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Review Article

# Towards describing the global impact of the COVID-19 pandemic on clinical radiography education: A systematic review

Olanrewaju Lawal<sup>a,\*</sup>, David Omiyi<sup>b</sup>, Helen York<sup>a</sup> and Theophilus N. Akudjedu<sup>c</sup>

<sup>a</sup> Department of Allied Health Professions, Midwifery and Social Work, School of Health and Social Work, University of Hertfordshire, UK

<sup>b</sup> School of Allied Health Professions and Midwifery, Faculty of Health Studies, University of Bradford, UK

<sup>c</sup> Department of Medical Science & Public Health, Faculty of Health & Social Sciences, Bournemouth University, UK

## ABSTRACT

**Introduction:** The sudden onset of the COVID-19 pandemic has brought significant and rapid changes to the traditional ways of providing radiography education, including adaptations to teaching and learning styles as well as disruptions to students' clinical placement. This review explored the impact of the pandemic on clinical radiography education globally.

**Methods:** A systematic literature search was conducted on relevant databases, including PubMed, Science Direct, CINAHL (Cumulative Index of Nursing and Allied Health Literature, and SCOPUS. All relevant articles were critically appraised for quality and subjected to information extraction and results-based convergent synthesis.

**Results:** A total of 17 articles met the inclusion and exclusion criteria for this review. The key findings are themed around challenges and benefits with the introduction of new teaching and learning approaches and resilience exhibited by students during the pandemic to overcome: inadequate support and mentorship while transitioning to fully qualified professionals, challenges with PPE usage, and impact on personal and academic life.

**Conclusions:** Globally, radiography students experienced several challenges, especially during the initial acute phase of the pandemic. The pandemic-related challenges identified in this review could negatively influence the radiography student attrition rates, consequently worsening the existing radiography workforce shortage. Thus, urgent

institutional level support systems and interventions would be necessary to mitigate the pandemic impact and improve the students' learning experience.

## RÉSUMÉ

**Introduction:** L'apparition soudaine de la pandémie de COVID-19 a entraîné des changements importants et rapides dans les méthodes traditionnelles d'enseignement de la radiographie, notamment des adaptations des styles d'enseignement et d'apprentissage ainsi que des perturbations dans les stages cliniques des étudiants. Cette revue a exploré l'impact de la pandémie sur l'enseignement de la radiographie clinique au niveau mondial.

**Méthodologie:** Une recherche documentaire systématique a été menée sur les bases de données pertinentes, notamment PubMed, Science Direct, CINAHL (Cumulative Index of Nursing and Allied Health Literature, et SCOPUS. Tous les articles pertinents ont fait l'objet d'une évaluation critique de la qualité et ont été soumis à une extraction d'informations et à une synthèse convergente basée sur les résultats.

**Résultats:** Dix-sept (17) articles au total ont répondu aux critères d'inclusion et d'exclusion de cet examen. Les principales conclusions portent sur les défis et les avantages liés à l'introduction de nouvelles approches d'enseignement et d'apprentissage et sur la résilience dont ont fait preuve les étudiants pendant la pandémie pour surmonter le

Contributors: All authors contributed to the conception or design of the work, the acquisition, analysis, or interpretation of the data. All authors were involved in drafting and commenting on the paper and have approved the final version.

Competing interests: All authors declare no conflict of interest.

Ethical approval: Not required for this article type.

\* Corresponding author at: University of Hertfordshire, College Lane, Hatfield AL 10 9AB.

E-mail address: [o.lawal4@herts.ac.uk](mailto:o.lawal4@herts.ac.uk) (O. Lawal).

manque de soutien et de mentorat pendant la transition vers des professionnels pleinement qualifiés, les défis liés à l'utilisation de l'EPI et l'impact sur la vie personnelle et universitaire.

**Conclusions:** À l'échelle mondiale, les étudiants en radiographie ont fait face à plusieurs défis, en particulier pendant la phase initiale aiguë de la pandémie. Les défis liés à la pandémie identifiés dans cette

*Keywords:* COVID-19; Radiography education; Medical imaging

## Introduction

The COVID-19 pandemic continues to disrupt key activities in virtually every sector of the global economy, including education. This has had serious implications for educational delivery and raises concerns, especially for healthcare training models with practical and clinical placement components [1-5]. The pandemic caused training institutions across the globe to suspend in-person campus activities in compliance with safe COVID-19 protocols to prevent the spread of the virus [6]. These safety measures required educators to rapidly adjust their teaching environment, educational strategies and delivery approaches with a subsequent, significant impact on both students' learning experience [7,8] and educators' workload and research output [3,9].

Globally, traditional radiography training at the undergraduate degree level includes a combination of classroom teaching, clinical skills learning in a laboratory and placement in a hospital setting [4,5]. These key training components are designed to give students a variety of learning experiences, required knowledge, skills, and competencies to practise safely and effectively following graduation. Of note, studies by McNulty et al. [4] and Foley et al. [5] highlight the existence of a wide variation of pre-qualification student training hours and years in clinical practice globally between radiography programmes.

The sudden onset of the COVID-19 pandemic has brought significant and rapid changes to these traditional ways of providing radiography education, including adaptations to teaching and learning styles. According to Komlayut, [10] the higher education sectors have utilised various information and communication technologies (ICT) to promote effective and accessible learning, which has proved very valuable in the pandemic. Online tutorials and courses, discussion forums, virtual classrooms, digital communication channels and course websites are some of the common applications in the pandemic. Radiography education has a wide practical element that necessitates a great degree of clinical demonstrations using phantoms or through effective peer practical learning, student-teacher interaction and/or clinical placement contacts. Clinical placements are a vital part of undergraduate radiography programmes as they prepare students for registration with national regulatory authorities [11]. In some settings, [12-14] innovative strategies were devised (including

étude pourraient avoir une influence négative sur les taux d'attrition des étudiants en radiographie, aggravant ainsi la pénurie actuelle de main-d'œuvre en radiographie. Ainsi, des systèmes de soutien et des interventions urgentes au niveau institutionnel seraient nécessaires pour atténuer l'impact de la pandémie et améliorer l'expérience d'apprentissage des étudiants.

simulations as reported by Hazell et al. [15]) and coordinated preparation plans with university partners and hospitals for safe clinical teaching delivery following the resumption of student placements.

Earlier in the pandemic, Astirbadi and Lockwood [16] reviewed the literature (i.e.,  $n = 4$  original articles plus a commentary) to explore the impact of the pandemic solely focused on diagnostic radiography students and in most cases, with focussed discussions relating to the United Kingdom landscape. Similarly, Ng [17] reviewed some very early publications (i.e., original articles:  $n = 6$ , editorial:  $n = 1$  and commentaries:  $n = 4$ ) focused on adaptations implemented for radiography education and their effects on stakeholders. As the pandemic is quickly evolving and with consequent rapid changes to radiography education, a comprehensive review that broadly captures the impact of the pandemic on all radiography education stakeholders (i.e., both students and educators) is relevant as proposed by Ng [17]. This systematic review attempts to provide a comprehensive highlight from a global perspective (see Table 1) towards describing the impact of the COVID-19 pandemic on clinical radiography education, focusing on both students and educators from varied settings – low and high resource environments. Findings from this study may help in framework development for health education institutions to improve students learning and staff experience and to ensure appropriate skills are acquired for both students and academic staff in the post-COVID era.

## Methods

As done in our previous work, [18] a mixed-methods systematic review strategy was employed to integrate the available evidence to provide a global insight into the impact of the pandemic on the teaching and learning activities of key stakeholders of clinical radiography education. Thus, data were obtained from primary studies of varied methodological designs while following the Cochrane Collaboration guide [19] and the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement guidelines [20]. Due to the quickly evolving nature of the pandemic, the urgency, and the necessity of generating robust findings to inform innovative and safe radiography education strategies, we failed to register the review protocols *a priori*. Of note, ethical approvals are not requirements for literature reviews.

Table 1  
Descriptive characteristics of relevant research studies.

No.	Authors & year	Methods				Study Aim (s)	Key findings	Quality
		Country & Continent of study	Sample Characteristics	Data collection approach	Study period & Duration			
1.	Abuzaid, Elshami & Noorajan (2021)	United Arab Emirates, Asia	59 diagnostic radiography students	1. Online survey 2. Focus groups	March to June 2020	To assess the students' experiences and challenges of using the clinical practice e-portfolio during the COVID-19 outbreak.	<ul style="list-style-type: none"> <li>a. The e-portfolio helped the students to develop skills to evaluate their commitment to learning and education.</li> <li>b. The students reported technical issues that can be resolved by training and technical support, and self-troubleshooting skills.</li> </ul>	Moderate
2.	Cushen-Brewster et al. (2021)	United Kingdom, Europe	17 participants comprised 9 diagnostic and therapeutic radiography students, 6 practice educators, and 2 academics.	Semi-structured interviews and focus groups	September to October 2020	To explore the experiences of students who were in the temporary register.	<ul style="list-style-type: none"> <li>a. Working during the pandemic had some emotional impact on them, but they felt colleagues and managers supported them effectively, and it enabled them to recover. They felt appreciated and part of the team.</li> <li>b. They are more aware of their competence, which has helped improve their confidence as professionals.</li> <li>c. The constant use of PPE has been uncomfortable.</li> </ul>	Moderate
3.	Higgins, Murphy & Hogg (2020)	United Kingdom, Europe	32 diagnostic radiography students	Online survey	7-week period	To examine second-year students' cohort task value and self-efficacy of an online teaching experience.	<ul style="list-style-type: none"> <li>a. The online approach effectively scaffolds student learning and the development of research skills and applicability.</li> <li>b. It facilitates student-student and student-instructor interaction</li> </ul>	High
4.	Ogolodom et al. (2021)	Nigeria, Africa	119 postgraduate diagnostic radiography students	Survey	Not stated	To assess the impact of COVID 19 on students' academic progress	<ul style="list-style-type: none"> <li>a. The workload at their hospital has not affected their availability to engage in postgraduate studies. A delay in completing the programmes increases their expenses and loss of job opportunities.</li> <li>b. Recommended the use of online courses and clinical demonstrations to support future students.</li> </ul>	High
5.	Rainford et al. 2020	Multinational*	1277 diagnostic radiography students	Online survey	January to June 2020	To examine students' clinical placement views during the initial COVID-19 pandemic outbreak	<ul style="list-style-type: none"> <li>a. Student challenges were accommodation and travel concerns, personal health, family health, childcare and financial worries.</li> <li>b. Recommendation– the need for flexibility to support students.</li> <li>c. Effective communication with students about clinical placements and their assessments.</li> </ul>	High
6.	Courtier et al. (2021)	United Kingdom, Europe	11 therapeutic radiography students	Focus group discussions	May 2020	To explore the experience of students transitioning to practitioners during the pandemic	<ul style="list-style-type: none"> <li>a. Covid-19 was an additional issue to worry about aside from the anxiety of transitioning to a professional.</li> <li>b. Few of the students would have preferred a short break before starting the role.</li> <li>c. Felt valued as a health professional because of their contributions.</li> <li>d. Mixed identity- practitioner and student</li> </ul>	High

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Table 1 (continued)

No.	Authors & year	Methods			Study Aim (s)	Key findings	Quality	
		Country & Continent of study	Sample Characteristics	Data collection approach				Study period & Duration
7.	Strudwick et al. (2021).	United Kingdom, Europe	6 practice educators, and 2 academics (An equal proportion of diagnostic and therapeutic radiographers)	Focus groups and interviews	October to November 2020	To explore the experience of academics and practice educators supporting students that are transitioning to practitioners during the pandemic	<ul style="list-style-type: none"> <li>a. Competence and the transition to registration- students were motivated to help during the pandemic.</li> <li>b. Support was provided by the academics (virtual learning platform), practice educators and other radiographers to ensure the students were comfortable with what they were doing in practice.</li> <li>c. Cross organisational communication and the importance of communication in supporting mental wellbeing.</li> </ul>	Moderate
8.	Boabeng, Rockson & Badger (2021)	Ghana, Africa	476 diagnostic radiography students	Online survey	May to July 2020	To assess students' knowledge of COVID-19 and its effects.	<ul style="list-style-type: none"> <li>a. The majority of the participants 335 (74.6%), followed the relevant guidance for COVID-19.</li> <li>b. Most of the participants (<math>n = 407</math>, 85.5%) reported that their learning was affected by the University closure.</li> <li>c. A majority of the participants (<math>n = 236</math>, 49.6%) "Strongly agree" that imaging modalities should be used as a diagnostic tool for COVID-19.</li> </ul>	Moderate
9.	Lawson-Jones et al. (2021)	United Kingdom, Europe	201 diagnostic radiography students	Open-ended questionnaires	May to June 2020	To explore students' experiences during the COVID-19 pandemic	<ul style="list-style-type: none"> <li>a. Many of the participants expressed anxiety and fear. They also showed positive emotions as they were happy with their choice of career.</li> <li>b. The participants reported concern about the use of technology and coping with online learning.</li> <li>c. The participants stated that support from institutions, friends, and family helped alleviate their anxiety.</li> </ul>	High
10.	Alhasan & Al-Horani (2021)	United Arab Emirates, Asia	212 diagnostic radiography students	Online survey	Not stated	To assess students' perspectives on the online delivery of lectures during the COVID-19 pandemic	<ul style="list-style-type: none"> <li>a. The majority of the participants were aware of COVID-19. The knowledge increases with the increasing year of study and clinical experience.</li> <li>b. Some of the participants (52%) were satisfied with the online delivery method. They believe this approach is stressful and requires more self-study.</li> <li>c. The students reported that improved communication infrastructures, staff and student training on how to use the online platforms, and availability of online facilities might enhance their learning experience.</li> </ul>	Moderate
11.	Blackburn et al. (2021)	United Kingdom, Europe	5 newly qualified diagnostic radiographers	Interviews	June to July 2020	To explore the experience of student radiographers' transitioning into qualified radiographers during the COVID-19 pandemic.	<ul style="list-style-type: none"> <li>a. Staffing issues and increasing patient numbers were perceived to have resulted in a lack of formal training. However, increased responsibility quickly helped improve their confidence level.</li> <li>b. The use of PPE was uncomfortable and hindered communication with patients.</li> <li>c. Social and professional support eased their transition.</li> </ul>	Moderate

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Table 1 (continued)

No.	Authors & year	Methods				Study Aim (s)	Key findings	Quality
		Country & Continent of study	Sample Characteristics	Data collection approach	Study period & Duration			
12.	Gumede & Badriparsad (2021)	South Africa, Africa	14 diagnostic radiography students	Interviews	June to July 2020	To explore the experience of students of the online learning during COVID-19	<ul style="list-style-type: none"> <li>a. The students expressed anxiety as a result of the change to the online delivery method. They found the approach challenging as they were not able to interact effectively with their tutors.</li> <li>b. The shortage of resources with a lack of computer skills affects students' motivation toward online learning. They believe that the support provided by their lecturers in this period helped them with the transition to online delivery methods.</li> </ul>	High
13.	Ofori-Manteaw, Dzidzornu & Akudjedu (2021)	Ghana, Africa	277 diagnostic, therapeutic radiography students and 14 educators	Survey	December 2020 to March 2021	To assess the effects of the COVID-19 pandemic on clinical radiography education	<ul style="list-style-type: none"> <li>a. Poor internet connectivity</li> <li>b. Insufficient time for academic discussion</li> <li>c. The clinical departments were reluctant to accept students.</li> <li>d. The majority of the educators reported that the pandemic had affected their research output.</li> </ul>	Moderate
14.	Palmaria & Osmar (2021)	Canada, North America	8 radiotherapy students	Questionnaire	May to July 2021	To assess the impact of COVID-19 on the students' confidence and preparedness to attend clinical placement	<ul style="list-style-type: none"> <li>a. The use of workshops to introduce the clinical environment to students is useful in improving their experience.</li> <li>b. The use of masks made communication difficult.</li> </ul>	Moderate
15.	Webster & Clark (2020)	United States of America, North America	274 diagnostic and therapeutic radiography educators	Mixed method survey	May 2020	To explore Educators' experience regarding COVID-19 response	<ul style="list-style-type: none"> <li>a. A majority of the participants were comfortable with change their lecture delivery format.</li> <li>b. Some clinical sites were unable to allow students to complete their rotations. The participants had issues modifying their students' clinical placement experience.</li> <li>c. There were issues reported regarding PPE procurement.</li> </ul>	High
16.	Tay et al. (2020)	Singapore, Asia	45 diagnostic radiography students	Survey	March 2020	To explore students' concerns regarding resuming clinical placement	<ul style="list-style-type: none"> <li>a. The students were concerned about resuming clinical placement.</li> <li>b. Video conferencing platforms were used to check on students' progress and provide pastoral support.</li> <li>c. Simulation skill-based laboratory sessions were used to make up for the limited clinical experience.</li> </ul>	Moderate
17.	Ng (2020)	Australia, Oceania	48 diagnostic radiography students	Retrospective study	August 2020	To evaluate the academic integrity of the online open-book assessment.	<ul style="list-style-type: none"> <li>a. There was no academic integrity issue with the online open-book assessments.</li> </ul>	High

Legend: \* = Australia, Austria, Belgium, Denmark, Ireland, Italy, Netherlands, Singapore, Slovenia, South Africa, United Kingdom and the United States of America. The QATSDD assessment tool was employed for quality assessment to reduce the risk of bias. This tool comprised 16 quality criteria, with 14 apply to qualitative studies, 14 to quantitative studies and all 16 to mixed methods papers. Each criterion scores from 0 to 3. Using the descriptions for each score, each included article is scored from 0 to 3 on each item within a scoring grid. In order to compare the quality of the included articles, an average of the quality score is calculated and converted into percentage quality scores for all studies of the same designs as a group. The studies were categorised as high quality if an aggregate score is above 70% is achieved, moderate quality for those scored between 50 and 70%, and low quality for those scored less than 50%, as done previously in Akudjedu et al.<sup>17</sup>. These aggregate quality scores were not a part of the article exclusion criteria. The omission of studies with low aggregate scores could limit the review's global essence, since some findings relate specifically to certain geographical regions.

### *Eligibility criteria*

Articles were included if they were published in English and explored the impact of the COVID-19 pandemic on clinical radiography education in relation to students and/or educators. Publications on the topic of the following formats were excluded: opinion reports, preprints, commentaries/editorials, literature reviews and primary studies with a focus outside of radiography education and/or those with a relatively small percentage of radiography students as part of a larger sample.

### *Data sources and search strategy*

To minimize the risk of omitting relevant publications on the topic, a broad spectrum of key databases: PubMed, Science Direct, CINAHL (Cumulative Index of Nursing and Allied Health Literature, and SCOPUS were searched. In addition, the "COVID-19 article collection" of key radiography journals (including, Radiography, Journal of Medical Imaging & Radiation Sciences (JMIRS), Journal of Medical Radiation Sciences (JMRS) and Radiologic Technology) were manually searched for relevant publications. The reference list of relevant primary studies and review articles were also searched for other relevant publications which may have been missed. For each database, the search strategy included keyword terms, synonyms and Boolean operator qualifiers (OR, AND). The keywords included: ["Radiography" OR "Medical Radiation Science" OR "Radiologic Technology" OR "Radiotherapy" OR "Radiation Therapy" AND "education" OR "students" OR "educators" AND "COVID-19" OR "pandemic"] were employed for the search. To increase the sensitivity to the databases and minimize the risk of missing relevant studies, the search combinations were refined to include appropriate subject headings, abbreviations and/or truncated syntax in accordance with the specifications of each database as done previously by Akudjedu and colleagues [18]. Using this search strategy, two researchers (OL and TNA) carried out an independent electronic literature search to identify relevant articles from the 1st of July to the 21st of December 2021.

### *Data extraction and synthesis*

Microsoft Excel 2019 and the RefWorks (ProQuest) referencing software were used together to manage the screening process and search outputs, including removing duplicates. Two reviewers double screened the remaining studies independently using the titles and abstracts against the eligibility criteria. Any disagreements were debated over by the two reviewers (OL and DO) until a consensus was reached. A third reviewer (TNA) double-checks the process to ensure the search strategy was adhered to. The included papers were then screened for full-text inclusion against the eligibility criteria by the same reviewers. These results were again compared, and any disagreements were discussed, with the third reviewer having the final decision on their eligibility. Each excluded full text was accompanied by a justification as to its exclusion.

To reduce the risk of bias and ensure a consistent appraisal of the included studies, the Quality Assessment Tool for Studies with Diverse Designs (QATSDD) tool was employed to evaluate the studies as suggested by Sirriyeh and colleagues [21]. See Table 1 Legend for a detailed explanation of the use and application of the QATSDD tool to this study. Similarly, any differences in quality assessment scores were discussed among the research team. All the included studies were subjected to a data extraction process that included the completion of a template with fields to capture the study methods, aims and key findings. The data extraction was completed by one of the authors and reviewed by all research team members.

A results-based convergent synthesis approach was employed for the synthesis of the findings. Briefly, the findings from the different methodological studies identified in our search are presented in a tabular format and analysed separately. The extracted qualitative data was analysed thematically while employing textual narrative synthesis for the extracted quantitative data. After qualifying the quantitative data, both results were integrated and synthesised [22-24] into themes to highlight the findings further.

## **Results**

### *Search results*

A total of 3782 articles from databases - [PubMed: ( $n = 157$ ), Science Direct: ( $n = 1546$ ), CINAHL: ( $n = 43$ ), and SCOPUS: ( $n = 2036$ )] with others obtained from additional sources ( $n = 83$ ) from our initial search. Furthermore, a total of 3803 articles remained after the removal of duplicates, and these were screened by titles and abstracts. As detailed in Fig. 1, 69 full-text articles were assessed for eligibility and 29 were included for a discussion in a consensus meeting. A total of 17 articles fulfilled the search criteria and were included in this review.

### *Study characteristics*

The quality of the articles reviewed was assessed against the QATSDD criteria. The quality assessment exercise ranked the included articles from moderate to high. Six articles were conducted in Europe, four were in Africa, three in Asia, two in North America, one in Oceania, and one multinational study. The studies included six qualitative, nine quantitative, and two mixed-methods designs. A common limitation noted with all the included studies that employed a closed-ended questionnaire approach was the lack of the involvement of participants in developing the data collection tools [2,3,12]. However, they all had open-ended questions at the end of their questionnaires, which allowed participants to provide comments on issues that were not covered in the questionnaire. Thus, this limitation has less impact on the findings, as the participants had an opportunity to comment on issues that had not been addressed in the survey instruments [25]. The participants of the various included studies were current students, newly qualified radiographers, academics and practice educators. Eleven of the studies focused on diagnostic radiography students, two focused

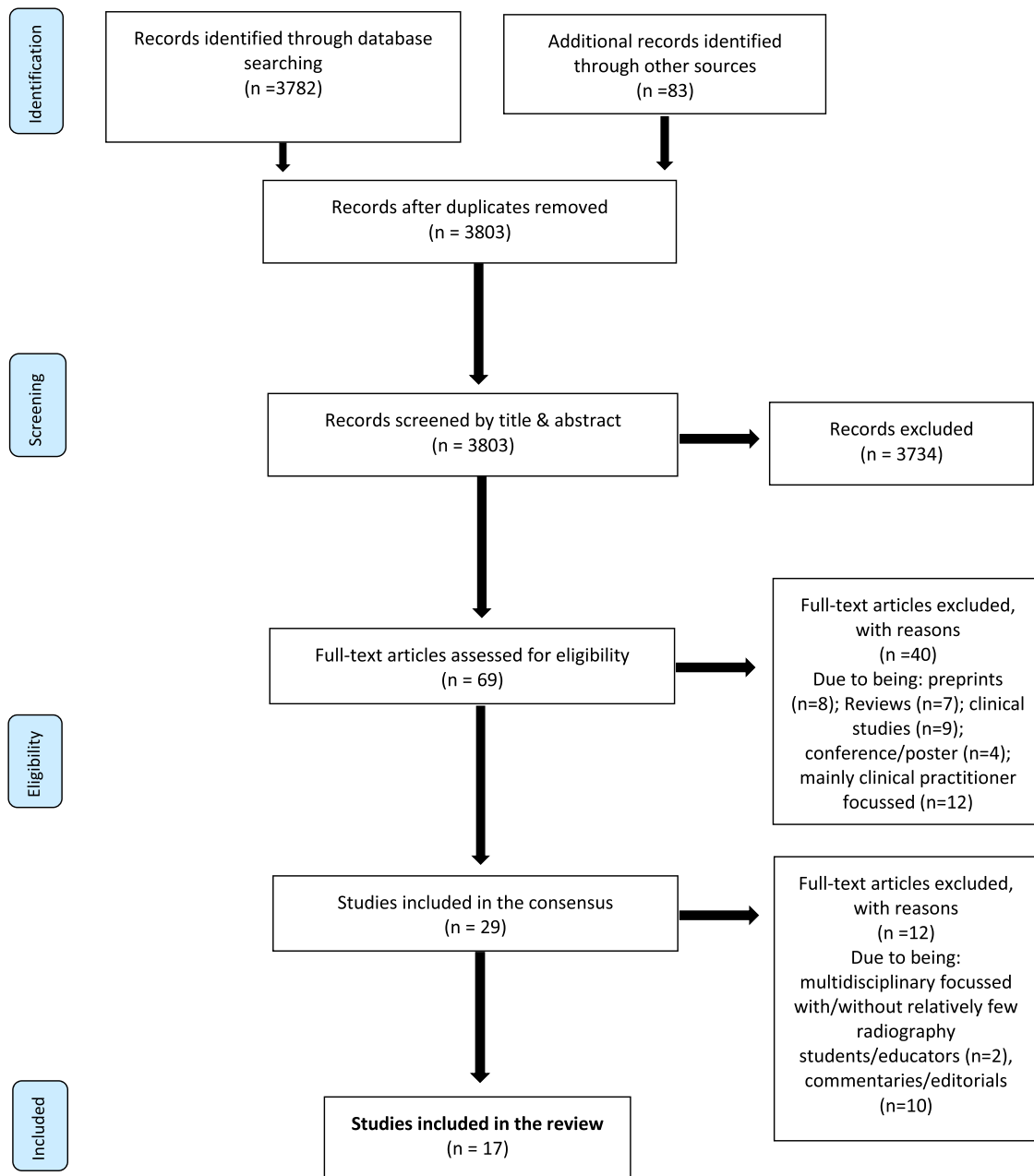


Fig. 1. PRISMA Flow diagram- search strategy.

on therapeutic radiography students, and four featured both groups of students, with some having educators as part of the sample (see Table 1).

#### Summary of the key findings

The findings of the articles were classified into two main themes; the introduction of new teaching and learning approaches and the challenges and resilience of students in the pandemic. A few benefits were associated with teaching and learning via the online platform, such as reduced cost and flex-

ibility. At the same time, the challenges include the struggle to use the platform effectively, increased stress levels and inadequate resources (in some settings).

Most of the papers showed that radiography students were willing to support the service delivery activities of the clinical departments where they were placed during the peak of the pandemic. However, the students were anxious due to the unprecedented nature of the pandemic, and they struggled to cope with the constant use of personal protective equipment whilst they were at the hospitals. These topics are discussed in greater depth in the subsequent section.



## Discussion

In this systematic review that explores the impact of the pandemic on clinical radiography education globally, the key findings are themed around challenges and benefits with the introduction of new teaching and learning approaches and resilience exhibited by students during the pandemic to overcome: insufficient support and mentorship while transitioning to fully qualified professionals, challenges with PPE usage and the impact on personal and academic life.

### *Theme 1: introduction of new teaching and learning approaches: benefits and challenges*

Most countries around the world introduced lockdowns to lower the spread of COVID-19 within their population. In order to continue learning while movement was restricted, higher institutions transitioned from face-to-face delivery to an online delivery format. The benefits identified by students include flexibility and reduced cost of transportation and living, as some students could study from home while living with family rather than renting accommodation closer to university [26,27]. Ng [28] showed that despite these flexibilities, standards of radiography education were maintained as online open-book assessments presented no issues relating to academic integrity. However, other studies show that learning via the online delivery method increased students' stress levels and anxiety [26,29-31].

The factors associated with the increased stress level are the inability to interact effectively with tutors, poor computer skills, and inadequate resources that prevailed critically in some settings. Notwithstanding, two studies [8,12] showed the effectiveness of the implementation of the online approach in the delivery of specific modules, as demonstrated by the students' good feedback. Of note, Abuzaid and colleagues [12] highlighted the need for improvement in communication infrastructure, at least in the United Arab Emirates for a good student and staff experience with online learning. It might be useful for institutions to train staff and students to improve their information technology (IT) skills and equip their institutions with high-quality communication equipment. The students believe that the support provided by their lecturers in this period helped them with the transition to online delivery methods. [29,32] This review recommends that improved communication infrastructure, staff and student training on how to use the online platforms, and availability of online facilities might enhance students' learning experience.

The only study conducted with postgraduate radiography students showed that even with the increased workload in their clinical roles, these professionals were concerned about their postgraduate studies and were not satisfied that there was no provision for studies to be transferred to the online format while there was lockdown [33]. They believed the delay in completing their programmes increased their expenses and could lead to missed career progression opportunities.

In place of clinical placement and practical laboratory practice, most clinical radiography training institutions employed

simulation sessions to augment students learning and make up for the required clinical hours for professional registration [13,34]. In a recent meta-synthesis [15] that explored the clinical readiness of students (including radiography students), the findings indicate that readiness was enhanced with increased use of simulation training. Thus, these findings strongly support the transition of learning and training to online formats during the pandemic to prepare students for clinical practice. Many students have had reduced clinical time during the pandemic, and these hours will need to be undertaken prior to graduation. This in itself is causing stress and concern for students in radiography education programmes in most parts of the world.

### *Theme 2: challenges and resilience of students in the pandemic: clinical placement and personal life*

In the COVID-19 pandemic, most radiography departments experienced staff shortages (as a result of illnesses, self-isolation and ongoing shortage issues) and increased patient influx [35,36]. Most studies [30,32,37,38] that explored the experience of radiography students on clinical placements during the pandemic showed that they were willing to support their clinical departments. This is highly commendable as it showed that they were genuinely interested in caring for others (patients). Also, the students believed that their contributions were valued by radiographers, managers, the government and members of the public [30,32,37,38]. This is consistent with findings from other studies among nursing [39] and medical students [40,41] in the United Kingdom during the pandemic. Consequently, the evidence, thus far, indicates that students could contribute to potentially reducing the workload burden on clinical radiography departments moving forward.

### *Subtheme 2a: student support challenges and the temporary register*

In some countries, for instance, in the United Kingdom and Australia, a temporary register was introduced for the registration of final year students with the respective professional regulatory bodies [42]. The students who were added to the temporary register found the transition challenging as they did not have as much support from staff or mentors as they would have had pre-pandemic due to the pressure on clinical departments [43]. However, they felt the experience helped improve their confidence in caring as well as supporting patients and competence in performing key radiological examinations. Mentorship support is important in helping newly qualified staff to develop their skills and understand how departments work [44]. Regular reflection activities could be used to complement the support the mentees might be getting from their mentors in order for them to develop as professionals effectively. In addition, this will help them cultivate a habit of independently identifying areas of their practice that are up to standard and aspects that needs improvement. Therefore, it is recommended that departments use the mentoring support approach combined with individual regular reflections on practice to support the staff new to their departments.

### *Subtheme 2b: use of personal protective equipment (PPE)*

The use of full PPE became mandatory in hospitals as an effort to reduce the spread of coronavirus from staff to patients or amongst colleagues [45,46]. Prior to the COVID-19 pandemic, staff only had to use the full PPE when they had a barrier nursed patient [47]. Students found the regular use of PPE uncomfortable, and it was a barrier to effectively communicating with patients [38,43,48]. This is similar to the findings of studies that assessed the opinion of other health professional trainees, as they also stated that communicating with patients and other colleagues was challenging in full PPE [49]. Thus, the need for an increased patient allocated time for clinical care examination and regular staff breaks are encouraged to manage staff and students' stress levels.

### *Subtheme 2c: anxiety as a result of the unprecedented pandemic*

Most of the studies (see Table 1) showed that students were anxious as they did not know what to expect from the government with regards to guidelines and the universities. The radiography students were concerned about the rapidly changing landscape around guidelines, supporting family and friends affected by COVID-19 and the impact of working alongside COVID-19 patients. However, it is worth mentioning that they felt that the support they had from their tutors, family, and friends helped alleviate this anxiety. There were reports that tutors provided one-on-one pastoral care sessions with students to help ease their anxieties [3].

Rainford and colleagues [2] reported that students were concerned about financial issues as well as accommodation and childcare. This is similar to the report by the Health Education England [50] that assessed the impact of COVID-19 on nursing and allied health students. Cushen-Brewster and colleagues [38] did not report this issue among the cohort of radiography students recruited in their study; however, this cohort was concerned about caring for patients with COVID-19. This might have been due to the financial support received by these students from the UK government at the time of that study. Radiology departments within the United Kingdom offered employment to most third-year students while still training as temporary staff during the pandemic. Thus, there is a need for financial support from various governments and educational institutions and/or clinical departments for students to lessen their burden and improve the student learning experience.

### **Limitations**

Despite the systematic nature of our literature search, it is possible that some studies might have been missed. The COVID-19 pandemic was still ongoing while this paper was written; thus, studies published since the search ended are not included. Therefore, an update might be required to include future studies. To lower the chances of missing relevant articles on the topic, an additional search was conducted in four

principal radiography journals, but articles published in non-radiography related journals might be difficult to find. We employed a robust synthesis methodology that allowed us to integrate findings of studies of varied designs. While this adds to the strength of this article, we acknowledge the associated limitation of this synthesis approach relating to the possibility of introducing changes to the interpretation/meaning of the data.

### **Conclusions**

This systematic review set out to explore the impact of the pandemic clinical radiography education globally. The COVID-19 pandemic has impacted radiography students' personal, clinical, and academic experiences. This was particularly around the rapid move to online learning and the impact of workload and staffing issues within the clinical settings, leading to inadequate placement opportunities. Students also experienced difficulties wearing PPE, which impacted communication, comfort, and increased their workload on placement. Of note, students exhibited resilience and rose above the pandemic-related challenges, and were willing to support their clinical placements and made valuable contributions to the care of patients.

In some cases, students joined temporary registration systems to enable them to work alongside their qualified colleagues. However, this early transition did cause some anxiety around the lack of support and mentorship, which are necessary for a smoother transition. Some students used this as an opportunity to improve upon their clinical confidence in practice before joining the workforce as fully qualified radiographers.

An ongoing concern is the impact on these students' mental health and well-being as they continue through the program and on to employment. The long-term impact on the mental health of health care students may take months to be fully recognised.

On a positive note, this global pandemic provided opportunities to upgrade educational modes of delivery and develop knowledge and competence in emerging technologies. It also resulted in the University staff re-evaluating delivery methods, curriculum content and placement opportunities. Globally, radiography students experienced several challenges, especially during the initial acute phase of the pandemic. The pandemic-related challenges identified in this review could negatively influence the radiography student attrition rates, consequently worsening the existing radiography workforce shortage. Thus, urgent institutional level support systems and interventions would be necessary to mitigate the pandemic impact and improve the student learning experience.

### **Recommendations**

Further research will be required to explore the long-term impact on the education of radiography students following the COVID-19 pandemic and the impact on postgraduate education.

Universities should further evaluate the requirements in relation to the impact of flexible education models in clinical/healthcare education, including radiography education. This would include evaluation of online learning platforms, online assessment methods and preparation of students for hybrid learning in higher education.

In addition, there will be a need for the government and universities to evaluate the impact of pastoral and mental health needs of students working through the pandemic and the development of health interventions that support the students in preparation for their ongoing academic progress and future careers. These interventions need to be culturally aware and time-sensitive.

## References

- [1] Ahmed H, Allaf M, Elghazaly. COVID-19 and medical education. *Lancet Infect Dis*. 2020;20(7):777–778.
- [2] Rainford LA, Zanardo M, Buissink C, et al. The impact of COVID-19 upon student radiographers and clinical training. *Radiography*. 2021;27(2):464–474.
- [3] Ofori-Manteaw BB, Dzidzornu E, Akudjedu TN. Impact of the Covid-19 pandemic on clinical radiography education: perspective of students and educators from a low resource setting. *J Med Imaging Radiat Sci*. 2021.
- [4] McNulty JP, England A, Shanahan MC. International perspectives on radiography practice education. *Radiography*. 2021.
- [5] Foley S, Paulo G, Vassileva J. Large differences in education and training of radiographers in Europe and Central Asia: results from an IAEA coordinated study. *Radiography*. 2021.
- [6] Toquero CM. Challenges and opportunities for higher education amid the COVID-19 pandemic: the Philippine context. *Pedagogic Res*. 2020;5(4).
- [7] Hill K, Fitzgerald R. Student perspectives of the impact of COVID-19 on learning. *All Ireland J High Educ*. 2020;12(2).
- [8] 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.
- [9] Higgins R, Murphy F, Hogg P. The impact of teaching experimental research online: research-informed teaching and COVID-19. *Radiography*. 2020;27(2):539–545.
- [10] Komlayut S. Assessing digital literacy skills using a self-administered questionnaire. *Rev Integrat Bus Econ Res*. 2017;6(3):74–85.
- [11] The Society of Radiographers. Improving retention of the radiotherapy workforce - the role of practice placements in student attrition from pre-registration programmes in England: executive summary and recommendations. 2013. Accessed online 28th of November 2021 at: <https://www.sor.org/learning-advice/professional-body-guidance-and-publications/documents-and-publications>.
- [12] Abuzaid MM, Elshami W, Noorajan Z. The impact of clinical practice e-portfolio in radiology education during COVID-19 outbreak. *Int J Cur Res Rev*. 2021;13(6):115.
- [13] Tay YX, Sng LH, Chow HC, Zainulidin 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):560–566.
- [14] Short M, Giles E. Innovative strategies implemented by universities to support medical radiation science students during the COVID-19 pandemic. *J Med Radiat Sci*. 2021.
- [15] Hazell L, Lawrence H, Friedrich-Nel H. Simulation based learning to facilitate clinical readiness in diagnostic radiography. A meta-synthesis. *Radiography*. 2020;26(4):e238–e245.
- [16] Astirbadi D, Lockwood P. COVID-19: a literature review of the impact on diagnostic radiography students. *Radiography*. 2021.
- [17] Ng CK. A review of the impact of the COVID-19 pandemic on pre-registration medical radiation science education. *Radiography*. 2021.
- [18] Akudjedu TN, Mishio NA, Elshami W, et al. The global impact of the COVID-19 pandemic on clinical radiography practice: a systematic literature review and recommendations for future services planning. *Radiography*. 2021;27(4):1219–1226.
- [19] Higgins J, Thomas J, Chandler J, Cumpston M, Li T, Page M. *Cochrane Handbook for Systematic Reviews of Interventions version 6.1. 2020 (updated September 2020)*. Cochrane; 2020 Accessed online 28th of November 2021 at: [www.training.cochrane.org/handbook](http://www.training.cochrane.org/handbook).
- [20] Moher D, Liberati A, Tetzlaff J, Altman DG, Group Prisma. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6(7):e1000097.
- [21] 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):746–752.
- [22] Noyes J, Booth A, Moore G, Flemming K, Tunçalp Ö, Shakibzadeh E. Synthesising quantitative and qualitative evidence to inform guidelines on complex interventions: clarifying the purposes, designs and outlining some methods. *BMJ Global Health*. 2019;4(Suppl 1):e000893.
- [23] Sandelowski M, Voils CI, Barroso J. Defining and designing mixed research synthesis studies. *Res Sch*. 2006 Spring; 13 (PMID: 20098638; PMID: PMC2809982): 29.
- [24] Sandelowski M, Voils CI, Leeman J, Crandell JL. Mapping the mixed methods-mixed research synthesis terrain. *J Mix Methods Res*. 2012;6:317–331. doi:10.1177/1558689811427913.
- [25] Beatty PC, Collins D, Kaye L, Willis GB, Wilmot A, Padilla JL. *Advances in Questionnaire Design, Development, Evaluation and Testing*. John Wiley & Sons; 2019 Incorporated.
- [26] Alhasan M, Al-Horani Q. Students' perspective on the online delivery of radiography & medical imaging program during COVID-19 pandemic. *J Med Imaging Radiat Sci*. 2021;52(4):S68–S77.
- [27] Currie G, Hewis J, Nelson T, et al. COVID-19 impact on undergraduate teaching: medical radiation science teaching team experience. *J Med Imaging Radiat Sci*. 2020;51(4):518–527.
- [28] Ng KKC. 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):610–616.
- [29] Gumede L, Badriparasad N. Online teaching and learning through the students' eyes – Uncertainty through the COVID-19 lockdown: a qualitative case study in Gauteng province, South Africa. *Radiography*. 2021.
- [30] Lawson Jones G, York H, Lawal O, Cherrill R, Mercer S, McCarthy Z. The experience of diagnostic radiography students during the early stages of the COVID-19 pandemic—a cross-sectional study. *J Med Radiat Sci*. 2021.
- [31] Boabeng G, Rockson P, Badger E. Perspective on Covid-19 pandemic among medical imaging students in Ghana. *Int J Innov Sci Res Technol*. 2021;6(4):163–173.
- [32] Strudwick RM, Cushen-Brewster N, Doolan C, Driscoll-Evans P. An evaluation of the experiences of academics and practice educators who supported radiography students working on the temporary HCPC register during the COVID-19 pandemic. *Radiography*. 2021.
- [33] Ogolodom MP, Mbaba AN, Nwodo VK, Ohagwu CC, Chiegwu HU. The impact of Covid-19 pandemic on academic and professional development programmes organised by the radiographers registration board of Nigeria. *J Biomedical Sci*. 2021;10(1):47.
- [34] Webster TL, Clark KR. haCOVID-19 Planning among radiologic science programs: response mitigation activities. *Radiol Technol*. 2020;92(2):100–112.
- [35] Akudjedu TN, Lawal O, Sharma M, et al. Impact of the COVID-19 pandemic on radiography practice: findings from a UK radiography workforce survey. *BJR| Open*. 2020;2:20200023.
- [36] Sim WY, Chen RC, Aw LP, et al. How to safely and sustainably reorganise a large general radiography service facing the COVID-19 pandemic. *Radiography*. 2020;26(4):e303–e311.

- [37] 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*. 2021;27(2): 316–321.
- [38] Cushen-Brewster N, Strudwick RM, Doolan C, Driscoll–Evans P. An evaluation of the experiences of radiography students working on the temporary HCPC register during the COVID-19 pandemic. *Radiography*. 2021.
- [39] Roca J, Canet-Vélez O, Cemeli T, Lavedán A, Masot O, Botigué T. Experiences, emotional responses, and coping skills of nursing students as auxiliary health workers during the peak COVID-19 pandemic: a qualitative study. *Int J Ment Health Nurs*. 2021.
- [40] Rainbow S, Dorji T. Impact of COVID-19 on medical students in the United Kingdom. *Germes*. 2020;10(3):240–243. doi:10.18683/germes.2020.1210.
- [41] Rolak S, Keefe AM, Davidson EL, Aryal P, Parajuli S. Impacts and challenges of United States medical students during the COVID-19 pandemic. *World J Clin Cases*. 2020;6(15):3136–3141 8.
- [42] The Health and Care Professionals Council. *Our approach to Closing the COVID-19 Temporary Register(s)*; 2021 Accessed online 28th of November 2021 at: <https://www.hcpc-uk.org/covid-19/temporary-register/our-approach-to-closing-the-covid-19-temporary-registers/>.
- [43] Blackburn NE, Marley J, Kerr DP, Martin S, Tully MA, Cathcart JM. Transitioning into the workforce during the COVID-19 pandemic: understanding the experiences of student diagnostic radiographers. *Radiography*. 2021.
- [44] The Society of Radiographers. *Mentoring: Guidance and Advice*; 2009 Accessed online 28th of November 2021 at [https://www.sor.org/getmedia/a169f208-0f06-47e0-afd4-3bef34908fa4/Mentoring\\_%20Guidance%20and%20advice](https://www.sor.org/getmedia/a169f208-0f06-47e0-afd4-3bef34908fa4/Mentoring_%20Guidance%20and%20advice).
- [45] Yan C, Lin J, Xu Y. Recommendations for coronavirus disease 2019 (COVID-19) prevention and infection control in the radiology department: chinese experience. *Clin Imaging*. 2021;69:33–36.
- [46] Zanardo M, Martini C, Monti CB, et al. Management of patients with suspected or confirmed COVID-19, in the radiology department. *Radiography*. 2020;26(3):264–268.
- [47] Abdelrahman MA, Alhasan M, Alewaidat H, Rawashdeh MA, Al Mousa DS, Almhdawi KA. Knowledge of nosocomial infection control practices among radiographers in Jordan. *Radiography*. 2017;23(4):298–304.
- [48] Palmaria C, Osmar K. COVID-19 stories of success: teaching and learning in a clinical setting during a pandemic. *J Med Imaging Radiat Sci*. 2021;52(4):505–510.
- [49] Dragomir GM, Fărcașiu MA, Șimon S. Students' Perceptions of Verbal and Non-Verbal Communication Behaviors during and after the COVID-19 Pandemic. *Appli Sci*. 2021;11(18):8282.
- [50] The Health Education England. *The Impact of COVID-19 on Students' Survey –Key Findings*; 2021 Accessed online 28th of November 2021 at: <https://www.hee.nhs.uk/our-work/reducing-pre-registration-attrition-improving-retention>.