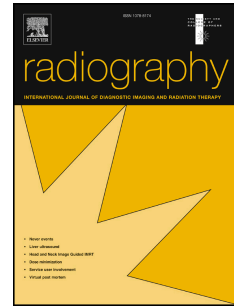


# Journal Pre-proof

A Review of the Impact of the COVID-19 Pandemic on Pre-registration Medical Radiation Science Education

Curtise K.C. Ng



PII: S1078-8174(21)00106-1

DOI: <https://doi.org/10.1016/j.radi.2021.07.026>

Reference: YRADI 2135

To appear in: *Radiography*

Received Date: 14 April 2021

Revised Date: 17 June 2021

Accepted Date: 27 July 2021

Please cite this article as: Ng CKC, A Review of the Impact of the COVID-19 Pandemic on Pre-registration Medical Radiation Science Education, *Radiography*, <https://doi.org/10.1016/j.radi.2021.07.026>.

This is a PDF file of an article that has undergone enhancements after acceptance, such as the addition of a cover page and metadata, and formatting for readability, but it is not yet the definitive version of record. This version will undergo additional copyediting, typesetting and review before it is published in its final form, but we are providing this version to give early visibility of the article. Please note that, during the production process, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

© 2021 The College of Radiographers. Published by Elsevier Ltd. All rights reserved.

**Title**

A Review of the Impact of the COVID-19 Pandemic on Pre-registration Medical Radiation  
Science Education

**Author**

Curtise K.C. Ng<sup>a</sup> (Corresponding author)

Email: curtise.ng@curtin.edu.au; curtise\_ng@yahoo.com.hk

Postal address: Discipline of Medical Radiation Science, Curtin Medical School, Curtin  
University, GPO Box U1987, Perth, Western Australia 6845, Australia

<sup>a</sup>Discipline of Medical Radiation Science, Curtin Medical School, Curtin University, GPO  
Box U1987, Perth, Western Australia 6845, Australia

**Acknowledgements**

None

**Declaration of interest**

None

**Conflict of interest statement**

None

Journal Pre-proof

**Title**

A Review of the Impact of the COVID-19 Pandemic on Pre-registration Medical Radiation Science Education

**Abstract***Objective*

The COVID-19 pandemic has changed traditional ways to provide pre-registration medical radiation science (MRS) (medical imaging and radiation therapy) education. This literature review explores the published pre-registration MRS education curriculum adaptations implemented in response to the pandemic and effects of the adaptations on stakeholders.

*Key Findings*

Eleven articles were identified through a systematic literature search. The included articles covered the pre-registration MRS curriculum adaptations implemented in response to the pandemic in 12 countries of five continents. Through changing content delivery and assessment modes from face-to-face to online, non-practical classes and academic assessments could continue without significant interruptions. However, cancellation / postponement of practical classes and clinical placements was common during COVID-19 lockdown. Simulated learning was used by some institutions to replace some practical classes and placements. Among the stakeholders of MRS education (students, academics and clinical educators), the students were most affected. The main impacts were negative psychological

effects and learning experiences. For the academics, they had common concerns about online learning quality and assessment integrity.

### *Conclusion*

This review of the early publications in the first year of the pandemic provides an illustration of the MRS curriculum adaptations implemented in five continents covering both English and non-English speaking countries and their effects on the stakeholders as yet. It is expected that more articles on this area will be published over time and hence allowing a more comprehensive review in the future.

### *Implications for Practice*

The included articles show provision of wellbeing support, good planning of online content delivery based on sound pedagogical approaches, implementation of computer-based simulation tools suitable for home-based learning environment and use of authentic online assessments would address the impacts on the students and academics.

### **Keywords**

Adaptation, coronavirus disease 2019, effect, medical imaging, radiation therapy, training

## Introduction

In December 2019, cases of coronavirus disease 2019 (COVID-19) were first reported in Wuhan, China. Since March 2020, the COVID-19 has become a global pandemic and caused significant impacts on everyone.<sup>1</sup> In response to the pandemic, restrictions of gathering and movement have become standard strategies for infection control.<sup>2</sup> These have subsequently changed traditional ways to provide pre-registration medical radiation science (MRS) (medical imaging and radiation therapy) education for ensuring continuity and supply of medical radiation practitioners (MRPs) (diagnostic radiographers and radiation therapists). The common changes include teaching delivery mode (from face-to-face to online) and cancellation / postponement / replacement of activities such as practical classes and clinical placements.<sup>2-12</sup>

Although these changes have a certain basis such as education literature about online and simulated learning, their rapid implementation implies many of these were not planned in advance.<sup>2,12,13</sup> After more than a year of the onset of the pandemic, COVID-19 is still not under control worldwide. It may take several years to end it.<sup>14</sup> Sustainable strategies for providing quality pre-registration MRS education that is able to meet fitness for practice, fitness for purpose and fitness for award requirements need to be determined.<sup>5,15</sup> Literature reviews about the adaptations of learning and teaching approaches for undergraduate radiology and nursing educations have been published elsewhere.<sup>16,17</sup> However, apparently, such review has not been available for the MRS profession yet. It is timely to review the literature about the COVID-19 impact on the pre-registration MRS education as a first step to determine the sustainable strategies for the 'new normal'. The purpose of this literature review is to explore the published articles to answer the question "What were the pre-

registration MRS education curriculum adaptations implemented in response to the COVID-19 pandemic and the effects of the adaptations on stakeholders?”

## Method

A traditional systematic literature search approach in line with recent literature reviews published in MRS journals was employed.<sup>18-20</sup> The literature search using electronic databases of scholarly publications (ScienceDirect, Pubmed, CINAHL and Embase) was conducted on 19<sup>th</sup> February 2021 to identify the articles about the COVID-19 impact on the pre-registration MRS education published between 2019 and 2021. Grey literature was not sought because there was a lack of well established methodological guidelines for this process.<sup>21</sup> The year range chosen should cover all articles about the COVID-19 published in journals as yet.<sup>14</sup> The search statement used was (“Radiography” OR “Medical Radiation Science” OR “Medical Imaging” OR “Radiation Therapy” OR “Radiotherapy”) AND (“Education” OR “Training”) AND (“COVID” OR “Coronavirus”). The selected keywords were based on the review purpose but not specific to the pre-registration curriculum adaptations in response to the pandemic and their effects on the stakeholders for minimising potential omissions of the relevant articles. Inclusion criteria were the articles written in English, published within the peer-reviewed journals and focussed on the pre-registration MRS education curriculum adaptations in response to the COVID-19 and / or the effects of the changes on the stakeholders. Conference abstracts and review articles were excluded as information provided in the former tended to be incomplete and the latter could only provide secondary information.<sup>22,23</sup>

After duplicate articles were removed from the database search results, the remaining articles were screened via a three-stage process (by evaluating 1. titles, 2. abstracts, and 3. full texts) against the exclusion criteria (conference abstracts, review articles, published before 2019, not written in English, not from peer-reviewed journals, not focussed on the pre-registration MRS education curriculum adaptations in response to the COVID-19 and / or the effects of the changes on the stakeholders). Each non-duplicate article identified through the database searching was included until a decision on its exclusion could be made (Fig. 1).<sup>24</sup> As the COVID-19 emerged less than two years ago, it was expected that not many relevant original research papers had been published. It was decided to use a narrative approach for this literature review. Hence, editorials and commentaries were included to provide a more holistic illustration of the adaptations implemented and their effects.<sup>17,25</sup>

All references cited in the included articles were checked for identifying additional, relevant papers. Quality assessment tool for studies with diverse designs (QATSDD) was used to assess quality of the included papers. The QATSDD was chosen because it could evaluate the quality of studies with diverse research approaches (e.g. quantitative, qualitative, mixed methods, etc.) with good reliability and validity.<sup>26</sup> The included papers were categorised into low (<50%), moderate (50%-70%) and high (>70%) qualities based on their QATSDD's quality assessment scores expressed as percentages.<sup>24</sup>

## **Results**

Eleven articles met the selection criteria and were included in the review (Fig. 1). Appendix A summarises key characteristics of these articles.<sup>2-12</sup> Six articles were original research papers with four determined high quality, and online questionnaires was the commonest data



collection tool (n=3).<sup>2,3,6,7,9,12</sup> Almost all articles were published in major MRS journals, *Journal of Medical Imaging and Radiation Sciences* (n=5),<sup>2,5,9,10,11</sup> *Radiography* (n=3)<sup>3,6,7</sup> and *Radiologic Technology* (n=1).<sup>12</sup> The included articles focussed on the COVID-19 impact on the pre-registration MRS education in Singapore (n=4),<sup>8-11</sup> Australia (n=3),<sup>2,4,5</sup> United Kingdom (UK) (n=2),<sup>3,6</sup> United States of America (USA) (n=1),<sup>12</sup> and multiple countries in five continents (n=1).<sup>7</sup> Nearly half of the articles (n=5) were about the clinical education adaptations.<sup>3,7-10</sup> Four covered the changes of multiple aspects of the MRS curriculum such as the clinical education and the modes of content delivery and assessment.<sup>4,5,11,12</sup> Among the stakeholders of the MRS education including students, academics and clinical educators, about half (n=5) focussed on the students' issues.<sup>2,3,6,7,11</sup>

#### *Clinical Education Adaptations*

Since the COVID-19 outbreak, intermittent lockdown had become a common measure to control it.<sup>3-5,7-10</sup> The lockdown had resulted in closures of some clinical centres or reductions of number and range of clinical cases for the others.<sup>7,8</sup> Subsequently, the MRS education providers had been required to cancel or postpone some students' clinical placements.<sup>3,5,7</sup> This change of placement arrangement could interrupt the supply of future MRPs which was a major concern of clinical educators of a Singaporean tertiary hospital.<sup>10</sup> It was because the Singaporean regulatory body, Allied Health Professions Council specified that a minimum of 1,200 hours of clinical training must be completed by MRS course graduates for registering with them as the MRPs. To ensure the continuous supply of MRPs, after two months of the lockdown, Singapore Institute of Technology (SIT) was allowed to resume the placements with shortened durations in early May 2020 for its students to meet the minimum clinical hour requirement for registration. However, its online questionnaire survey showed that about

half of its second and third year students worried about having the clinical placements during the pandemic due to increased chances of COVID-19 infection at the clinical centres and during travelling, and transmitting the COVID-19 to family members.<sup>9</sup> The SIT's students also expressed concerns about the reductions of clinical placement lengths and case volumes which affected their clinical competence development, and expected that the SIT should adjust corresponding case report assignment requirements accordingly.<sup>11</sup> To address these students' concerns, the SIT's academics and clinical educators worked collaboratively to provide special arrangements for resuming the placements. These included provisions of online refresher infection control training and enhanced clinical placement information packages prior to the placements, better placement site allocation for shortening travel time, daily twice temperature monitoring, reduction of educator-student ratio to 1:1 with dedicated clinical educators, removal of placements in emergency department (ED) and intensive care unit (ICU), change of assessment mode from summative to multiple formative, uses of simulated learning in physical MRS laboratories to address any clinical competence gaps and WhatsApp Messenger (Facebook, Inc., California, USA) for enhancement of communication between the students and the educators, and provision of wellbeing support.<sup>8,9</sup> However, the resumption of clinical placements also increased pressure faced by their clinical educators due to handling backlog of cases and supervising the students at the same time, and failing underperforming students affected by the reduction of clinical exposure. Recognitions from public and hospital management, and supports from the academic institution, clinical educator workshops and experienced educators were considered essential to address these issues.<sup>10</sup>

For other countries such as UK,<sup>27</sup> USA<sup>12</sup> and Australia,<sup>28</sup> their professional / regulatory bodies only needed their MRS course graduates meeting all required competences for

registration and did not specify the minimum clinical training hours required. This had provided a greater flexibility for the education providers to adjust the clinical education arrangements. For example, Courtier et al.<sup>3</sup> reported that their radiation therapy (RT) students were removed from the clinical placements and started working as temporary registrants at earlier stages of the pandemic in UK. However, the students participated in their online focus group interviews expressed mixed feelings about their professional identity (technically students with remaining academic components pending for completion but working as clinical staff) with various degrees of readiness for the change. Also, the COVID-19 caused extra uncertainties despite feeling valued as the radiation therapists earlier. Currie et al.<sup>5</sup> cancelled / postponed their medical imaging and radiation therapy placements during the lockdown but allowing their nuclear medicine students who started the placements before the lockdown to continue.<sup>4</sup> Remote access to computer-based simulation (CBS) software was arranged for their radiation therapy students as a replacement for some clinical placements.<sup>5</sup> The adaptation of the placement arrangement did not need their regulatory body approval provided that the learning outcomes of the course remained unchanged.<sup>4</sup> An online questionnaire survey study involving 274 USA MRS academics showed more than 70% of the participants felt comfortable with modifying their clinical placement arrangements in response to the lockdown. Nearly all (92.7%) of the respondents suspended the placements and about half (48.9%) used the simulated learning to replace them, leading to a median clinical hour reduction of 150 hours in one semester.<sup>12</sup>

For the online questionnaire survey study involving 1,277 MRS students from 12 countries of five continents by Rainford et al.,<sup>7</sup> they indicated that the majority of students in many countries were removed from the clinical placements at the early stages of the pandemic based on anecdotal evidence but their survey finding showed nearly half of their participants

were required to complete the clinical training between January and June 2020 for maintaining the future MRS workforce numbers. About two thirds of the participants indicated various levels of concern about having the placements during the pandemic and their levels of concern were associated with their domestic and health circumstances. The students who had the underlying health conditions or lived with family members having the underlying conditions expressed higher levels of concern while the final year students and recent graduates were statistically significantly less likely to have any worry ( $p < 0.05$ ). This was because the underlying health conditions such as cancers and chronic lung diseases were risk factors for severe COVID-19 illness. About one fifth of the participants indicated that they were unconfident in using personal protective equipment and dissatisfied with placement arrangement communication. Also, half of them expressed a concern about completion of clinical assessments in a timely manner due to limited case availability.

#### *Content Delivery and Assessment Mode Changes*

Unlike the clinical placements, the learning and teaching activities, and the assessments for the academic component of the MRS courses could continue in most cases even during the lockdown but with the online formats.<sup>2,4-6,11,12</sup> Learning management system (Blackboard Learn, District of Columbia, USA), video tutorial creation tool (Camtasia, TechSmith, MI, USA), game-based learning platform (Kahoot!, Oslo, Norway) and online conferencing platforms (Zoom, California, USA; Microsoft Teams, Washington, USA; Microsoft Skype, Washington, USA; and WebEx, Cisco Systems Inc., California, USA) were commonly used for the online content delivery.<sup>5,6,12</sup> Nearly all participants (89.4-95.3%) of the survey involving 274 USA MRS academics by Webster and Clark<sup>12</sup> felt comfortable with changing the content delivery mode from face-to-face to online due to instructional supports provided

by their institutions in contrast to 70.4-71.1% being comfortable with adjusting the clinical placement arrangements. For the transition to the online learning in Australia, Currie et al.<sup>5</sup> perceived this was a generally positive experience because the online learning improved their students' attendance, class dynamics, access and equity. Similar findings were also reported in the UK survey study by Higgins et al.<sup>6</sup> that their students indicated the use of Microsoft Teams enhanced group communication and collaboration, and the online learning required less study time because of travelling not needed.

Regarding the delivery of practical classes which was more challenging when compared to non-practical ones such as lectures, workshops and tutorials, the CBS software was used by some survey participants (USA MRS academics) of Webster and Clark.<sup>12</sup> However, their participants also indicated synchronous virtual tours of clinical facilities via the online conferencing platforms such as Zoom could be used to cover some practical activities. Currie et al.<sup>5</sup> used a similar approach in Australia to demonstrate practical skills to their students through asynchronous practical videos but requiring their students to complete intensive face-to-face laboratory sessions after the lockdown. Nevertheless, when there was no creative way to provide the online practical classes, these classes might be removed from the MRS courses. For example, the practical classes were removed entirely from the SIT's MRS course, negatively affecting its students' learning experience.<sup>11</sup>

In spite of the aforementioned positive findings reported by Webster and Clark,<sup>12</sup> 50% of their participants (USA MRS academics) expressed a concern about online learning quality. Teo et al.<sup>11</sup> indicated that the students' suboptimal online learning experience in Singapore was due to a lack of appropriate home-based learning environments and immediate feedback provided by their lecturers, and different students' study paces affecting subsequent group

discussions. However, these negative students' experiences seemed contradictory to findings of the online collaborative enquiry-based learning study by Higgins et al. in UK.<sup>6</sup> The online collaborative enquiry-based learning was a pedagogy emphasising online collaboration between peers to learn practice related concepts through research. To enhance the collaboration, the Microsoft Teams instead of the Blackboard Learn was used for sharing documents, asynchronous and synchronous discussions between the students, and academic staff to provide real-time support and feedback online. These instructional strategies for the online learning were carefully designed to address the common issues of the online learning such as a lack of student-student and student-tutor interactions, leading to the positive students' learning experiences. For example, the majority (68%-91%) of their students indicated strong agreements on both task value and self-efficacy for learning and performance within this online experimental research module despite that their students' academic results of this module were not evaluated specifically.<sup>6</sup> Hence, this demonstrated the importance of having the MRS academics to work with their institutional instructional designers for adapting the content delivery mode to achieve the quality online learning.<sup>12</sup> However, for the delivery of research module online, just changing the instructional strategies was not adequate because data collection might be prohibited during the lockdown. For Higgins et al.,<sup>6</sup> they provided experimental data to their students for completing the research module. Currie et al.<sup>5</sup> indicated that some of their honours research project students were required to change research directions to non-human contact-based studies as a remedy.

Similar to the teaching delivery, traditional invigilated tests / examinations were generally not allowed when there were the COVID-19 restrictions on gathering and movement. Some MRS academics used online open book assessments to replace the traditional invigilated assessments because this might not require lots of time for the transformation.<sup>2,5</sup> However,

online assessment integrity was a common concern of many MRS academics.<sup>2,5,12</sup> Ng<sup>2</sup> used plagiarism detection software, Turnitin (CA, USA), a manual search for highly irrelevant assessment answers, and an assessment score statistical analysis to detect any contract cheating occurred in two online open book assessments of a medical radiation pathology subject in Australia. No contract cheating was found in that study and the main contributor for maintaining the online open book assessment integrity was strict assessment time limits (e.g. same as original invigilated assessments, etc.). However, he also suggested that an online viva voce would be a suitable alternative to the traditional invigilated assessments. For the online collaborative enquiry-based learning study by Higgins et al. in UK,<sup>6</sup> an online presentation was used to assess their students' performance and their students thought this was less stressful when compared to the face-to-face situation as there was no assessor staring at them.

For the survey study by Webster and Clark,<sup>12</sup> they identified the strict examination time limit (81.4%), a lockdown browser for restricting computer functions (49.3%), assessments redesigned as authentic ones (42.3%) and online proctoring solutions (27%) were common strategies for maintaining the online assessment integrity in USA. However, when the sophisticated lockdown browser and the online proctoring solutions were not available, browser history checking and invigilation through online conferencing platforms such as Zoom could be used instead. Although the use of online assessment proctoring had become more common, some members of the teaching team of Currie et al.<sup>5</sup> indicated that its implementation was challenging. They suggested the use of authentic assessments to replace the traditional invigilated tests / examinations would be a better choice. To further address the online assessment integrity concern, additional strategies such as an implementation of

academic integrity program and an academic integrity statement submission before the assessments could be used.<sup>2,12</sup>

## **Discussion**

Only 11 articles (including six original research papers) meeting the selection criteria is expected because the COVID-19 pandemic has only occurred for less than two years. However, these papers cover the adaptations of the major (clinical and academic) components of the pre-registration MRS curriculum and their effects on the key stakeholders (students, academics and clinical educators) in 12 countries (Australia, Austria, Belgium, Denmark, Ireland, Italy, Netherlands, Singapore, Slovenia, South Africa, UK and USA) of five continents (Asia, Africa, North America, Europe, and Oceania).<sup>2-12</sup> Hence, this review illustrates a general picture of the impact of the COVID-19 on the pre-registration MRS education.

This literature review reveals the MRS academics and clinical educators could continue providing the MRS education with the modified arrangements (including the online delivery of the non-practical classes and the academic assessments, and the use of simulated learning to replace some practical classes and clinical placements) to their students during the pandemic. There are still some interruptions to the pre-registration MRS education (mainly about the cancellation / postponement of the practical classes and the clinical placements). Also, there is a lack of standard approaches for the adaptations which can be due to a great variation of circumstances (e.g. frequencies and durations of the lockdown, COVID-19 restriction types, resource availabilities, etc.) in different countries / regions / institutions.<sup>2-12</sup> Similar findings are also noted in the literature reviews about the adaptations of learning and



teaching approaches for the undergraduate radiology and nursing educations during the COVID-19.<sup>16,17</sup>

Although the simulated learning is commonly reported as the replacement for some clinical placements and practical classes, the simulations in the physical MRS laboratories and use of immersive three-dimensional (3D) virtual reality (VR) simulation tools such as VR software by Virtual Medical Coaching Ltd (Christchurch, New Zealand) and VERT (Vertual Ltd., East Yorkshire, UK) may not be feasible during the lockdown.<sup>5,9,13,29</sup> The CBS programs such as Shaderware Virtual Radiography (Darlington, UK), MRI Simulator (The Institute for Advanced Clinical Imaging, Georgia, USA) and Netrad (administered by University of Sydney, Cumberland, Australia) which are more readily applicable to the home-based learning environment are more COVID-19 compliant.<sup>5,24</sup> However, with preparations in advance, it is feasible for the students to utilise some immersive 3D VR simulation tools at home. For example, the VR software by Virtual Medical Coaching Ltd only requires generally available equipment such as HTC Vive Pro headsets and hand controllers (Taoyuan, Taiwan) for using it in the home-based learning environment.<sup>29</sup> With the high fidelity simulation tools, this might allow international MRS students to continue studying online for an extended period due to COVID-19 travel restrictions.<sup>13,30</sup>

Nevertheless, findings of a survey study with 205 Australian academic, clinical and accrediting stakeholders published in 2011 shows that even for a well designed simulated learning program, it could only replace about 10-20% of clinical hours of a MRS course.<sup>31</sup> Also, according to recent literature reviews,<sup>13,24</sup> effectiveness of the simulated learning including the CBS has only been evaluated based on perceptions of the students and MRS academics rather than the students' actual competencies. Given the less predictable,

intermittent nature of the lockdown and the recent advancements of the high fidelity simulation tools,<sup>29,32,33</sup> management of academic institutions should at least consider making an investment in these high fidelity simulation products for minimising the potential cancellation / extended delay of the clinical placements and the practical classes in the future.<sup>12,13</sup>

Apparently, among the stakeholders, the MRS academics have been least affected by the adaptations and their students have been most affected.<sup>2-12</sup> Nevertheless, the challenges faced by the MRS academics cannot be underestimated. For example, it is difficult to work from home for changing and delivering the MRS curriculum when optimal work environments such as free from distractions, reliable internet and adequate bandwidth are not available. The adaptations also create uncertainties and cause extra workload to the academics and hence increasing their stress together with the general COVID-19 impacts such as worries about getting infected and potential redundancies, and feeling isolated despite that peer support through informal online meetings regularly may help to address some of these.<sup>5</sup> Besides, the institutional instructional designers would be good resource people to support the academics in adapting the curriculum for achieving good student learning outcomes and hence relieving some of their stress potentially.<sup>12</sup>

For the impacts of the MRS curriculum adaptations on the stakeholders reported in all included articles except Ng's study, they are only based on the perceptions of the stakeholders.<sup>2-12</sup> Similar issues are also noted in the literature review about the adaptations of learning and teaching approaches for the undergraduate nursing education during the COVID-19.<sup>17</sup> Hence, future studies should be conducted to objectively assess these impacts. For example, clinical performance of newly registered MRPs who have experienced the

adapted curriculum should be evaluated to ensure that they are fit for purpose.<sup>15,17</sup>

Longitudinal studies about the academic performances of the students who have experienced the online learning during the pandemic should also be conducted.<sup>2,17</sup>

### *Limitations*

This literature review has several limitations. Only 11 articles (including six original research papers) written in English are identified through the systematic literature search using the electronic databases of scholarly publications. Situations of some non-English speaking countries may not be covered. Also, the grey literature is not included. However, this review is still able to provide the illustration of the MRS curriculum adaptations implemented in five continents covering both English and non-English speaking countries and their effects on the stakeholders during the pandemic. Not many articles published on this topic area also highlights the importance of conducting further studies to increase the knowledge base. Besides, only one person was involved in the article selection and quality assessment processes leading to potential bias. Nonetheless, it is expected that the use of PRISMA guidelines and QATSDD for these processes can address the bias issue to some extent.<sup>26,34</sup>

### **Conclusion**

This literature review reveals the pre-registration MRS curriculum adaptations implemented in response to the COVID-19 pandemic in 12 countries of five continents. Through changing the content delivery and assessment modes from face-to-face to online, the non-practical classes and the academic assessments could continue without the significant interruptions. However, the cancellation / postponement of the practical classes and the clinical placements

was common during the COVID-19 lockdown. The simulated learning was used by some institutions to replace some practical classes and placements.

Among the stakeholders of the MRS education, the students were most affected. The main impacts on them were the negative psychological effects and learning experiences. For the academics, they had the common concerns about the online learning quality and the assessment integrity. It is suggested that the provision of wellbeing support, the good planning of online content delivery based on the sound pedagogical approaches, the implementation of CBS tools suitable for the home-based learning environment and the use of authentic online assessments should be able to address these issues to some extent. However, all but one of the included articles have not objectively assessed these impacts. Also, their long-term consequences have not been explored yet. Further research is warranted for determining the sustainable strategies for the 'new normal'.

### **Word Count**

Abstract: 279

Manuscript: 3,994

## Appendix A

Key characteristics of included articles.

Author, year and country	Journal	Article type	Inquiry Area	Methodology	Participants	Evaluation	Key Findings	Quality
Courtier et al. (2020) – UK <sup>3</sup>	<i>Radiography</i>	Original study	Feelings & expectations of final year radiation therapy (RT) students who were removed from their clinical placements & started working as temporary registrants during COVID-19	Qualitative (Online focus group)	Cardiff University's final year RT students (n=7)	Thematic analysis	<b>Mixed feelings</b> about professional identity (technically student but working as clinical staff); feeling valued as radiation therapists earlier; expecting COVID-19 causing extra uncertainties; various degrees of readiness for change	High (76.2%)
Currie (2020) – Australia <sup>4</sup>	<i>European Journal of Nuclear Medicine and Molecular Imaging</i>	Editorial	Australian perspective on COVID-19 impact on nuclear medicine (including education)	Qualitative (Narrative approach)	Charles Sturt University's (CSU) nuclear medicine (NM) academics	NA	Change of teaching delivery mode from face-to-face to online; 4 <sup>th</sup> year NM students who started clinical placement before lockdown could continue while placements for	Low (16.7%)

							other cohorts were postponed; Not necessary to obtain registering body's approval for these changes as course learning outcomes unchanged	
Currie et al. (2020) – Australia <sup>5</sup>	<i>Journal of Medical Imaging and Radiation Sciences</i>	Commentary	Experiences of educators in MRS teaching during COVID-19	Qualitative (Narrative approach)	CSU MRS academics	NA	Generally positive experience in transitioning to online learning due to higher student attendance, greater class dynamics and improved access & equity; Mixed responses about transitioning to online assessments; Use of demonstration videos for online practicals and Zoom for other online classes; clinical placements postponed / cancelled; Changes of some honours research project directions	Low (21.4%)

Higgins et al. (2020) – UK <sup>6</sup>	<i>Radiography</i>	Original study	Undergraduate radiography students' perception of task value and self-efficacy of online collaborative enquiry-based learning in an experimental research module during COVID-19	Mixed methods (Online questionnaire survey with closed & open questions)	2 <sup>nd</sup> year diagnostic radiography students of a North West England Region University (n=32)	Survey reliability: Cronbach alpha coefficient; Closed questions: % of responses; Open questions: content analysis	Response rate: 73%; Majority (68%-91%) of participants indicated strong agreements on both task value & self-efficacy for learning & performance within the experimental research module; Use of Microsoft Teams enhanced group communication & collaboration; Online learning required less time due to no associated travel; Online presentation reduced students' stress	High (81.3%)
Ng (2020) – Australia <sup>2</sup>	<i>Journal of Medical Imaging and Radiation Sciences</i>	Original study	Evaluation of integrity of 2 online open book assessments with different formats (1. tightly time	Mixed methods retrospective study	3 <sup>rd</sup> year MRS students of an Australian university (n=48)	Review of Turnitin reports & search for highly irrelevant assessment answers to	No cheating evidence was found in all Turnitin reports & online open book assessment answers; Traditional	87.5% (High)

			restricted and 2. take home) in an undergraduate medical radiation pathology subject during COVID-19			detect any cheating; Descriptive & inferential statistics to identify any abnormal assessment score pattern	invigilated end of semester assessment mean score (88.2%) and corresponding online open book one (90.9%) were similar (p=0.098) but online open book mid-semester assessment mean score (62.8%) was statistically significantly lower than respective traditional invigilated one (71.8%) suggesting no cheating (p<0.0001)	
Rainford et al. (2020) - Australia, Austria, Belgium, Denmark, Ireland, Italy, Netherlands, Singapore, Slovenia, South	<i>Radiography</i>	Original study	Student radiographers' concerns about clinical placement during COVID-19	Mixed methods (Online questionnaire survey with closed & open questions)	Non-1 <sup>st</sup> year radiography students including recent graduates from 14 institutions in 12 countries (n=1277)	Closed questions: % of responses & t-test; Open questions: content analysis with quasi-statistics	35.4% of participants felt 'not at all worried' to be a radiographer; 64.6% indicated various levels of concern and their domestic / health circumstances played significant roles in this; Final	Moderate (62.5%)



Africa, UK & USA <sup>7</sup>							year students and recent graduates were statistically significantly less likely to have any worry ( $p<0.05$ ); 23.5%, 50% and 19.9% expressed concerns about communication related to clinical placement, clinical assessment completion and not confident in PPE usage respectively	
Tay et al. (2020a) – Singapore <sup>8</sup>	<i>Korean Journal of Medical Education</i>	Commentary	Singapore Institute of Technology (SIT) experiences of radiography clinical education during COVID-19	Qualitative (Narrative approach)	SIT radiography students, academics & clinical educators	NA	Clinical education adaptations: Pre-placement-provisions of online refresher training in infection control & enhanced clinical practice information package; Placement-temperature monitoring, educator-student ratio reduced to 1:1, students excluded	Low (23.8%)

							from ED and ICU, controlled movement of students, use of WhatsApp for enhancing communication & wellbeing support, removal of high-stake clinical assessments; Post-placement-students' competence gaps addressed by simulated learning	
Tay et al. (2020b) – Singapore <sup>9</sup>	<i>Journal of Medical Imaging and Radiation Sciences</i>	Original study	SIT's experiences of radiography clinical education during COVID-19	Mixed methods (Narrative approach & online questionnaire survey)	SIT radiography students (n=45), academics & clinical educators	Online questionnaire: % of responses	54% of 2 <sup>nd</sup> & 51% of 3 <sup>rd</sup> year students expressed concerns about having clinical placements during the pandemic; Main concerns: infected with COVID-19 at clinical centres, during travelling & transmitting the virus to family members; Mitigation strategies: online pre-placement	Low (37.5%)

							infection control training, reduced students' travel time, placement length & exposure to high risk clinical areas (subsequently addressed by simulated learning), use of health surveillance systems, WhatsApp for mental health support & dedicated clinical supervisors to minimise interaction with others during placement	
Tay et al. (2020c) – Singapore <sup>10</sup>	<i>Journal of Medical Imaging and Radiation Sciences</i>	Commentary	Needs & concerns of radiography clinical educators during COVID-19	Qualitative (Narrative approach)	Radiography clinical educators of a Singaporean tertiary hospital	NA	Concerns: Cancelling international students' clinical training, suspending placement affecting future radiographer supply, spreading virus to family members, assessing students'	Low (26.2%)

							performance, providing negative feedback, failing students affected by reduction of practice opportunities & increased workload; Needs: recognitions from public & management, supports from experienced educators & academic institutions & clinical educator workshop	
Teo et al. (2020) – Singapore <sup>11</sup>	<i>Journal of Medical Imaging and Radiation Sciences</i>	Commentary	Student radiographers' perspective on COVID-19 impact on learning	Qualitative (Narrative approach)	SIT's radiography students (n=3)	NA	Suboptimal experience with fully online learning due to lacking in appropriate home-based learning environment, immediate feedback & practice opportunities, different students' study paces	Low (16.7%)

							affecting group discussions; Clinical placement: Concerns about reduced placement length & examination number for practice, no reduction of assessment workload & infected with COVID-19 at clinical centres	
Webster and Clark (2020) – USA <sup>12</sup>	<i>Radiologic Technology</i>	Original study	Experiences of educators in MRS curriculum adaptation during COVID-19	Mixed methods (Online questionnaire survey with closed & open questions)	MRS academics in USA (n=274)	Closed questions: descriptive statistics (frequency, %, median & IQR); Open questions: content analysis	Response rate: 23.9%; 89.4-95.3% of participants felt comfortable with changing modes of content delivery & assessments and increasing uses of educational technology & virtual resources while only 70.4-71.1% indicated comfortable with modifying clinical placement arrangements;	High (87.5%)

							92.7% & 48.9% of respondents suspended clinical placements & used simulated learning as a remedy respectively; 50% of participants concerned about quality of online learning; Median effectiveness score of all mitigation strategies: 7.65 (0-completely ineffective & 10-highly effective); Median clinical hour reduction: 150h	
--	--	--	--	--	--	--	---	--

ED=emergency department; ICU=intensive care unit; IQR=interquartile range; MRS=medical radiation science; NA=Not available; PPE=personal protective equipment; UK=United Kingdom; USA=United States of America

## References

1. World Health Organization (WHO). *Archived: WHO timeline - COVID-19*. Geneva: WHO; 2021 [cited 2021 March 25]. Available from <https://www.who.int/news/item/27-04-2020-who-timeline---covid-19>.
2. Ng CKC. Evaluation of academic integrity of online open book assessments implemented in an undergraduate medical radiation science course during COVID-19 pandemic. *J Med Imaging Radiat Sci* 2020;**51**(4):610-6. <https://doi.org/10.1016/j.jmir.2020.09.009>.
3. Courtier N, Brown P, Mundy L, Pope E, Chivers E, Williamson K. Expectations of therapeutic radiography students in Wales about transitioning to practice during the Covid-19 pandemic as registrants on the HCPC temporary register. *Radiography* 2020. <https://doi.org/10.1016/j.radi.2020.09.001>.
4. Currie G. COVID19 impact on nuclear medicine: an Australian perspective. *Eur J Nucl Med Mol Imaging* 2020;**47**(7):1623-7. <https://doi.org/10.1007/s00259-020-04812-z>.
5. Currie G, Hewis J, Nelson T, Chandler A, Nabasenja C, Spuur K, Barry K, Frame N, Kilgour A. COVID-19 impact on undergraduate teaching: medical radiation science teaching team experience. *J Med Imaging Radiat Sci* 2020;**51**(4):518-27. <https://doi.org/10.1016/j.jmir.2020.09.002>.
6. Higgins R, Murphy F, Hogg P. The impact of teaching experimental research on-line: research-informed teaching and COVID-19. *Radiography* 2020. <https://doi.org/10.1016/j.radi.2020.11.014>.
7. Rainford LA, Zanardo M, Buissink C, Decoster R, Hennessy W, Knapp K, Kraus B, Lanca L, Lewis S, Mahlaola TB, McEntee M, O'Leary D, Precht H, Starc T, McNulty JP. The impact of COVID-19 upon student radiographers and clinical training. *Radiography* 2020. <https://doi.org/10.1016/j.radi.2020.10.015>.

8. Tay YX, Chow HC, Ooi CC. Impact on clinical learning during coronavirus disease 2019 pandemic: from disruption to recovery and the new norms. *Korean J Med Educ* 2020;**32**(4):297-305. <https://doi.org/10.3946/kjme.2020.176>.
9. 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 Imaging Radiat Sci* 2020;**51**(4):560-6. <https://doi.org/10.1016/j.jmir.2020.08.012>.
10. Tay YX, Cai S, Chow HC, Lai C. The needs and concerns of clinical educators in radiography education in the face of COVID-19 pandemic. *J Med Imaging Radiat Sci* 2021;**52**(1):3-8. <https://doi.org/10.1016/j.jmir.2020.10.004>.
11. Teo LW, Pang T, Ong YJ, Lai C. Coping with COVID-19: perspectives of student radiographers. *J Med Imaging Radiat Sci* 2020;**51**(3):358-60. <https://doi.org/10.1016/j.jmir.2020.05.004>.
12. Webster TL, Clark KR. COVID-19 planning among radiologic science programs: response mitigation activities. *Radiol Technol* 2020;**92**(2):100-12.
13. Ng CKC. Evidence-based education in radiography. In: Brown T, Williams B, eds. *Evidence-based Education in the Health Professions*. London: Radcliffe Publishing Ltd; 2015:448-68.
14. The Lancet Microbe. COVID-19 vaccines: the pandemic will not end overnight. *Lancet Microbe*. 2021;**2**(1):e1. [https://doi.org/10.1016/S2666-5247\(20\)30226-3](https://doi.org/10.1016/S2666-5247(20)30226-3).
15. Ng CKC, White P, McKay JC. Establishing a method to support academic and professional competence throughout an undergraduate radiography programme. *Radiography* 2008;**14**(3):255-64. <https://doi.org/10.1016/j.radi.2007.05.003>.



16. Darras KE, Spouge RJ, de Bruin ABH, Sedlic A, Hague C, Forster BB. Undergraduate radiology education during the COVID-19 pandemic: a review of teaching and learning strategies. *Can Assoc Radiol J* 2021;**72**(2):194-200.  
<https://doi.org/10.1177/0846537120944821>.
17. Goni-Fuste B, Wennberg L, Martin-Delgado L, Alfonso-Arias C, Martin-Ferrer ML, Monforte-Royo C. Experiences and needs of nursing students during pandemic outbreaks: a systematic overview of the literature. *J Prof Nurs* 2021;**37**(1):53-64.  
<https://doi.org/10.1016/j.profnurs.2020.12.004>.
18. Baker MA, MacKay S. Please be upstanding - a narrative review of evidence comparing upright to supine lumbar spine MRI. *Radiography* 2021;**27**(2):721-6.  
<https://doi.org/10.1016/j.radi.2020.11.003>.
19. Di Michele L, Thomson K, McEntee MF, Kenny B, Reed W. Knowledge translation: radiographers compared to other healthcare professionals. *Radiography* 2020;**26**(Suppl 2):S27-32. <https://doi.org/10.1016/j.radi.2020.06.007>.
20. Al Mahrooqi KMS, Ng CKC, Sun Z. Pediatric computed tomography dose optimization strategies: a literature review. *J Med Imaging Radiat Sci* 2015;**46**(2):241-9.  
<https://doi.org/10.1016/j.jmir.2015.03.003>.
21. Adams RJ, Smart P, Huff AS. Shades of grey: guidelines for working with the grey literature in systematic reviews for management and organizational studies. *Int J Manag Rev* 2017;**19**(4):432-54. <https://doi.org/10.1111/ijmr.12102>.
22. Scherer RW, Saldanha IJ. How should systematic reviewers handle conference abstracts? A view from the trenches. *Syst Rev* 2019;**8**(1):264. <https://doi.org/10.1186/s13643-019-1188-0>.

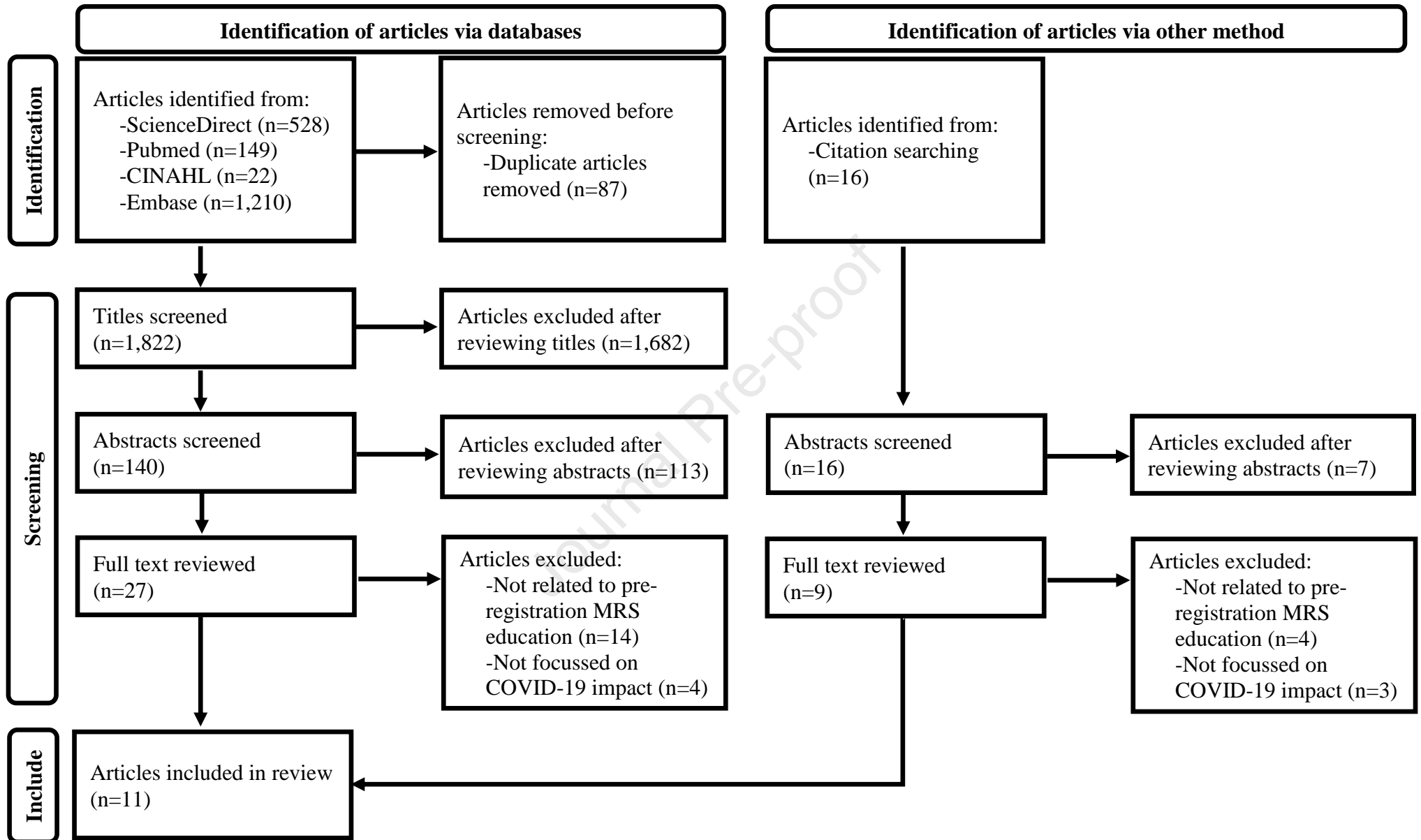
23. Maggio LA, Sewell JL, Artino AR Jr. The literature review: a foundation for high-quality medical education research. *J Grad Med Educ* 2016;**8**(3):297-303.  
<https://doi.org/10.4300/JGME-D-16-00175.1>.
24. Chaka B, Hardy M. Computer based simulation in CT and MRI radiography education: current role and future opportunities. *Radiography* 2020.  
<https://doi.org/10.1016/j.radi.2020.11.010>.
25. Ferrari R. Writing narrative style literature reviews. *Medical Writing* 2015;**24**(4):230-5.  
<https://doi.org/10.1179/2047480615Z.000000000329>.
26. Sirriyeh R, Lawton R, Gardner P, Armitage G. Reviewing studies with diverse designs: the development and evaluation of a new tool. *J Eval Clin Pract* 2012;**18**(4):746-52.  
<https://doi.org/10.1111/j.1365-2753.2011.01662.x>.
27. The Society and College of Radiographers. *Coronavirus (Covid-19): advice for pre-registration education providers and students*. London: The Society and College of Radiographers; 2020 [cited 2021 April 9]. Available from:  
[https://www.sor.org/news/educators/coronavirus-\(covid-19\)-advice-for-pre-registration](https://www.sor.org/news/educators/coronavirus-(covid-19)-advice-for-pre-registration).
28. Australian Health Practitioner Regulation Agency. *National principles for clinical education during COVID-19*. Melbourne: Australian Health Practitioner Regulation Agency; 2021 [cited 2021 April 9]. Available from:  
<https://www.ahpra.gov.au/News/COVID-19/National-principles-for-clinical-education-during-COVID-19.aspx>.
29. 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;**27**(1):208-14. <https://doi.org/10.1016/j.radi.2020.07.017>.

30. Australian Trade and Investment Commission. *Important COVID information*. Sydney: Australian Trade and Investment Commission; 2021 [cited 2021 April 13].  
<https://www.studyinaustralia.gov.au/English/Study-in-Australia-student-support/latest-information-and-updates-student-support>.
31. Thoires K, Giles E, Barber W. The use and perceptions of simulation in medical radiation science education. *The Radiographer* 2011;**58**(3):5-11. <https://doi.org/10.1002/j.2051-3909.2011.tb00149.x>.
32. Institute for Government. *Timeline of UK coronavirus lockdowns, March 2020 to March 2021*. London: Institute for Government; 2021 [cited 2021 April 12]. Available from: <https://www.instituteforgovernment.org.uk/sites/default/files/timeline-lockdown-web.pdf>.
33. Australian Bureau of Statistics. *One year of COVID-19: Aussie jobs, business and the economy*. Belconnen: Australian Bureau of Statistics; 2021 [cited 2021 April 12]. Available from: <https://www.abs.gov.au/articles/one-year-covid-19-aussie-jobs-business-and-economy>.
34. PRISMA. *Transparent reporting of systematic reviews and meta-analyses*. Ottawa: PRISMA; 2015 [cited 2021 April 13]. <http://www.prisma-statement.org/>.

**Figure Legends**

**Figure 1.** PRISMA flow diagram. MRS=medical radiation science

Journal Pre-proof



**Author Statement and Declaration of Interest**

I wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

I confirm that the manuscript has been read and approved by the named author and that there are no other persons who satisfied the criteria for authorship but are not listed. I further confirm that the order of author listed in the manuscript has been approved by myself.

I confirm that I have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing I confirm that I have followed the regulations of my institution concerning intellectual property. I further confirm that any aspect of the work covered in this manuscript that has involved either experimental animals or human patients has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

I understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). He is responsible for communicating with the other about progress, submissions of revisions and final approval of proofs. I confirm that I have provided a current, correct email address which is accessible by the Corresponding Author.

Signed by the author as follows:

Curtise Kin Cheung Ng (Corresponding author)

17<sup>th</sup> June 2021

Journal Pre-proof