

Educational Advances in Medicine & Surgery

Online Learning Resources for Radiology Education: An Educational Perspective

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Keywords: education, radiology, online learning resources, Artificial Intelligence

<https://doi.org/10.62186/001c.123611>

Academic Medicine & Surgery

The COVID-19 pandemic significantly disrupted radiology education, leading to a rapid transition from traditional in-person instruction to online learning. This article reviews the innovative digital tools and strategies adopted during this period, such as microlearning, virtual reality, and tablet apps, which were central in maintaining educational quality. While online platforms offered flexibility, accessibility, and global reach, challenges such as the lack of personal interaction and variability in resource quality persisted. The article emphasizes the importance of balancing online and in-person learning and highlights future directions in radiology education, including the integration of Artificial Intelligence (AI) and Virtual Reality (VR) to enhance training. By leveraging these advancements, radiology education can continue to evolve, offering comprehensive and adaptable learning experiences for trainees.

INTRODUCTION

The COVID-19 pandemic caused significant disruptions to radiology education, leading to a shift from in-person instruction to online learning. With traditional hands-on experiences largely replaced by digital tools and remote methods, educators were required to adapt quickly. They employed active learning strategies, such as microlearning and visual aids, to fit the new digital format.¹ The adoption of innovative tools, including tablet apps and visual aids, became central to enhancing learning. Microlearning—comprising short, focused segments of content—proved effective in maintaining educational quality during this period. This shift accelerated the uptake of digital technologies, fundamentally reshaping the landscape of radiology education.^{1,2}

Teaching and assessment methods also evolved, with virtual reality, gamification, and technology-enhanced learning tools gaining prominence. These innovations helped bridge the gap left by the lack of in-person interactions and hands-on training, necessitating that educators develop new technological skills to support the digital learning environment.²

The pandemic prompted a swift move from workplace-based learning to online platforms, introducing innovations such as online electives, tele-simulation, telehealth, and virtual repositories of radiology and pathology images. Live-streamed or pre-recorded videos were used to simulate clinical experiences, providing a virtual approximation of hands-on practice.³

Despite these advancements, challenges persisted. The lack of personal interaction and standardisation in

telemedicine curricula created significant obstacles. Additionally, the transition required increased faculty time, technical resources, and devices. Nevertheless, the shift to online learning provided valuable insights and methods for medical educators to adapt their practices.³

The purpose of this article is to review the various online learning tools and strategies that emerged during the COVID-19 era. It focuses on the effectiveness of digital learning tools, such as tablet apps and visual aids, in maintaining the quality of radiology education.¹

The article also examines the significance of these online resources for radiology trainees. E-learning modules, such as the Radiology-Integrated Training Initiative (R-ITI), have proven effective for foundational learning. Trainees have valued modules featuring imaging cases, layer annotation, and self-assessment elements. However, certain aspects of radiology training, particularly those requiring subjective judgement and tacit knowledge, remain challenging to convey through online platforms.⁴

Balancing online and in-person learning is essential. Online platforms serve as a valuable complement to traditional training, particularly for theoretical knowledge and basic skills. It is crucial for content to be tailored to the learning needs and preferences of trainees to enhance the effectiveness of online radiology education.⁴

TYPES OF ONLINE LEARNING RESOURCES

[Radiopaedia.org](https://radiopaedia.org) is a crucial resource for radiology trainees, enhancing access to teaching file cases. It provides permanent availability of cases accessible from any device with an internet connection. Features include key images, learning

objectives, full DICOMs for PACS-like review, and the ability to create playlists for structured learning modules. This platform is particularly useful for introductory primers on radiotracers, scintigraphy, and PET, as well as for preparing for calls related to common nuclear studies. It effectively addresses the limitations of traditional PACS-based teaching files by offering a more versatile and accessible learning tool.⁵

The “Learning Radiology” e-book by William Herring is another valuable resource. This introductory text covers both normal and abnormal imaging across various modalities. It emphasises pattern recognition and includes essential concepts of patient safety, dose reduction, and the latest imaging technologies such as ultrasound, MRI, and CT. This book is aimed at medical students and other learners needing to interpret radiologic images.⁶

Platforms like Coursera and edX offer a range of radiology courses catering to various aspects of radiology education. These courses include web-based conferencing, online lectures, and other digital learning resources. They provide interactive and secure learning environments, which proved especially relevant during the COVID-19 pandemic.⁷ The RSNA Online Learning Portal is another significant resource, offering educational materials, board preparation content, and updates on emerging radiologic technologies. It also provides opportunities for mentor pairing, project development workshops, and career development. The RSNA Annual Meeting features trainee-specific events and networking opportunities for professional growth.⁸

Radiology-TEACHES is a case-based education portal using clinical decision support. This multi-institutional platform focuses on teaching appropriate resource utilisation, patient safety, and cost awareness. It has shown significant knowledge gains in specific areas, with high learner satisfaction and improved ability to select appropriate imaging studies.⁹ Anatomy apps and virtual dissection tools, including virtual reality, augmented reality, and games, enhance anatomical learning. These tools are used to teach various aspects of anatomy, such as internal, ear, nose, temporal bone, surgical, neuro, and cardiac anatomy. They provide valuable alternatives when access to cadavers or mannequins is limited.¹⁰

Platforms such as YouTube, Vimeo, and specific radiology webinar series offer a wide range of video content. This includes case clips, live discussions on Facebook, lectures, and quizzes. Facebook Live videos are particularly noted for their high engagement, with more median views, likes, shares, and subscribers. These platforms cover various radiology topics, reflecting a broad interest without a clear favourite.¹¹

Together, these resources provide comprehensive and flexible learning opportunities for radiology trainees, leveraging modern technology to address and overcome traditional educational challenges (TABLE 1).

Site Link	What the Site is About
https://radiopaedia.org	Radiology teaching file cases and structured learning tools.
Learning Radiology e-book by William Herring	Introductory radiology textbook covering various imaging modalities.
Coursera and edX	Online radiology courses with interactive learning environments.
RSNA Online Learning Portal	Educational materials and professional development for radiology.
Radiology-TEACHES	Case-based education focusing on appropriate imaging and safety.
Anatomy apps and virtual dissection tools	Virtual anatomy learning tools using AR, VR, and interactive apps.
YouTube, Vimeo, and radiology webinar series	Video content on radiology, including case clips and live discussions.

Table 1. Types of Online learning resources

EVALUATION CRITERIA FOR ONLINE RESOURCES

The credibility and accreditation of online resources are essential for ensuring the reliability and accuracy of educational content. Accreditation by recognised bodies, such as the Accreditation Council for Graduate Medical Education (ACGME), ensures that programmes meet high educational standards.¹² Comprehensive content evaluation is vital, as it ensures that online resources cover critical aspects such as eligibility, applications, curriculum, and programme characteristics. Ruddell et al.¹² observed that many online platforms for nuclear medicine and radiology training often fall short in providing detailed content, highlighting the need for accredited and peer-reviewed materials. Accreditation helps maintain consistency in quality, ensuring that educational standards are upheld across different learning platforms.

Incorporating expert feedback is another key criterion. Crowdsourcing platforms can assist in assessing the comprehension of radiology reports and improving content clarity.¹³ This approach helps identify areas where learners and patients may struggle, enabling ongoing improvements in educational materials. Additionally, innovative methods such as gamified crowdsourcing can produce expert-quality labels for medical data, enhancing the overall quality of online resources.¹⁴

Effective online resources should encourage active learning and user engagement. Interactive tools, such as discussion forums, can bridge the gap between patient needs and radiology education, offering a more engaging learning experience.¹⁵ Technological advancements, including web-based conferencing, video platforms, and e-learning modules, have significantly enhanced interactive learning. The COVID-19 pandemic has further accelerated this trend, making online education an integral part of radiology training.⁷ Furthermore, platforms like pathCast provide free, accessible learning resources, which help reduce disparities between resource-rich and resource-poor regions, thus supporting global accessibility in radiology education.¹⁶

The accessibility and usability of online resources are crucial for effective learning. The integration of mobile devices and Internet of Things (IoT) technology improves accessibility and user engagement in radiology education. These technologies support a seamless workflow in radiology practices and enable personalised learning experiences.¹⁷ A user-friendly design is essential for online resources, ensuring they are easy to navigate and compatible with mobile devices. This flexibility allows learners to access high-quality educational content at any time and from any location, making learning more accessible and adaptable to various lifestyles.¹⁷

BENEFITS OF ONLINE LEARNING IN RADIOLOGY

One of the main advantages of online learning platforms is the ability to control the pace of study. Learners can adjust their learning speed to suit their individual needs, allowing them to spend more time on challenging topics while moving quickly through material they are already familiar with.⁷ This customisation is particularly beneficial for radiology professionals, including trainees and practising physicians, who can fit their learning around their busy schedules and stay updated with the latest developments in the field.¹⁶ Online resources offer access at all hours, which is ideal for learners in different time zones or with varying work commitments. The ability to access materials at any time supports ongoing education, allowing learners to revisit content and stay informed about the latest practices in radiology.¹⁷ This constant availability enhances learning opportunities and facilitates continuous professional development.⁷

Online platforms provide a wide array of resources, including textbooks, articles, video lectures, and interactive modules. This variety enriches the learning experience by offering multiple perspectives and teaching methods, catering to different learning styles and needs.⁷ Access to global experts and international conferences through online platforms exposes learners to a range of viewpoints and practices. This broad exposure helps develop a comprehensive understanding of radiology by incorporating international perspectives and cutting-edge practices.¹⁶ Online platforms are regularly updated with the latest research and clinical guidelines, ensuring that learners have access to current information. This is crucial for maintaining relevance in the rapidly evolving field of radiology.⁷

The use of multimedia elements such as videos, animations, and simulations enhance the understanding of complex radiological concepts and procedures. This approach caters to various learning styles and makes intricate information more accessible and engaging.¹⁵ Many platforms include interactive case studies that enable learners to apply their knowledge in simulated scenarios. This practical experience is essential for developing critical thinking and diagnostic skills in a risk-free environment.¹⁶ Incorporating gamified elements, such as quizzes and challenges, can significantly boost engagement and motivation. This approach not only makes learning more enjoyable but also en-

hances its effectiveness by adding elements of fun and competition.¹⁴

CHALLENGES AND LIMITATIONS

Online learning resources often vary significantly in quality and accuracy, presenting challenges in maintaining consistency. Some platforms may lack rigorous peer review or accreditation, which can lead to potential misinformation.¹²

The effectiveness of online learning can be compromised by technical issues such as unreliable internet connections or subpar platform usability. These challenges are particularly pronounced in regions with limited technological infrastructure.¹⁷

Online learning generally lacks the personal interaction and networking opportunities that traditional in-person training offers. The absence of face-to-face mentorship can restrict opportunities for direct guidance, feedback, and professional connections.^{13,15}

STRATEGIES FOR EFFECTIVE ONLINE LEARNING

Establishing a well-organised study plan is essential for successful online learning. Regular scheduling and consistency in study routines are crucial for managing the self-paced nature of online courses and ensuring consistent progress.⁷

Engaging in online communities, such as forums, discussion groups, and social media, significantly enhances the learning experience. Active participation provides valuable opportunities for discussion, feedback, and networking. Interacting with peers and experts can help clarify doubts and deepen understanding.^{15,16}

Employing a variety of online tools and resources—such as video lectures, interactive case studies, and discussion platforms—can create a more comprehensive learning experience. Combining these resources helps address different learning styles and can fill potential gaps in knowledge.^{14,17}

FUTURE DIRECTIONS IN ONLINE RADIOLOGY EDUCATION

Artificial Intelligence (AI) has the potential to revolutionise diagnostic training through automated feedback and simulations, providing learners with immediate insights and corrections.¹⁴ Virtual Reality (VR) offers immersive, hands-on learning experiences, particularly useful for complex case studies that require detailed exploration and interaction.¹⁷

Integrating online resources with traditional in-person training can offer a balance of flexibility and convenience while preserving the benefits of direct mentorship and practical experience.⁷ Blended learning approaches can help bridge the gaps inherent in online education, enhancing its overall effectiveness and ensuring a more comprehensive learning experience.¹⁶

Continuous development and adaptation to emerging technologies are essential for keeping educational programmes current and effective.¹⁵ Regular innovation in content delivery and interactive tools will not only enhance learning outcomes but also address the evolving needs of radiology education.¹²

CONCLUSION

Online learning in radiology offers several significant benefits. The flexibility and convenience of self-paced learning and 24/7 availability enable adaptability to varied schedules and individual learning preferences. Additionally, online platforms provide access to a wide range of materials and global expertise, which enriches educational opportunities. The use of multimedia tools and interactive case studies further enhances the learning experience, making it more engaging and effective.

However, there are also notable challenges and limitations. Quality control remains a critical issue due to variability in content quality, which necessitates rigorous evaluation. Technical issues such as internet access and platform usability can affect the overall learning experience. Moreover, the lack of face-to-face mentorship and

networking opportunities can restrict practical learning experiences.

Despite these challenges, online resources hold substantial potential for enhancing radiology education. They offer innovative and flexible learning solutions that can adapt to the evolving needs of the field.

Trainees and educators are encouraged to embrace online learning and actively contribute to its development. By doing so, they can help maximise its benefits and further advance the radiology community.

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CONFLICT OF INTEREST

The authors have no competing or conflict of interest to declare.

FINANCIAL SOURCES

No financial sources were received that could have influenced the manuscript.

Submitted: August 24, 2024 EDT, Accepted: September 11, 2024 EDT



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