



Future Online Radiology Education: The Importance of Curriculum

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Take-home points

- The coronavirus disease 2019 (COVID-19) pandemic has severely disrupted diagnostic radiology services and training. In-person radiology education disruptions can be mitigated using virtual online tools to enable interactive large-group teaching and Picture Archiving and Communications System (PACS) informatics-driven and game-based learning modules for self-directed learning.
- Radiology educators should review our teaching assumptions and learn to apply education theory to support a coherent curriculum.
- We should invest in faculty development and seek opportunities for consultation, collaboration, and research with experts in health professions education.
- Radiologists must combine their content and technological expertise with pedagogical knowledge to adapt appropriate curricula to learners' needs in this and future pandemics.

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The coronavirus disease 2019 (COVID-19) outbreak affected health systems worldwide, with implications for radiology practice, research, and education; learning from the first Severe Acute Respiratory Syndrome (SARS) crisis in 2003, many radiology departments responded quickly to protect patients and staff [1]. The prioritization of infection control measures has resulted in a reduced workload in radiology departments due to cancellations of outpatient imaging studies and elective interventional procedures [2]. Although we experienced different conditions during the height of the pandemic lockdown, there was a common disruption to the conventional workplace-based education and planned instructional activities essential for professional development. Radiologists responded to these challenges by being adaptable and inventive, restructuring our teaching technology to pivot abruptly to socially distanced remote working [3]. More significantly, the pandemic resulted in a required shift in culture in all facets of education, which not only helped hasten the adoption and implementation of technology-enhanced learning methods but also called into question well-recognized and practiced pre-pandemic pedagogies and methodologies in medical education that were made inappropriate or irrelevant despite their longevity and perceived importance [4]. In this editorial, we describe three initiatives using online virtual platforms to continue radiology education during the pandemic and reflect on lessons learned for the future.

We first describe how a popular final-year medical student radiology workshop pivoted online during the pandemic: "Survival Radiology" was previously a full-day interactive

case-based in-person workshop introducing important and urgent radiological core knowledge expected for interns [5]. We found that the online platform allowed personalized remote viewing of radiological images and enhanced real-time interactions using online “word cloud” and “image hot spot” audience response systems (Fig. 1) and “live” chat responses from supporting faculty (who were not the main speaker) [5]. Such contemporaneous feedback and deliberate blending of the most beneficial aspects of existing face-to-face interactions with the strengths of online platforms can improve content delivery and ultimately enhance a learner’s educational experience [6,7].

Next, we addressed the decreased attendance of real patients with brain tumors during resident neuroradiology rotation. We overcame the lack of reporting opportunities using a database of past histology-proven cases within the clinical Picture Archiving and Communications System (PACS), which had been previously collected for a separate machine learning validation project. With this brain tumor PACS worklist, residents can individually review the images at their own pace and check their diagnosis against an answer key (Fig. 2). This project leveraged existing informatics tools as a learning platform in a self-directed, asynchronous manner [8,9].

Finally, we developed an online e-learning module aimed at teaching magnetic resonance (MR) safety concepts set in a virtual 3D radiology department, including simulated patient screening scenarios and decision-making in managing an emergency MR-related accident. Such serious games provide realistic, immersive, engaging, and relatable play, incorporating formative assessment minigames

with instantaneous feedback in a non-threatening safe environment that cannot be otherwise created [10].

The three examples above illustrate how resourceful radiology educators can quickly adapt and use virtual online platforms during the height of the pandemic [6,11]. More importantly, as we transition to a post-pandemic world, we should take the opportunity to familiarize ourselves with basic pedagogical concepts and medical educator skillsets. We need to reflect on the advantages and drawbacks of virtual teaching by combining old and new teaching methods based on sound principles. Designing and implementing effective online learning curricula involves clarity in course expectations and outcomes, developing an e-community, selecting and optimizing online tools to encourage interaction, creating an environment in which the exchange of ideas can flourish, and providing timely and targeted feedback, all within a student-centered environment [12]. A basic understanding of fundamental pedagogical concepts such as Bloom’s Taxonomy, active learning, and student feedback would go a long way in creating purposeful experiences for teachers and learners [13].

The main advantage of teaching using remote platforms is increased accessibility, even in unprecedented geographically diverse regions [11]; however, videoconferencing fatigue is an important limitation [14,15]. Hence, it is timely to consider the curriculum and pedagogical design to continue the next step in the development of online (and offline) teaching methods and resources, since what developed organically and out of sheer necessity in the early days of pandemic education may be haphazard and unfit for purpose in the long run. It is time

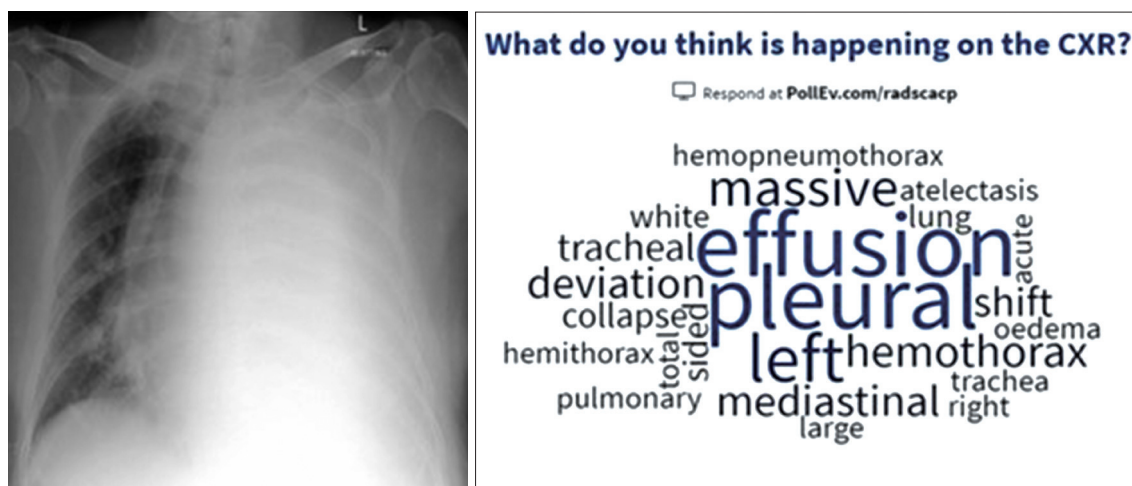


Fig. 1. Screenshot of “word cloud” audience response systems used in Survival Radiology online virtual workshop for medical students. We found that audience response systems and “live” chat functions enhanced learners’ educational experiences.

#	Name	Number	Location	Diagnosis 1	Diagnosis 2
1	Dummy	SDummy	Bilateral lateral ventricles	Central neurocytoma	Choroid plexus carcinoma
2	Dummy	SDummy	Left frontoparietal	Meningioma	Glioblastoma
6	Dummy	SDummy	4 th ventricle	Medulloblastoma	Ependymoma
7	Dummy	SDummy	Right striatocapsular + temporal	Glioblastoma	Lymphoma
8	Dummy	SDummy	Right parietal	Glioblastoma	Lymphoma
9	Dummy	SDummy	Pituitary fossa	Pituitary macroadenoma	Craniopharyngioma
10	Dummy	SDummy	Suprasellar	Craniopharyngioma	Pituitary macroadenoma
11	Dummy	SDummy	Cerebellar vermis	Haemangioblastoma	Pleomorphic astrocytoma

Fig. 2. An example of answer key of Picture Archiving and Communications System worklist of patients with brain tumor for self-directed asynchronous resident review during neuroradiology rotation. We overcame the lack of reporting opportunities during the pandemic by leveraging existing informatics tools.

to review and plan according to pedagogical principles so that the overarching curriculum is appropriate and not impractical or incoherent. Three baseline requirements are necessary to enable this late/post-pandemic change management. First, radiology departments should emphasize and invest in faculty education and development [16]. Second, radiologists should seek opportunities for consultation, collaboration, and research with pedagogical experts in university medical education departments [17]. Finally, and most crucially, clear learning outcomes within the curriculum are needed, tailored to their different backgrounds and needs, including residency trainees, medical students, and radiographers: they all have different needs.

There are many limitations to this editorial, and it barely scratches the surface of post-pandemic initiatives. We did not cover major topics that deserve separate discussions, including procedural and interventional radiology, assessments/examinations, interprofessional education, and simulations. However, we hope that this will be a conversation starter regarding whether online virtual/remote platforms can replicate the intangible atmosphere and nuances of in-person interactions, how to develop and incorporate blended learning for teaching, and role modeling

such domains as non-interpretive skills, mentoring, and leadership skills [18,19]. Video recordings and remotely supervised, technology-enhanced learning methods such as augmented/virtual reality in immersive learning environments may be novel but may also be hampered by being extremely resource-intensive [20]. Several other important literature-supported emerging trends, such as flipped classrooms, interprofessional education, and gamification, can also be explored.

Online radiology educational best practices should be underpinned by sound pedagogical theory and a coherent curriculum; thus, in addition to our content and technical knowledge, radiology teachers should master the appropriate pedagogical knowledge to prepare to educate and inspire our learners in this and future pandemics.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: all authors. Data curation: Choie Cheio Tchoyoson Lim. Supervision: Choie Cheio Tchoyoson Lim.

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