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Commentary

Diagnostic radiography education amidst the COVID-19 pandemic: Current and future use of virtual reality (VR)

Christopher M Hayre[a,b,*] and Andrew Kilgour[a]

[a] *School of Dentistry & Medical Sciences, Faculty of Science, Charles Sturt University, NSW, Australia*
[b] *School of Health and Sport Sciences, University of Suffolk, Ipswich United Kingdom*

Introduction

The COVID-19 pandemic required significant change within higher education institutions worldwide. In our institution, for instance, the COVID-19 pandemic caused several challenges, notably, students being unable to attend allocated placement sites. This created an opportunity in our radiography programme to utilize virtual reality (VR), in response to shortfalls in placement exposure for students. Whilst VR has been recognized within the radiography curricula prior to COVID-19, adjunct to other forms of learning and teaching tools [1,2], its uses during the pandemic have naturally expanded. Typically, radiography students are exposed to a range of learning methods, including lectures, tutorials, technical positioning sessions, coupled with compulsory attendance of clinical placement. Yet, our sudden need for social distancing, isolation, and for some, strict lockdown measures, required sudden need for change in our academic delivery [3]. Here, in Australia, like many other countries transnationally, lectures were transitioned online, and this coincided with some students unable to complete clinical placements because of restrictions placed by either clinical centres or local health districts [4]. This was unprecedented and as clinical placements were suspended, it required an alternate assessment strategy to satisfy the learning outcomes of subjects. VR, then, played a critical role within our institution in order to ensure students were not disadvantaged any more than necessary and able to progress in their undergraduate degree.

Our sudden need for change is also identifed elsewhere. Tay et al [4] study in Singapore recognized the need for adaptation and suspension of clinical training for undergraduate students and the incorporation of simulation as part of the clinical model. Further, O'Connor et al [5] found that the use of 3D virtual radiography remained an invaluable pedagogical tool for student radiographers. This application for assessment purposes arguably provides an opportunity to explore an enhanced level of appropriateness of VR for future years. The VR software employed to assess students in our institution was *Shaderware*, allowing students to handle radiographic equipment, choose receptor placement, collimation, side marker placement, exposure factor selection and the control of scatter for a range of radiographic examinations. Our commentary begins by highlighting reliance on this technology during the COVID-19 pandemic to ensure that students were not disadvantaged any more than necessary. The cessation of clinical placements in both public and private radiology sites required alternate means of assessing students performing radiographic examinations [6]. By using *Shaderware,* students were asked to 'perform' selected general radiographic examinations, using a computer, whilst considering the abovementioned facets in the examination(s). As a collective, this method of assessment was deemed appropriate by staff members, in recognition it critically abided to institutional quality standards whilst meeting regulatory body requirements. By considering this, it enables us, as academics, to critically reflect on whether a 'new educational normal' or 'new educational abnormal' arises in respect to VR technology and how it could be adopted in more diverse ways in radiography education post COVID-19. In this paper, it is argued that new opportunities can arise because of unconventional academic assessment methods, which for some students may widen their participation, which may have been deterred in the past. Lastly, this paper reflects on future possibilities of learning and teaching for radiography in a post COVID-

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* Corresponding author at: Commentary, Charles Sturt University, Wagga Wagga, New South Wales, Australia.
E-mail address: chayre@csu.edu.au (C.M. Hayre).

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19 world, which encompasses a multifaceted pedagogical approach, later becoming 'teleradiography'.

Reliance of VR in diagnostic radiography during the COVID-19 pandemic

The use of VR in health and rehabilitation settings continues to support the needs of healthcare professionals and service users in an array of specialties [7]. VR is being utilised by disciplines transnationally and remains primarily focused on replicating and/or replacing real-life experiences akin to the human senses; notably visual, auditory, haptic, and olfactory [8–10]. Prior to the COVID-19 pandemic, VR technology was utilized in radiography. For example, Sapkaroski, Mundy and Dimmock [1] demonstrated how VR simulation could be used for radiographic hand positioning tasks, when compared to conventional role-play learning. Further, Almestehi et al [2], in their systematic review, identified the growing body of evidence relating to using virtual simulation as a training/learning tool. Whilst the abovementioned examples provide some clarification of its use before COVID-19, the last 18 months have demonstrated increased onus on VR technology to satisfy a lack of clinical exposure amongst students.

An initial examination of the literature illustrates few published works reflecting on the utilization of VR as a substitute for clinical placement. Conventionally, a central component of radiography curriculum is, and remains the need for students to engage in both X-ray practical exercises at university, coupled with attendance in hospital placements [4]. The latter enabling students to gain 'real-life' experiences prior to becoming a registered diagnostic radiographer. Importantly, then, a central part of the clinical model is to undertake radiographic examinations, whereby students are assessed on their technical ability and deemed either satisfactory or unsatisfactory [11]. VR software, however, was used to replicate patients attending for radiographic examinations. Importantly, this allowed students to 'perform' radiographic examinations virtually by means of using personal computers (PC), yet, this change clearly juxtaposed the physical, verbal, and non-verbal tenets required to perform radiographic examinations in a hospital environment.

VR enabled diagnostic radiography educators the ability to assess the performance of students undertaking radiographic examinations, whilst importantly allowing them to progress within their undergraduate studies. An important question arises following the use of VR as a viable replacement tool: were radiography students advantaged or disadvantaged during their use of VR, and what impact could this have in future years? In response, this commentary offers conjectures that examine advantages and disadvantages of VR as a viable alternative during the COVID-19 pandemic, allowing for further discussion and debate. On the one hand, our reliance (and advantage) of VR technology during the pandemic resolved a significant issue in terms of satisfying examination requirements; yet on the other hand, as students begin to return to clinical placement, it is important to reflect not only on our reliance with this technology, but perhaps how it could become more 'adjunct' in radiography education in future years. It remains clear that our reliance and need for VR equipment remained a central component in adapting to a worldwide pandemic, but, we must also question its application, and whether in some situations, could replace or be used in adjunct to clinical assessment, thus considered the 'new normal'? This warrants further discussion, which we will now consider.

VR technology for radiography education: A 'new normal' or 'new abnormal'?

Our reliance on VR technology requires some critical reflection concerning its virtues and pitfalls and question whether it could replace a conventional model. A recent paper by Pottle acknowledges that whilst VR software is a useful tool for supporting and facilitating education, it affirms that it is not the panacea that will replace humanistic components [12]. Whilst this study was published before the emergence of COVID-19, it could be argued, however, that the applicability of VR will depend on the learning outcomes intended for undergraduate education. For example, if students' progress in accordance with an institution's quality standards, it is argued that VR could be increasingly adopted in future years, although we forewarn the importance of patient/human contact. Two advantages stand out if this is considered. First, students with preexisting conditions, who were perhaps previously deterred from entering radiography on the grounds of physical agility could become immersed, virtually, within an undergraduate programme. Whilst we accept that clinical placement is paramount for most graduating radiographers, for others, however, deciding to embark on an undergraduate radiography programme could be driven by non-clinical opportunities, such as teaching, learning or research. Thus, would a combination of virtual teaching and simulation satisfy educational requirements for a student seeking an academic or research career in radiography? Second, for students who may require intercalation due to ill-health or other personal issues, may also benefit by engaging with VR to resolve outstanding clinical competencies, thus not disadvantaged because of unforeseeable illness or bereavement, for instance. These are two examples whereby immersive VR could be applied or used in adjunct towards a 'new academic normal' in a undergraduate diagnostic radiography degree programme and help navigate students' needs and progression.

It is important to highlight here that the authors are not proposing a radiography degree based on VR in response to limited patient/human contact for students. The abovementioned conjectures, however, offer a lens that could utilize VR technology as an adjunct tool if/when necessary to help students with mitigating circumstances. The interpretation and 'value' of VR within any radiographic curriculum will depend on many factors, yet, this commentary seeks to offer some original thought and discussion around how VR could remain adjunct, either temporary or permanently, within the radiography curriculum based on previous successes during the pandemic.

A caveat to the abovementioned virtues is that VR could be considered as a 'new abnormal' as VR fails to expose students

to the everyday culture of a clinical environment [13]. This is important, as students are often required to reflect on observed experiences as part of their undergraduate learning, coinciding with the need to communicate appropriately with peers [14]. These facets remain central, but arguably distant with VR tools. This 'learning through observation' and then 'learning by doing' remains an important part of clinical education, whereby hands-on practical experience, coupled with critical reflexivity, enables students to consider their own actions, behaviours and attitudes in the workplace [11]. Moreover, another clear component for any prospective healthcare registrant is the ability to convey empathy, communication with, and compassion for their patients. Thus, if VR could replace components of clinical practice and assessment (as observed during the COVID-19 pandemic), the caveats should be captured elsewhere.

Another argument, which is important to highlight here, is that perhaps some incumbent radiography students may only wish to engage with the academic content of the discipline, as eluded above. Although we accept that most students entering radiography seek to work clinically, this does offer a route for some students whose goal is not focused on the vocational elements of radiographic practice. This is not commonplace here in Australia, nor in other parts of the world, but it may become plausible for individuals in future years with either preexisting disabilities or intentional career goals to perhaps pursue a research or educational career in diagnostic radiography. Here, VR may help 'research focused' students bypass clinical components associated with radiography, but also provide them with the clinical knowledge and understanding of the production of radiographs which is required during medical imaging examinations. As witnessed in this pandemic, VR succeeded in progressing students as a viable replacement tool for 'real-life' clinical placement(s), thus an emerging question arises: could it be used again?

VR in a post COVID-19 educational setting: A multifaceted pedagogical approach?

In a post COVID-19 world, could VR have a greater role as an assessment tool in radiography education? As identifed , advantages and disadvantages associated with VR did satisfy educational demands during the COVID-19 pandemic. The former has potential ramifications for incumbent radiography students who may be disadvantaged by physical disability. The latter suggests that VR fails to expose students to the everyday workplace culture, limits human interaction, and fails to accurately assess the altruistic behaviour of students. An example outside of radiography, which shares the importance of 'human touch' are those professions akin to rehabilitating patients, i.e. physiotherapy or occupational therapy. The value of this 'hands-on' role in assisting patients has been one of the key challenges when considering moving rehabilitation services 'remotely' or 'digitally' [15]. Our need to be 'physically present' with patients, in radiography, is shared by Russell [15] asserting our need to 'physically touch' patients as it remains central in guiding, directing and facilitating movement..

Radiography shares these attributes, whereby students learn to 'touch' and maneuver patients into position in order to ensure sound diagnostic images. Whilst Russell [15] concedes that we may need to overcome the rationality that being physically present is superior, in radiography we may also need to find a balance between ensuring that students are exposed to everyday positioning techniques, but coupled with innovative technologies that support learning needs where appropriate. Whilst perhaps seen as problematic in light of our need (as radiographers) to be 'physically present' through touch and guidance, in terms of radiographic positioning, this pandemic has taught us that educational change has, at times, relied solely upon teleradiography whereby VR acted as a viable alternative to clinical placement attendance with notable success. In short, the absence of VR tools in our contemporary space could have stalled student progression by failing to expose them to alternate methods and importantly meeting learning outcomes within the curriculum.

In the past, we have witnessed telemedicine at the forefront of reaching and treating individuals isolated because of either physical impairment, or geography. It has also been used in other pandemics, notably the treatment of Ebola [16]. In contemporary incidents, the widespread impact of COVID-19 has perhaps raised further questions as to whether, as healthcare educationalists, we begin to incorporate teleradiography further, which includes not only VR, but other forms of emerging technology, such as the Internet of Medical Things (IoMT) and artificial intelligence (AI). It could be argued that as emerging technology continues to facilitate the everyday needs of individuals it could become integrated into our everyday modes of educational delivery. As academics, educators, and scholars, we have had to think critically about our own academic practices of learning, teaching and scholarly activity via remote technology. There is, perhaps now, a stronger rationale for adopting multifaceted pedagogical approaches that not only aids student learning, but widens participation amongst prospective radiography student cohorts.

Conclusion

This commentary sought to provide a positional statement reflecting on the application of VR for radiography education in higher education. The commentary began by recognising our reliance on alternate forms of technology, in particular VR, in response to COVID-19 when radiography students were detached from clinical placements. This is important, because at a time of social isolation and lockdown measures, alternate pedagogy and assessment methods were needed to ensure that students were not disadvantaged and were able to 'progress' accordingly.

Then, we examined the potential of a 'new academic normal' and/or 'new academic abnormal' in response to successes observed, whereby VR facilitated student progression and also met the learning outcomes of radiographic subjects. Here, we recognised the importance VR may have for widening participation amongst prospective students with preexisting disabilities, who may have historically been deterred due to the phys-

icality pertaining to job performance. Contrary to this, potential hindrances link to student observation, reflexive practice, communication, and assessment of altruistic behaviours with patients are noted upon the immersion in a VR environment.

Lastly, we proffer the possibility of a paradigmatic shift within radiography education, whereby multifaceted pedagogy through the utilisation of innovative and emerging technologies, such as VR (or IoMT/AI), fosters progressive teleradiography in curriculum design. Clearly, VR does not offer a 'one size fits all' model, but its current use and success for maintaining student progression, coincided with meeting quality standards, is worthy of further discussion and debate transnationally.

References

[1] Sapkaroski D, Mundy M, Dimmock MR. Virtual reality versus conventional clinical role-play for radiographic positioning training: a students' perception. *Radiography*. 2019;26(1):57–62.

[2] Almestehi M, Alomaim W, Rainford L, Rainford L, et al. Tole of virtual reality simulator (ScanTrainer) as a multidisciplinary training tool in transvaginal ultrasound: a systematic review and narrative synthesis. *Radiography*. 2019;25(3):260–268.

[3] Elmer T, Mepham K, Stadtfeld C. Students under lockdown: Comparisons of students' social networs and mental health before and during the COVID-19 crisis in Switzerland. *PLOS ONE*. 2020;15(7).

[4] Tay YX, Sng LH, Chow HC, Zainuldin MR. Clinical placements for undergraduate diagnostic radiography students amidst the COVID-19 pandemic in Singapore: preparation, challenges and strategies for safe resumption. *J Med Imag Rad Sci*. 2020.

[5] O'Connor M, Stowe J, Potocnik J, Giannotti N, Murphy S, Rainford L. 3D virtual reality simulation in radiography education: the students' experience. *Radiography*. 2021.

[6] Radianti J, Majchrzak TA, Fromm J, Wohlgenannt I. A systematic review of immersive virtual reality applications for higher education: design elements, lessons learned and research agenda. *Comp Edu*. 2020;147:1–29 103778.

[7] Hayre CM, Muller D, Scherer M, eds. *Virtual Reality in Health and Rehabilitation*. CRC Press; 2020.

[8] Bhagat KK, Liou W, Chang C. A cost-effective interactive 3D virtual reality system applied to military live firing training. *Virtual Reality*. 2016;20:127–140.

[9] Chen KB, Sesto ME, Ponto K, et al. Use of virtual reality feedback for patients with chronic neck pain and kinesiophobia. *IEEE Trans Neur Syst Rehab Eng*. 2017;25(8):1240–1248.

[10] Chi B, Chau B, Yeo E, Ta P. Virtual reality for spinal cord injury-associated neuropathic pain: Systematic review. *Ann Phys Rehab Med*. 2019;62(1):49–57.

[11] Kilgour AJ. Assessment of competency in radiography students – a new approach. *The Radiographer*. 2011;58(3):33–37.

[12] Pottle J. Virtual reality and the transformation of medical education. *Future Healthcare J*. 2019;6(3):181–185.

[13] Samadbeik M, Yaaghobi D, Bastani P, Abhari S, Rezaee R, Garavand A. The applications of virtual reality technology in medical groups teaching. *J Adv Med Edu Profess*. 2018;6(3):123–129.

[14] Baird MA. Towards the development of a reflective radiographer: challenges and constraints. *Biomed Imag Intervent J*. 2008;4(1):e9.

[15] Russell TG. Physical rehabilitation using telemedicine. *J Telemed Telecare*. 2007;13(5):217–220.

[16] Ohannessian R. *Telemed Poten Appl Epid Situat*. 2015;4:95–98.