⁶ Researchers such as Kahn¹⁶ have advanced the digital transition by creating internet-based collections of meticulously reviewed radiological images. These resources possess dual functionality, acting as educational instruments and tools for clinical decision-making. Detailed indexing, such as MeSH codes and patient information, allows for more precise searches compared with traditional systems, thus broadening educational access.¹⁶⁻¹⁸

Different e-learning platforms provide diverse experiences (Table 1). Some learning platforms in radiology are “educator-centric,” using structured curricula that are especially advantageous in subspecialties, such as neuroradiology and pediatric radiology.¹⁹ By contrast, other platforms adopt a more decentralized approach, supporting peer-to-peer learning but requiring strict quality control to prevent unreliable content.^{20,21} The choice of a particular platform often depends on the learner’s objectives and the specific learning context. In an intervention study by Salajegheh et al.,²² the research findings highlight the significant potential of e-learning to strengthen the improvement of X-ray interpretation skills among medical students. This study underscores the crucial importance of well-designed, interactive e-learning materials. Regardless of the chosen system, maintaining ongoing quality assurance and content curation is imperative due to the critical nature of radiological diagnosis and treatment.¹⁹

Considerations of accessibility and cost-effectiveness are essential in the selection and usage of e-learning resources. Despite the exceptional benefits of these digital platforms in content and flexibility, the need for high bandwidth and sometimes specialized hardware can restrict their

use, particularly in low-resource settings.²³ Hussein²³ investigated these factors by analyzing three variables: acceptance, accessibility, and savings. The research discovered that acceptance was the most important aspect determining the efficacy of e-learning, with accessibility and cost savings having a less significant impact.

Progressive technologies have the potential to enhance radiology e-learning experiences. Interactive functions, such as keypads and wireless interfaces, are frequently included, augmenting the learning experience.^{20,21} Simulators provide immersive environments for practicing interventional techniques and comprehending hospital-based systems, such as Picture Archiving. Overdyk and McEvoy²⁴ evaluated the potential of handheld computers to enhance workflow efficiency, and the results indicated that the system has potential for educational purposes.²²

The ethical challenges of online platforms in education include issues of privacy, surveillance, autonomy, bias, and discrimination.²⁵ In education, there are concerns about data breaches by tech companies and users inadvertently sharing excessive personal metadata.²⁵ There is a moral dilemma when students and parents are compelled to use online platforms or AI systems despite these privacy concerns in schools.²⁵ The surveillance capacity of these platforms threatens students’ participation and sense of security, whereas predictive algorithms can undermine individual autonomy, possibly perpetuating societal biases.²⁵

ChatGPT in radiology education

The rising role of ChatGPT in radiology education

ChatGPT, an AI-based language model developed by OpenAI, is becoming an increasingly valuable resource in radiology education.^{26,27} Designed to understand and process natural language, ChatGPT can answer questions, provide explanations, and even suggest courses of action across a wide range of topics. Its conversational abilities, similar to those of a human, and its contextually relevant responses make it an effective tool for radiology residents and professionals.^{27,28} ChatGPT is an advanced language model that uses deep learning techniques to produce human-like responses to natural language inputs. Built on the generative pre-trained transformer architecture, these models harness the power of deep learning to generate human-like text based on

patterns identified from vast amounts of textual data. A significant strength of ChatGPT is its expertise in natural language processing (NLP), enabling it to understand and produce coherent text. This proficiency, derived from comprehensive training on diverse datasets, allows it to simulate dialogue-like interactions pertinent to radiology or other subjects.²⁹

NLP is the technology behind how computers understand and respond to human language, designed to bridge the gap between human communication and computer understanding. It uses a variety of techniques to interpret human language: tokenization, which breaks up a sentence into individual words or phrases called “tokens;” parsing, akin to diagramming a sentence, establishes the structure and word relationships within a sentence; sentiment analysis, which determines the emotional tone behind words; named entity recognition, involving identifying and classifying names of people, organizations, and locations into predefined categories; part-of-speech tagging, which assigns grammatical categories to each word, such as nouns, verbs, and adjectives; and machine translation, entailing text translation from one language to another, a complex task that requires understanding the grammar and context in both languages.³⁰

Language modeling and generation underpin ChatGPT’s text creation capabilities. The model is trained to predict the next

word in a sequence, enabling the crafting of coherent sentences and paragraphs. When processing a prompt, ChatGPT first breaks down the input text into tokens. It then uses these tokens to grasp the context and meaning. To generate a response, ChatGPT predicts the next token in the sequence, based on the previous ones, and continues this prediction process until a complete answer is formed. Attention mechanisms are employed throughout, allowing the model to focus on different parts of the input as needed, which is essential for understanding context and generating pertinent responses. By integrating these NLP techniques, models such as ChatGPT can perform a variety of language understanding and production tasks, from conversational interactions to language translation and beyond.³⁰

The use of AI and AI chatbots alongside traditional teaching methods has shown significant potential and has garnered substantial attention in research.^{27,28,31} One of the primary advantages that ChatGPT brings is in the creation of learning assessments.^{27,32} ChatGPT has demonstrated capability in generating exercises, quizzes, and scenarios that can be employed in a classroom setting to aid in resident practice and assessment (Figure 2). ChatGPT can streamline the design of learning assessments, potentially improving question quality. Zhai³³ suggests that educators can utilize ChatGPT to devise assessment items, enhancing the quality by adhering to standardized frameworks. How-

ever, it is important to note that although AI can suggest assessment tasks, these suggestions may not always encapsulate all the targeted learning objectives.³⁴ Hence, while Han et al.³⁵ utilized ChatGPT to draft a multiple-choice question for a medical topic, they also highlighted the importance of refining such AI-generated questions to better fit specific course requirements.³⁶

Another advantage of pedagogical practices is the potential for educators to integrate innovative strategies, such as the flipped classroom approach, using ChatGPT.³⁷ ChatGPT’s vast array of features has been highlighted by experts who emphasized its capabilities in generating comprehensive lesson plans and presentations (Figure 3).³⁷ Moreover, ChatGPT’s potential as a virtual personal tutor is undeniable. Unlike traditional tutoring methods constrained by time and location, ChatGPT offers round-the-clock support.²⁷ Furthermore, AI tools provide feedback and tailored answers specific to students’ academic queries.^{28,35,38}

The ability to distill vast amounts of information is crucial for learners, and ChatGPT excels at this. It can process and summarize information efficiently, presenting it in an understandable manner, which can be particularly valuable for revision or to get a grasp on new topics (Figure 4).³⁹ Collaborative learning experiences are enriched through scenarios and structured discussions. ChatGPT has been successfully used to create dialogues for educational purposes (Figure 5). Specifically, when tasked with creating dialogues to be imported into Google Dialogflow, a popular platform for creating chatbots, ChatGPT succeeded in the task.³⁵ ChatGPT can generate varied scenarios for group activities, thereby aiding residents in their collaborative efforts. It can also lay down discussion structures and provide real-time feedback, thereby enhancing group discussions and debates.⁴⁰ This collaborative angle is emphasized further by Gilson et al.⁴¹, who noted that the discourse in small-group problem-solving is particularly beneficial for student learning.

The advantages of tools such as ChatGPT have been highlighted for enhancing student outcomes and promoting critical thinking. In a 2023 study, Sánchez et al.⁴² noted that ChatGPT promotes the development of critical thinking, particularly in a theoretical context. By promptly and accurately answering specific inquiries, ChatGPT provides students with relevant and timely information, enhancing their exploration and understanding of various subjects.

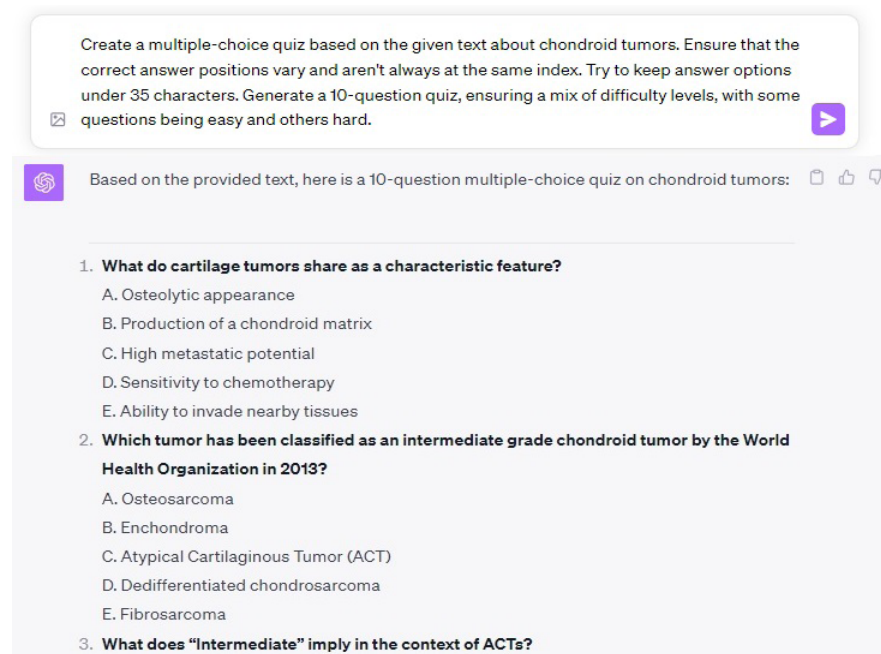


Figure 2. ChatGPT learning assessment creation. ChatGPT, Chat Generative Pre-Trained Transformer.

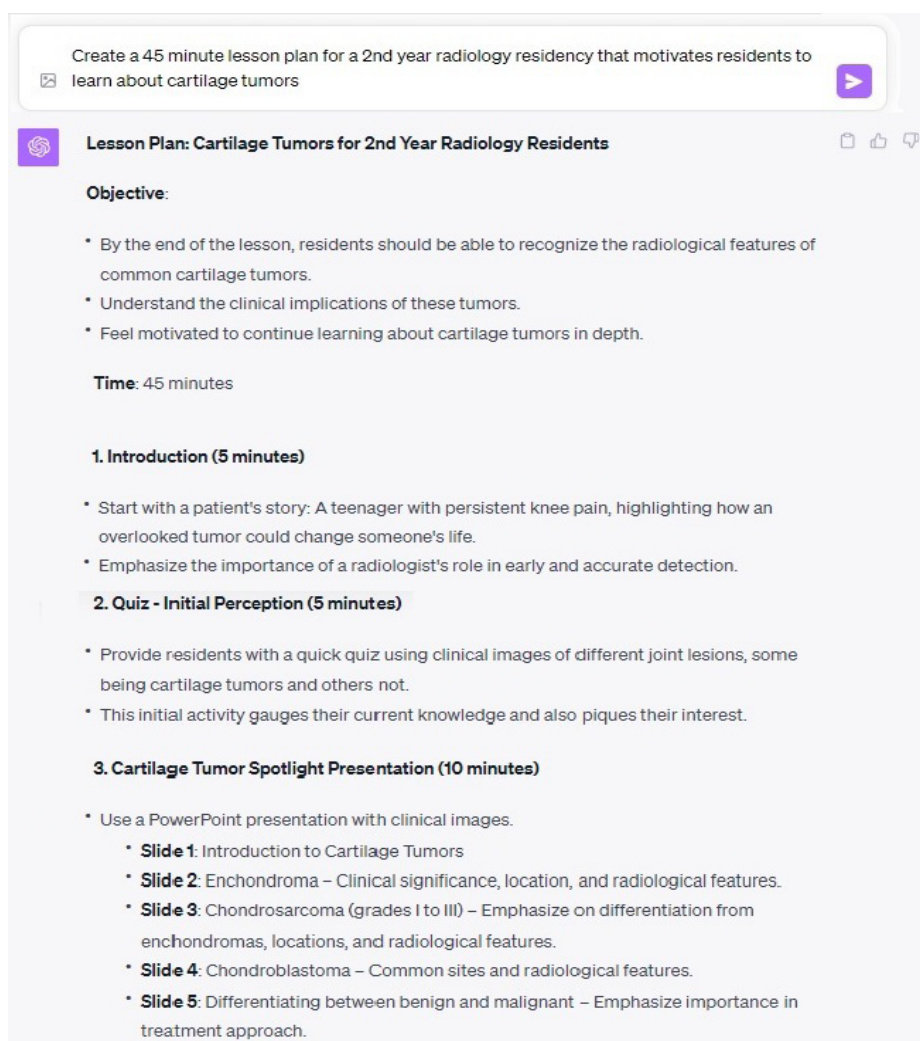


Figure 3. ChatGPT's lesson plan generation capabilities. ChatGPT, Chat Generative Pre-Trained Transformer.

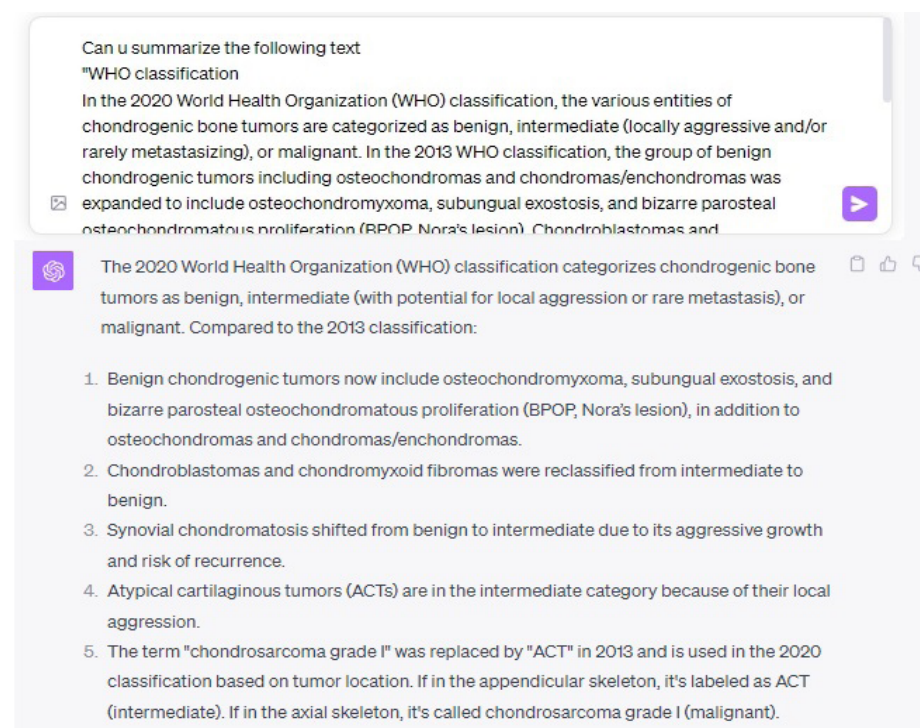


Figure 4. ChatGPT simplifies information. ChatGPT, Chat Generative Pre-Trained Transformer.

ChatGPT is particularly useful in preparing learners for high-stakes assessments, such as radiology board exams. By simulating diverse exam scenarios, including interactive question and answer sessions, ChatGPT aids in comprehensive exam preparation, allowing students to effectively enhance their knowledge and critical thinking skills.^{43,44} AI can also be used for essay grading, though its effectiveness is still debated.⁴⁵ In addition, ChatGPT can be useful for translating educational materials into various languages, enhancing the accessibility of resources for a global student body (Figure 6).³⁵ Machine translation is not new, but AI models such as GPT-4 have continued to advance the field.⁴⁵

A study by Ausat et al.²⁶ on the use of ChatGPT in learning emphasized that technology serves only as a tool and cannot fully replace the role of a teacher. The authors stress the importance of integrating technology appropriately and effectively and developing competence among teachers in managing learning with technology.

Tili et al.⁴⁶ conducted a case study on ChatGPT's role in education. They stressed the importance of accurate content, noting inconsistencies in answers given to the same questions by different users. The team expressed concerns about the quality of assessments generated by ChatGPT and emphasized the need for clearer guidelines. While recognizing ChatGPT's potential, they highlighted its shortcomings, such as a lack of emotional depth and trustworthiness in responses. They underscored the need for careful inclusion of ChatGPT in educational contexts.⁴⁶

The role of ChatGPT in radiology and academic applications

ChatGPT's utilization of NLP capacities assists radiologists in the analysis of medical images, presenting a significant advancement in radiology. When provided with information from an imaging modality's findings, the model produces a series of potential diagnoses for consideration (Figure 7).¹⁴ To maximize ChatGPT's precision, it is crucial to supply it with specific prompts tailored to the medical images in question.⁴⁷ By providing detailed prompts that include the patient's medical history, symptoms, and distinctive image features, ChatGPT assists learners in enhancing their diagnostic skills. Additionally, ChatGPT is useful for giving real-time feedback during questioning, doubt clarification, or case discussions, thereby enriching the learning process.²⁸

In the field of radiology, ChatGPT's utility is notably constrained by the discipline's inherent visual emphasis.⁴⁸ Although ChatGPT can provide assistance based on textual descriptions of findings, it may overlook errors introduced by human interpreters. In clinical

scenarios, the need to describe an image in text to an AI, rather than allowing the AI to analyze it directly using pattern recognition algorithms, introduces an unnecessary step that may compromise efficiency. For radiological image analysis, specific AI tech-

nologies, including radiomics⁴⁹ and deep learning models,⁵⁰ are particularly suitable. These models, trained on extensive datasets, excel at identifying complex patterns in radiological images and extracting quantitative features, thereby enhancing their potential efficacy for diagnostic and predictive tasks. Building on the limitations of ChatGPT in radiology, the emergence of the Large Language-and-Vision Assistant (LLaVA) addresses some of these challenges.¹³ As a visual chatbot capable of processing both textual and visual data, LLaVA offers a more integrated approach to AI in healthcare.¹³ Its potential in radiology promises increased diagnostic accuracy and lighter workloads for radiologists.²⁹ It is crucial to understand that these AI instruments are designed to augment, not replace, human skills in radiology.

With the latest updates, ChatGPT has gained the ability to interpret images. In a recent study, researchers evaluated GPT-4V(i-sion), an enhanced multimodal model that combines language and visual understanding. The study aimed to assess its capabilities across various tasks, input types, and operational modes, and to develop effective prompting strategies. The preliminary findings indicate that although GPT-4V is adept at managing multimodal inputs and shows promise in fostering novel interactive capabilities, such as visual referring prompts, it is not yet highly accurate and sometimes makes erroneous claims. The study suggests that GPT-4V could lead to more research into multimodal applications and enhanced problem-solving methods.⁵¹ However, there is a lack of sufficient research or experience in interpreting radiological images. By understanding the capabilities and current limitations of GPT-4V in image interpretation, educators and professionals in radiology can begin to explore the integration of AI-assisted learning and diagnostic strategies. This emerging technology may revolutionize how radiological data are taught and interpreted, prompting a re-evaluation of curricula.

ChatGPT also excels as a research tool. It is notable for its ability to organize ideas for writing tasks. By providing it with prompts, ChatGPT can quickly generate outlines and assist in the initial stages of research and writing (Figure 8).⁵² However, researchers should approach its output with caution and are advised to adjust and verify ideas produced by the tool to prevent inaccuracies.³⁷ ChatGPT plays an instrumental role in aiding students and researchers by helping them structure their thoughts and con-

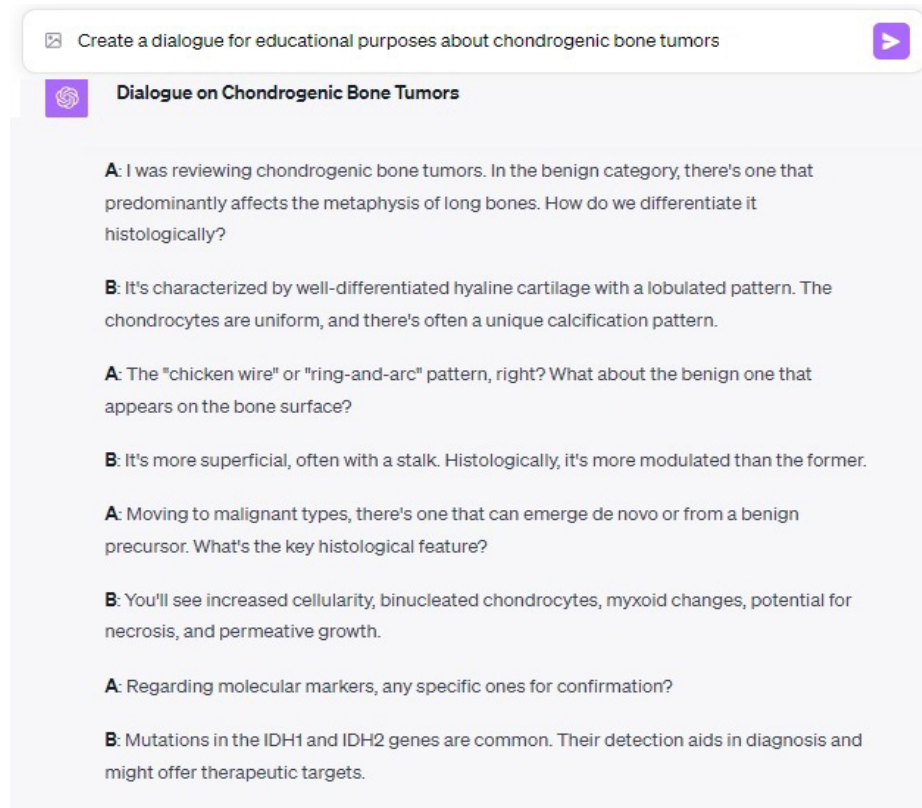


Figure 5. ChatGPT in educational dialogue creation. ChatGPT, Chat Generative Pre-Trained Transformer.

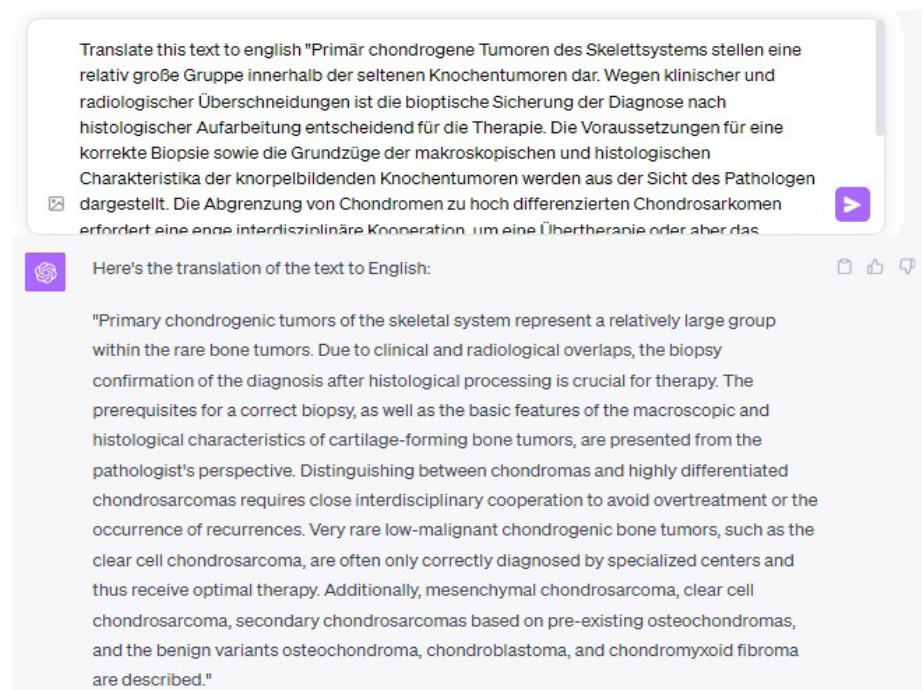


Figure 6. Translating educational materials into multiple languages with ChatGPT. ChatGPT, Chat Generative Pre-Trained Transformer.

cepts efficiently for writing assignments.^{36,52} A study by Pech-Rodríguez et al.⁵³ evaluated ChatGPT's performance across various academic tasks. The findings indicated that the platform can generate grammatically correct essays; however, it often includes redundant

information and may omit deeper insights. When tackling mathematical problems, ChatGPT showed inconsistencies, especially when its results were compared with those from MATLAB, suggesting potential reliability issues in academic tutoring. Moreover,

although ChatGPT proved informative on general topics, it occasionally fell short in providing comprehensive answers to more intricate subjects. The study underscored the risks of overly depending on such platforms and highlighted the challenges in regulating this emerging technology.

In radiology, large language models (LLMs), such as ChatGPT, offer significant advancements in organizing patient care. By automatically analyzing radiology requests, LLMs efficiently determine which specific scan is needed for a patient.^{30,54} They streamline this process by using details from the request forms, ensuring each patient receives a timely and accurate imaging study. Additionally, LLMs are capable of sorting these imaging requests by urgency. They take into account the severity of medical situations, which allows the most critical patients to be attended to first.³⁰ This thoughtful organization of the imaging needs of patients helps in managing the workflow of radiology departments effectively, ensuring that time-sensitive cases are given priority and resources are used wisely.³⁰ Through these innovations, LLMs can greatly enhance the handling of patients, leading to faster and more effective medical care.^{30,54}

Building on the application of AI chatbots in radiology, their influence has further extended into other domains, such as dermatology,⁵⁵ orthopedics,⁵⁶ allergy, and immunology.⁵⁷ The advancements in NLP have enhanced the capabilities of these chatbots. Consequently, they play an integral role in various facets of medicine, including aiding in diagnostics, offering up-to-date medical insights, and formulating patient-specific treatment recommendations.⁵⁷

Emerging trends and radiologists' perception of artificial intelligence

Radiologists recognize the potential benefits of AI in fields beyond just education. Over 80 AI algorithms have received US Food and Drug Administration (FDA) clearance for clinical use.⁵⁸ However, there are also reservations about how these technologies may reshape their profession. An American College of Radiology survey revealed that only 33.5% of radiologists are integrating AI into their clinical practices.⁵⁸ Larger radiological practices tend to lean more toward AI integration, given their specialized research activities and superior resources. The inconsistency in the performance of many FDA-cleared AI algorithms concerns these professionals. Even so, 95% of survey participants are not prepared to let AI function autonomously.

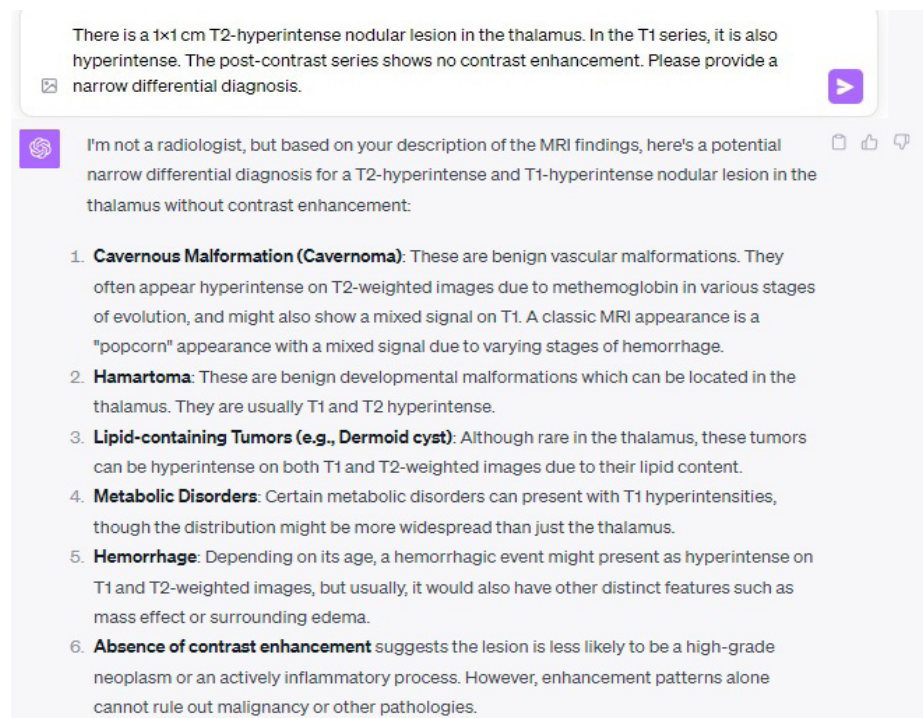


Figure 7. Narrowing the differential diagnosis with ChatGPT. ChatGPT, Chat Generative Pre-Trained Transformer.

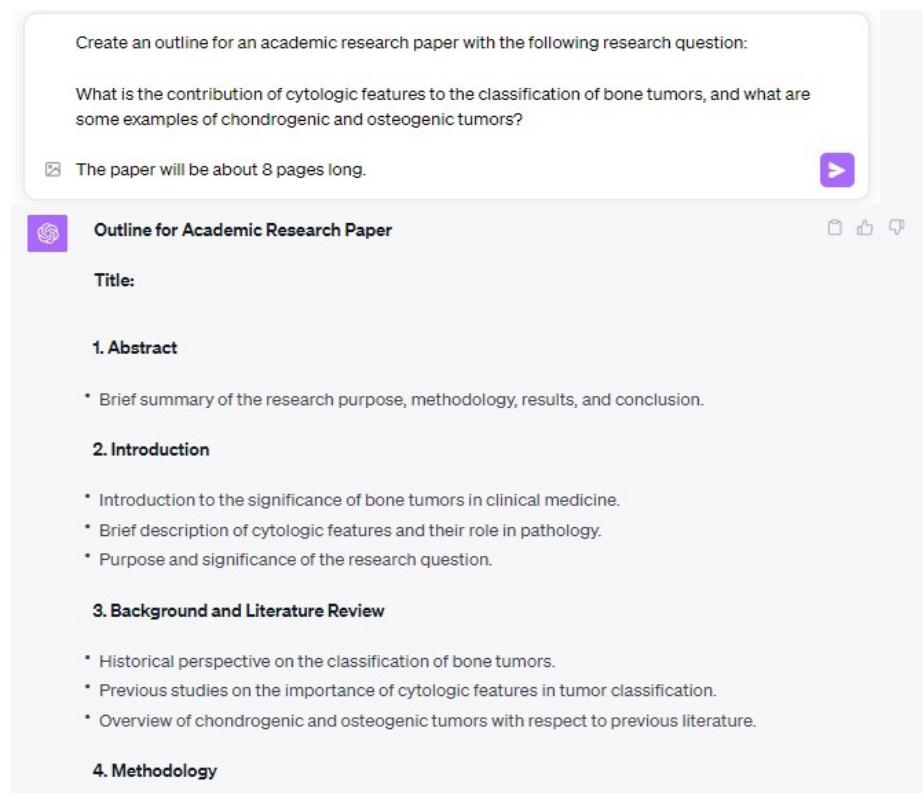


Figure 8. Using ChatGPT for research outlining. ChatGPT, Chat Generative Pre-Trained Transformer.

Many, however, acknowledge the enhancement AI brings to their practice, proving advantageous for both the practitioners and their patients.⁵⁸ In this regard, integrating AI may empower radiologists to undertake more intricate tasks, fostering greater job satisfaction and enhancing patient care.⁵⁹ At present, AI shows promising potential to augment radiological interpretations significantly.^{58,59} AI promises enhanced precision and speed in medical imaging evaluations, offering invaluable support to radiologists during the diagnostic phase. Among the pivotal AI applications in radiology are computer-assisted detection and diagnosis, image-based therapeutic guidance, and automated image analysis and interpretation.²⁹ Survey findings from Grace et al.⁶⁰ propose that AI could outpace human capabilities in various intricate tasks in the coming decades.

The great debate: tool or threat?

The debate about AI's role in the future of radiology is ongoing. Some consider AI as a tool that will augment radiology. By contrast, others perceive AI as a potential job threat.⁵⁹ Although data suggest AI may surpass human abilities in specific tasks, opinions about its influence in specialties such as radiology remain divided.⁵⁹ Amid these concerns about the job landscape, it is essential to recognize that radiology is not solely about image interpretation. It also entails patient interactions and clinical decision-making, aspects deeply rooted in the "human touch." Although AI can support radiologists during diagnosis, the expertise of a radiologist is essential for the final assessment. Moreover, AI algorithms have not reached the level where they can entirely supplant human judgment and decision-making.²⁹ Furthermore, there is a growing shortage of radiologists, including trainees.

Patients' perspective on artificial intelligence

Patients largely endorse the incorporation of AI in radiology as an auxiliary tool for radiologists. However, they voice concerns about placing trust in unsupervised AI, potential liability challenges, and the potential erosion of human connection and empathy in their healthcare.⁵⁹ Additionally, the risks of bias leading to discrimination, data privacy dilemmas, and intensified privacy concerns for individuals with uncommon diseases remain prevalent.⁶¹

Potential pitfalls and limitations in radiology education

ChatGPT, while a transformative tool, can sometimes generate inaccurate content due to its limited data, which may cause students to receive outdated or even false information.³⁴ Therefore, it is crucial for users, especially students, to cross-reference ChatGPT's responses with current, reliable sources to ensure the accuracy and relevancy of the information they are using. For instance, if a student inquires about recent scientific advancements, ChatGPT may not have access to the latest research published after its last update, potentially leading to a knowledge gap. Detailed analysis of this limitation highlights the need for continuous updates and verifications, which could include a mechanism where ChatGPT references the date of its last dataset update to inform users of its knowledge limitations. Furthermore, being trained on vast datasets, it can inadvertently echo biases present in them, such as political or racial biases, or those based on data from primarily affluent nations.³⁶ This underscores the importance of a critical approach when interacting with AI outputs, emphasizing the need for educators to teach media literacy and critical thinking skills that enable students to discern and mitigate these biases. A direct comparative example can be observed when ChatGPT is tested on cultural sensitivity topics where its responses may lean toward majority viewpoints or widely published literature, not accurately reflecting the diverse perspectives or the nuance present in global discussions.

Moreover, there is a growing worry about plagiarism, as ChatGPT's unique text generation can often evade traditional plagiarism detectors, challenging the core of academic integrity.³⁶ Additionally, unlike human educators, ChatGPT lacks emotional intelligence, which may affect a student's learning experience.⁴⁵ Its operation is primarily pattern-based, which means sometimes it may not truly grasp or tailor feedback on the concepts it presents.⁴⁵ As its adoption grows, concerns related to data privacy surface, especially given the ambiguities surrounding data storage and the potential risks of users sharing sensitive information.⁴⁶ To mitigate these risks, future directions may include implementing stringent data governance frameworks and offering clear, user-friendly options to manage data consent. Furthermore, enhancing transparency around how

data are used and stored could assuage user concerns and foster a more trusting relationship with such AI tools.

Comparative analysis

Personalization and interactivity

Utilizing advanced machine learning algorithms, ChatGPT offers a dynamic, adaptive approach to educational engagement that promises to revolutionize the way individual learning pathways are supported. ChatGPT customizes its responses to each learner, providing immediate and personalized feedback based on their distinct learning needs.²⁸ Owing to its structure, ChatGPT can infer relationships between words, perform logical language reasoning tasks, and generate responses when prompted with personalized questions.⁶² In a recent study, when ChatGPT was informed that a learner had dyslexia, it provided recommendations for learning materials suited to that particular learner.³⁶ Other studies suggest that ChatGPT could provide an interactive learning environment accessible at any time, potentially leading to the better retention of information and a more enjoyable learning experience.^{27,41}

However, e-learning content varies, ranging from complex interactive learning sessions to static web pages with links.⁶³ Although online communities and discussion forums add a layer of interactivity, they lack the AI-driven, real-time personalization that ChatGPT provides.⁶⁴

Visual learning and complex concepts

E-learning tools have a clear advantage when it comes to teaching complex concepts that require visual aids, such as image interpretation, procedural demonstrations, and 3D anatomical representations.⁶⁵ ChatGPT, being primarily text-based, may not be as effective in this regard.^{11,48} To address this limitation, integrating ChatGPT with visual resources could potentially enhance the learning experience for radiology residents. For instance, residents could watch a video demonstration of a radiology technique and then use ChatGPT for further clarification.

Cost, accessibility, quality, and currency of information

ChatGPT can potentially reduce costs associated with traditional radiology education, offering an interactive, AI-driven learning experience. With minimal financial

barriers to accessibility, it may be attractive to students and institutions with limited budgets.^{14,48}

By contrast, e-learning tools may require subscription fees or be restricted to certain institutions. However, these platforms often justify their cost by providing comprehensive and peer-reviewed content.⁶⁶ Accessibility and language barriers may limit the reach of these valuable resources.⁶⁶

Many people appreciate ChatGPT for general information. However, its consistency and accuracy are debated.^{33,46} Many believe it cannot be a substitute for specialized expertise, and users are advised to verify its responses with reliable sources.^{33,46} E-learning tools range from high-quality, expert-reviewed content to less reliable, user-generated material.^{66,67} This variability highlights the need for a critical evaluation of the credibility and accuracy of these resources.

ChatGPT has an edge in providing almost up-to-date information because it can be periodically updated with new developments in radiology.¹⁴ However, it does not update its data on a daily or weekly basis, especially regarding release dates, which may cause students to receive outdated or even false information.³⁶ In comparison, e-learning tools may not always be updated regularly, which could result in the dissemination of outdated or inaccurate information.^{66,67} Maintaining the currency of educational resources is often a resource-intensive and time-consuming task, causing some platforms to lag in incorporating the latest advances in radiology. Table 2 offers a more comprehensive comparison of ChatGPT and e-learning tools as radiology educational resources.

User experience, interface, adaptability, learning curve

ChatGPT's design, rooted in the chat-based interface, offers a user-friendly approach to information-seeking. Tlili et al.⁴⁶ study underscored the value of this simplicity, especially given the widespread use of messaging platforms in modern digital communication. This interface design ensures users can engage without a steep learning curve, drawing parallels with daily online interactions.⁴⁶

In a practical application setting, a workshop in Palermo showcased the adaptability and approachability of the ChatGPT interface among high school students.⁶⁸ The study illustrated the students' initial curiosity and

eagerness to engage, followed by a period of refinement in their interaction strategies. As they became aware of ChatGPT's capabilities and limitations, students adjusted their questioning techniques, demonstrating the platform's malleability to user-driven interactions. It was observed that high school students' perceptions of AI changed notably after a hands-on workshop with ChatGPT. The findings revealed that students felt less threatened by AI after the workshop, with most expressing positive emotions toward ChatGPT. However, a few found it repetitive and not very human-like.

While the platform's linguistic capabilities are commendable, ensuring grammatical correctness and coherence, it is not devoid of flaws. Although AI can craft essays with proper grammar, the content may not always be optimal. Redundancies, superficial insights, and an occasional lack of in-depth analysis were some of the highlighted shortcomings. Such findings emphasize that while ChatGPT can be a beneficial aid, critical thinking and discernment remain crucial when interpreting its responses.⁴⁶

By contrast, online learning platforms, as experienced by radiography students in Gauteng Province, South Africa, offer a structured learning environment that demands adaptability from users.⁶⁹ These platforms come equipped with various tools and features, which can initially be overwhelming for user experience, yet are essential for comprehensive remote learning. However, adaptability becomes crucial, especially when technological resources are scarce or when students are navigating a new "normal," such as during the COVID-19 lockdown.⁶⁹

It is essential to consider that there will be a significant learning curve when it comes to both AI tools and E-learning platforms.⁷⁰ However, as highlighted by Tlili et al.⁴⁶, ChatGPT offers a chat-based interface, making it intuitive for users familiar with messaging platforms. The anticipated significant learning curve for physicians in the medical field can be attributed to several factors. First, older individuals who are not familiar with technology may encounter hurdles when using AI tools or e-learning platforms. Second, there is a need for educational institutions to incorporate AI into medical curricula, implying potential curriculum changes and resource allocation. Third, successful AI adoption may also rely on effective collaboration with industry partners, thereby requiring professionals to develop new skills and

adapt to industry practices. Collaborations between academia and industry may lead to the development of user-ready AI tools.⁷¹

Future directions

In the context of radiology education, notable disadvantages of ChatGPT include its data dependency and potential biases.¹⁸ ChatGPT may not always offer accurate information, particularly in specialized fields such as radiology, where knowledge is ever-evolving.³⁴ Additionally, biases in the training data, such as the overrepresentation of certain imaging techniques or underrepresentation of particular pathological conditions, could affect the quality of the educational content generated by ChatGPT.^{36,72} To address the potential impacts on future radiology education paradigms, it is paramount to integrate ChatGPT with expert-curated e-learning resources, peer-reviewed articles, and real-world radiological case studies. This integration ensures an in-depth and precise educational journey for radiology students. The synergy between ChatGPT and e-learning resources leverages the unique advantages of both platforms, forging a comprehensive educational paradigm (Table 3). Their synergistic use not only merges their individual strengths but also augments the overall educational quality. Collaboration between AI developers and medical experts in platforms such as ChatGPT is also crucial.⁷¹ Such collaboration ensures the accuracy and reliability of disseminated health information. It also addresses ethical concerns, keeps up with the dynamic nature of medical knowledge, and provides the needed contextual understanding for patient-specific advice. This partnership is vital for both user safety and regulatory compliance.

In conclusion, ChatGPT and traditional digital learning resources each offer unique advantages and challenges in the context of radiology education. The personalized, interactive experience of ChatGPT complements the visual and specialized offerings of e-learning tools. Although it is unlikely that AI will completely replace traditional methods of studying radiology, such as reviewing electronic or printed materials and analyzing case examples, a well-rounded educational experience can be achieved by utilizing the strengths of both resources. Future studies should focus on intervention research to highlight the impact of using ChatGPT in conjunction with e-learning resources for radiology training.

Table 2. Additional aspects of ChatGPT and e-learning tools e-learning platforms

	ChatGPT	E-learning
Personalization and interactivity	AI-driven, adaptive feedback tailored to individual needs ^{27,33,60}	Varies; from complex interactive sessions to static pages. ⁵⁸ Lack of real-time AI personalization ⁶²
Visual learning	Text-based ¹¹	Superior for visual aids and demonstrations ⁶³
Cost and accessibility	Lower costs with high accessibility ^{14,45}	May have subscription fees or institutional restrictions ⁶⁴
Quality and currency of information	Nearly up-to-date but may lack accuracy. ^{33,43} Users advised to verify	Quality varies; updates may be infrequent ^{64,65}
User experience and interface	Intuitive chat-based interface ⁴³	Structured but potentially overwhelming initially ⁶⁷
Adaptability	High adaptability among users ⁶³	Essential but may pose challenges ⁶⁷
Learning curve	Easier for those familiar with messaging. ⁴³ In some instances, significant learning curve ^{68,69}	Significant, especially for tech-unfamiliar individuals ^{68,69}

ChatGPT, Chat Generative Pre-Trained Transformer; E-learning, electronic learning; AI, artificial intelligence.

Table 3. Synergistic benefits of ChatGPT and e-learning in various impact AreasLearning

	ChatGPT	E-learning
Personalized learning paths	Adapted to individual queries and learning speeds ²⁷	Structured the curriculum and provided the content in modular format ⁶⁷
Interactive case discussions	Simulated discussions and provided insights on presented cases ³⁷	Presented radiological cases and images for analysis ²²
Instant feedback	Gave real-time feedback and answers to queries ²⁷	Provided the platform for submission and review of interpretations ¹⁶
AR and VR integration 3D visualization of anatomy and pathologies	Offered interactive guidance and explanations within AR/VR environments*	Created AR/VR simulations and visualizations*
Continuous updates	Updated information and provided recent research insights ³³	Managed and structured updates, notifications, and module revisions ¹⁶

*This information was compiled by the authors from a comprehensive review of related literature or experience. ChatGPT, Chat Generative Pre-Trained Transformer; E-learning, electronic learning; AR, augmented reality; VR, virtual reality.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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