Received: 30 July 2021 | Revised: 23 December 2021 | Accepted: 16 January 2022

DOI: 10.1111/jcal.12653

ARTICLE

Journal of Computer Assisted Learning WILEY

A systematic scoping review and textual narrative synthesis of physical and mixed-reality simulation in pre-service teacher training

Gordon O. Ade-Ojo | Marianne Markowski | Ryan Essex | Marlon Stiell | Jill Jameson

School of Health Sciences, Institute for Lifecourse Development, Centre for Workforce Development, Faculty of Education, Health and Human Sciences, University of Greenwich, London, UK

Correspondence
Gordon O. Ade-Ojo, School of Health Sciences, Institute for Lifecourse Development, Centre for Workforce Development, Faculty of Education, Health and Human Sciences, University of Greenwich, Avery Hill Campus, London SE9 2UG, UK.
Email: g.o.ade-ojo@greenwich.ac.uk

Abstract

Background: Due to recent lockdown conditions, which restricted opportunities for face-to-face contact and the ability to be physically in schools, the need for novel, safe ways to train pre-service teachers emerged even more pressingly. Whilst virtual simulation has received some attention in pedagogy and its benefits have been demonstrated in many disciplines, there appears to be less synthesized evidence on the use of physical and/or mixed-reality simulation utilized in teacher training.

Objectives: The goal of this systematic scoping review was to summarize and synthesize the literature on the use of physical and/or mixed-reality simulation in pre-service teacher training.

Methods: A systematic scoping literature review combined with a textual narrative synthesis was undertaken. Ten reference databases were searched in May 2020: Academic search premier, CINAHL, Education Research Complete, Humanities International Complete, Psychology and Behavioural Sciences Collection, PsycInfo, Teacher Reference Center, Science Direct, Web of Science and Scopus.

Results and Conclusions: Following inclusion/exclusion criteria assessment and screening, 13 articles were included for appraisal and synthesis. Seven papers examined physical simulations, while the remainder examined mixed-reality simulations. The evidence from this review suggests that simulation, including physical and mixed-reality types, could be used as a tool to increase confidence, self-efficacy, classroom management skills and communication.

Implications: In comparison to other fields (e.g., nursing, medicine and aviation) simulation in education appears to be in its infancy—more large-scale research is needed. At the same time, this review indicates that mixed-reality simulation in particular has the potential for contributing to teacher education, because it offers the potential for learning in various contexts when compared to traditional didactic teaching practices.

KEYWORDS
initial teacher training, mixed-reality simulation, physical simulation, pre-service teacher training

1 | INTRODUCTION

Simulation in education is often defined in the context of its feature of placing students/learners in real-life situations. Essentially, simulation is seen as an approach to teaching that utilizes the process of creating a replica of real-life situations in order to develop students' response to such a situation if and when confronted with it in their actual practice. This view of simulation in education is encapsulated in Kim et al. (2016) who define simulation as 'the pedagogical approach of providing students with the opportunity to practice learned skills in real-life situations' (Kim et al., 2016, p. 152). Although simulation has been used across a range of disciplines, including STEM (e.g. Campos et al., 2020) and a range of health-related disciplines (Jackson et al., 2020), in initial teacher education (ITT), the use of simulation is far less common. Progressively, however, there has been a growing interest in its potential in education, including its use with teacher trainees and as a means to train qualified teachers.

Teacher training programmes in the UK have a placement component, which requires trainee teachers to be placed in institutions in order for them to be directly involved in school settings and with real-life students. In many cases, that period of attachment ranges between 24 and 32 weeks (Department for Education, 2021). In relation to the placement component of teacher training, simulation has a number of potential applications and advantages over traditional classroom-based placements. Among these are the 'ability to repeat scenarios with specific learning objectives, practice for longer periods than are available in real life, use trial and error, experience rare or risky situations, and measure outcomes with validated scoring systems' (Kaufman & Ireland, 2019), its benefit as a preparatory tool pre-class (Badiee & Kaufman, 2014) and its contribution to the development of teacher trainees' interpersonal development (Clark et al., 2016). A systematic review of literature that examined computer-based simulation used in pre-service teacher training (Theelen et al., 2019) concluded that most studies in this review 'identified the positive impact of simulation on specific aspects of trainee teachers' development such as classroom management and teaching skills. While the literature is not explicit on how simulation actually improves the training experience of trainee teachers, there is an indication that much of the recorded improvement is seen as induced by the follow-up reflective discussions after trainees' engagement with simulation activities. Typifying this view, Sotille and Brozik (2004) note that 'The most important part of the scenario was the debriefing that occurred after the judges reached a decision' (Sotille & Brozik, 2004, p. 2). In essence, simulation induces development, not only through participation, but also through the follow-up process of thinking about the engagement. It is this process that defines the learning to be gained for both trainee and trainer. Crucial to this process are the elements of immediacy and repetitiveness (Kim et al., 2016). This means that simulation enables both the learner and the teacher to identify progress and gaps in the skills to be gained.

The need to explore and utilize the advantages associated with simulation is more pressing in the context of contemporary situation induced by the pandemic. Because of the pandemic, there are now a number of contemporary and practical concerns that make the need to explore the use of simulation in teacher training even more urgent. The pandemic has limited the opportunity for trainee teachers to engage with their traditional placement opportunities. While schools are taking their classrooms online and/or offer remote learning and teaching during the pandemic, teacher training education does not seem to have been adequately prepared to fully embrace the technological possibilities that are offered with the use of simulation. While the readily available alternative of online teaching and learning has become the replacement for face-to-face teaching and learning, there is some measure of uncertainty about the quality of the teachers being produced under the circumstances, with employing schools hesitant about the readiness of recent graduates to take on the challenges of teaching. Anecdotal evidence suggests that the rate of employment of newly graduated trainee teachers might be lower than previous rates at the same time of the year. It is in the context of this development that alternatives such as simulation become crucial.

Simulation is often explored within the framework of typology or, at least, features of its different forms. Such explorations have focused largely on three key features: physical as against virtual simulation (e.g. Hirt & Beer, 2020; Pottle, 2019), level of fidelity ranging from low through medium to high fidelity (e.g. Beaubien, 2004; Howard, ; Munshi et al., 2015) and similarities and differences between simulation and serious games (e.g. Crookall, 2010). Studies exploring the relationship between simulation and fidelity have tended to explore the potential significance of the level of fidelity for the efficacy of simulation, with some concluding that the level of fidelity has no real impact on the effectiveness of simulation (e.g. Massoth et al., 2019) and others that the impact remains controversial (e.g. Munshi et al., 2015). Connolly et al. (2008) note that 'serious games have been developed for the broader purposes of training and behaviour change in business, industry, marketing, healthcare and government NGOs as well as in education (Sawyer & Smith., 2008)'. 'Serious games' therefore have a 'serious' intention, as Krath et al. (2021) observe, based on 'the idea of using positive gameful experiences for the sake of a serious purpose, for example, education or behaviour change, rather than focusing on entertainment.' To fulfil the educational outcomes of 'serious games' (Zhonggen, 2019), game-based mechanisms are designed with pedagogical aims. There is some overlap between simulations and serious gaming, but broadly speaking simulations create scenario-based environments that may or

may not include gaming elements (Lamb et al., 2018; Vlachopoulos & Makri, 2017).

Another typology, virtual reality (VR) simulation involves utilizing the potentials offered by technological advancement in the use of software 'to create an immersive simulated environment' (Pottle, 2019, p. 181). One of the hallmarks of virtual reality simulation is the use of immersive gadgets such as virtual reality headsets or VR 3D glasses because these locate users 'inside an experience, where they can engage with the environment and virtual characters in a way that feels real' (Pottle, 2019, p. 181). In essence, the real defining feature of VR is 'from immersion and the sense of presence—the feeling of 'being there'—that it generates' (Gutiérrez et al., 2007; Makowski et al., 2017; Pottle, 2019, p. 181). This contrasts with the type of simulation that utilizes physical presence such as in the use of role-play, which, although it also aims to use the creation of real-life experience to stimulate learning, relies more heavily on the involvement of human participants. Overall, virtual simulation is presented as an emerging but powerful tool, which can facilitate the achievement of specific learning goals (Pottle, 2019).

Slightly related to VR is augmented reality (AR) in simulation. Whereas VR provides a dynamic view of structures and the ability of the user to interact with them, AR provides the ability of projecting virtual information and structures over physical objects, thus enhancing or altering the real environment (Pantelidis et al., 2018, p. 77). Essentially, AR draws on technological advancement to enhance the physical context. According to Pantelidis et al. (2018), p. 78), 'AR differs from VR as its target is not to construct a fully artificial environment but to overlay computer-generated images onto images of the real world'. AR, therefore, aims to incorporate the physical environment, at least visually, but in a form that is enhanced through the deployment and integration of virtual images. Arguably, this can promote fuller or better engagement of the learner.

Another simulation type emerges from pulling together the features of virtual and physical simulations and is often referred to as mixed-reality simulation. Mixed-reality simulation is simulation where real and simulated environments are combined in such a way virtual and real objects interact with each other in real time (Cohen et al., 2020; Milgram & Kishino, 1994). Evidence from the literature suggests that mixed reality simulation, when targeted at the development of specific skills, tends to be fruitful. For example, Cohen (2020, p.208) mixed simulation with coaching and found that it 'had significant and large improvements on skills relative to those who only reflected on their teaching. The study also observed significant coaching effects on candidates' perceptions of student behaviour and ideas about next steps for addressing perceived behavioural issues' Cohen (2020, p.210). Studies such as the above give a hint that mixed simulation might hold some potential for effective use in teacher education.

Considerations of the use of VR in general and also those with a view to pedagogy and pedagogical environments had already noteworthy attention (Hamilton et al., 2021; Renganayagalu et al., 2021; Sauvé et al., 2007; Theelen et al., 2019); hence, this systematic scoping review focuses on physical and mixed-reality simulations to address the gap in literature. Existing literature reviews on virtual simulations have reviewed the use of VR for the last thirty years and pointed toward VR's usefulness in training cognitive skills, such as spatial memory, learning and remembering procedures and psychomotor skills (Hamilton et al., 2021; Renganayagalu et al., 2021) and its underuse in professional training (Renganayagalu et al., 2021).

The ongoing sets out clearly that there are variations to the structure of stimulation and that these variations inform the different ways in which educators have engaged with simulation. It is from these recorded variations that one central and two subsidiary research questions for this review emerge.

2 | METHOD

2.1 | Aims and objectives

The aim of this systematic scoping review was to summarize and synthesize the literature on the use of simulation in pre-service teacher training. Our objectives were to explore the academic literature around simulation that has been utilized in pre-service teacher training by gathering the research aims, scope, methodological approaches, the type of simulation and whether there is evidence that identified simulation types could be utilized for teacher training.

Our central research question is: Is there any evidence that different simulation types, different features of simulation or a combination of simulation features can facilitate its use in the development of teacher education? Related to this are two subsidiary questions: What does the literature tell us about the effectiveness of simulation in replacing face-to-face elements of initial teacher training (ITT) and, to what extent can simulation facilitate the comprehensive delivery of ITT without or in combination with the face-to-face element? Answers to these questions will enable teacher educators and their institutions to develop strategies for delivering quality ITT education in the face of obstacles such as the ones presented by COVID-19.

2.2 | Design

Given the above aims, a scoping review that employs a systematic search to scan the literature and to provide a synthesis was utilized with the aim "to map the literature on a particular topic or research area and provide an opportunity to identify key concepts; gaps in the research; and types and sources of evidence to inform practice, policymaking, and research" (Pham et al., 2014, p. 373). Based on Arksey and O'Malley's (2005) original framework, this involved the following steps: (1) identification of area of interest, (2) literature search to identify relevant studies, (3) study selection, (4) data charting by extracting data in tabular (or graphical) format for the purpose of data synthesis and (5) data summary and write-up (Arksey & O'Malley, 2005; Pham et al., 2014). This review follows a data-based convergent synthesis design employing the textual narrative synthesis approach. That is, both

qualitative, quantitative and mixed-methods studies were identified in a single search, integrated throughout analysis, synthesis and presentation (Lucas et al., 2007; Noyes et al., 2019). The PRISMA-ScR guidelines (Tricco et al., 2018) and Joanna Briggs's scoping review protocol have been followed (Peters et al., 2020).

2.3 | Search methods

Ten reference databases were searched: Academic search premier, CINAHL, Education Research Complete, Humanities International Complete, Psychology and Behavioral Sciences Collection, PsycInfo, Teacher Reference Center, Science Direct, Web of Science, Scopus. Preliminary search terms were developed to reflect a number of the core concepts, these related to the population of interest (pre-service teachers) and simulation. The final search terms used were ("student teachers" OR "teach* train*" OR "preservice teacher" OR "pre-service teacher" OR "undergraduate teach*" OR "teach* education") AND ("simulation-based" OR "simulation based learning" OR simula* OR virtual). The final search was carried out in May 2020. Results were collated and duplicate articles were removed. A Research Assistant carried out an initial review of the articles, removing results were obviously irrelevant or that did not meet our inclusions criteria (see Section 2.4).

2.4 | Inclusion/exclusion criteria

A total of 78 studies were retained. The reference lists of these studies were search, resulting in a further 86 results. These 164 articles were assessed against the following inclusions/exclusion criteria (see Figure 1 PRISMA diagram).

2.5 | Inclusion

- The study used simulation to evaluate or develop a teaching skill or was used as a pedagogical tool
- Participants in the study were teacher-trainees
- The study included physical elements of simulation (i.e. role play, physical props) or mixed-reality simulations. For our purposes a simulation was considered mixed-reality if it blended physical and virtual/digital element, such as virtual environments where other students acted as avatars consistent with (Lindgren et al., 2016)
- The study was peer reviewed and primary research
- The article was written in English with an available full-text version

2.6 | Exclusion

- Conference abstracts
- Studies that utilized simulation, that did not aim to develop the teaching skills of participants, that is studies that reviewed the usability of simulations
- Studies that were published before the year 2010
- Studies that included serious games/gaming as opposed to simulation (Sauvé et al., 2007)
- Studies that utilized online environments that were not purposefully designed for teacher education (i.e. Second Life)
- Studies that utilized computer-based simulation, where there was no physical input from others (i.e. computer based simulations that were automated).

Against the above criteria, 13 studies were included in the review and analysis (see Figure 1, PRISMA flow diagram).

2.7 | Data extraction

Data from the included studies was extracted by three authors (Redacted for review purpose) and categorized according to the source, country of where the research took place, study aims and objectives, research methods/design and sample information, participants, measures of analysis, main outcomes, and quality appraisal scores and issues (see Table 1, data extraction).

2.8 | Quality appraisal

Two researchers (redacted for review) independently assessed 13 full-text articles using the Mixed Methods Appraisal Tool (MMAT), Version 2018 (Hong et al., 2018). Articles were segregated according to whether they were of quantitative (descriptive; non-randomized; randomized), qualitative or mixed-methods design and assessed using the criteria for their category within the tool.

2.9 | Data summary and synthesis

Studies were combined to summarize descriptive statistics of the study characteristics, followed by a textual narrative synthesis (Lucas et al., 2007). This approach arranges disparate study types into more homogenous sub-groups, which aids in the synthesizing of different types of evidence. Study characteristics, context, quality, and findings are reported according to a standard format, and similarities and differences are compared across studies (Lucas et al., 2007).

3 | RESULTS

3.1 | Quality appraisal results

Overall, the quality of the studies in this review varied substantially (Figure 2, appraisal diagram). The qualitative studies had the highest quality, with the mixed methods studies having the lowest overall quality. For the qualitative studies, most shortcomings related to the results of these studies being substantiated by data. For the mixed methods studies, deficits were identified across a number of domains. No studies had effectively integrated the different components of

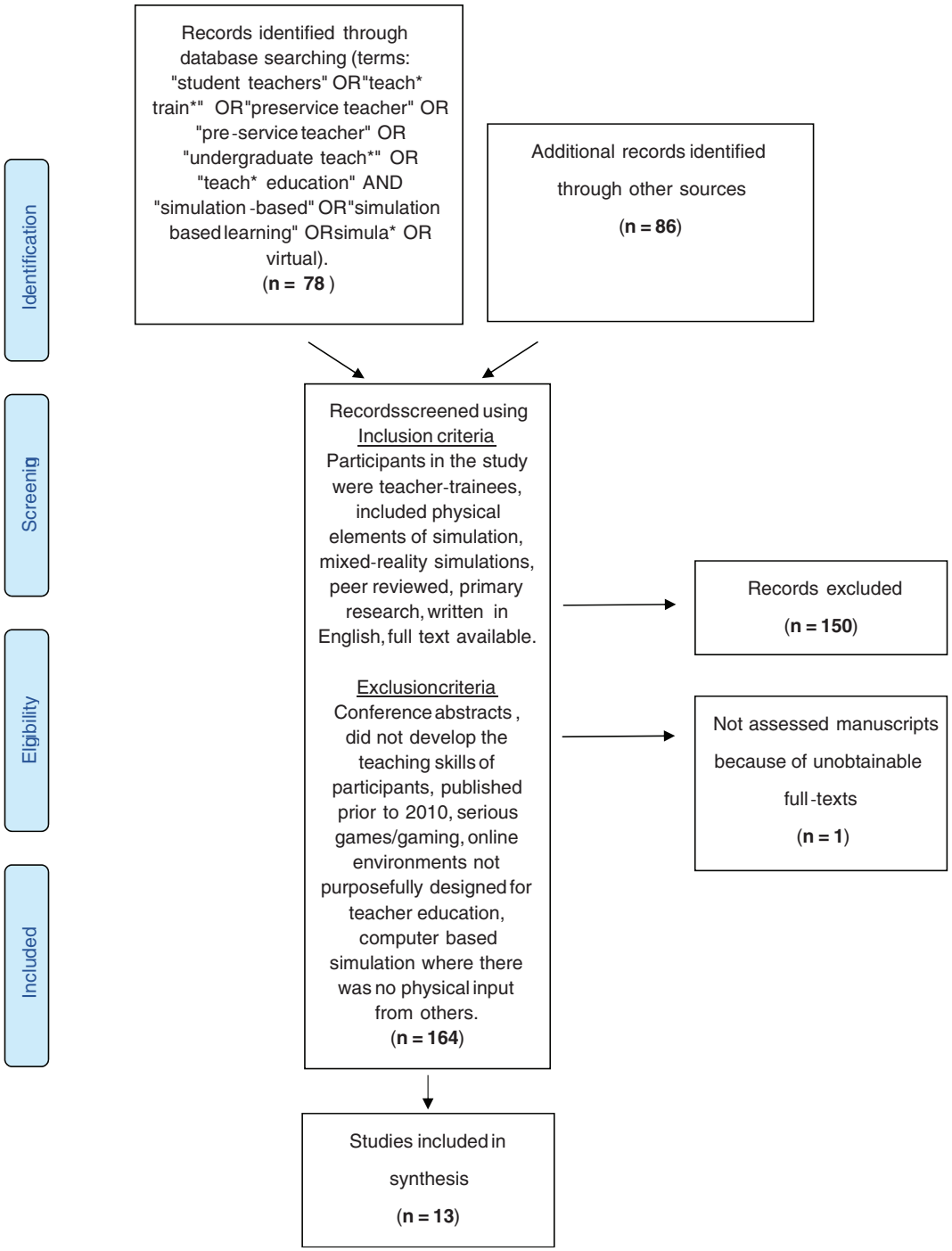

FIGURE 1 Prisma Flow diagram

their study, while very few had provided a rationale for using mixed methods or adequately interpreted the results of the study. The one quantitative study, failed to report baseline characteristics of its participants (Gundel et al., 2019).

3.2 | Combined study descriptive results

Of the 13 papers included in this review, eight used qualitative methods (Amador, 2017, 2018; Baghurst, 2014; Dalinger et al., 2020; Dotger et al., 2015; Hume, 2012; Piro & O'Callaghan, 2019; Zach & Ophir, 2020), four used mixed methods (Bautista & Boone, 2015; Ferguson, 2017; Ledger et al., 2019; Peterson-Ahmad, 2018), while one article employed quantitative methods (Gundel et al., 2019). The studies took place in six different locations with the majority taking place within the USA (9), Australia (1), Canada (1), Israel (1) and New Zealand (1). The combined number of participants within the qualitative studies was 112 with Amador (2018) not stating sample size. The total number for the quantitative population is 53 and the combined mixed-methods sample population was 457. The earliest

TABLE 1 Summary of studies included in review

Author	Year	Country	Sample	Type of simulation	Study aims	Methods/design	Measurement/analysis	Outcomes	Quality appraisal score
Amador	2017	USA	Pre-service teachers ($n = 19$)	Physical—video recording and role play	This study examined a video simulation task in a mathematics teacher education course to engage preservice teachers in considering both the teaching and learning aspects of mathematics lesson delivery	Qualitative	Thematic analysis	Results indicate that preservice teachers primarily focus on classroom elements and the teacher when viewing the simulation content, which raises questions for how to support an emphasis on students' mathematical thinking	3/5
Amador	2018	USA	Pre-service teachers' ($n =$ not stated)	Physical—video recording and role play	This study explored a self-created scripted video simulations in which preservice teachers designed, acted in and filmed mathematics classroom scenarios. The intent was to understand how preservice teachers perceived the process and how they worked through the video simulation process	Qualitative	Thematic analysis	Preservice teachers considered the technology use beneficial and valued learning from the experience, thus showing promise for incorporating video simulations in teacher education programmes	4/5
Baghurst	2014	USA	Pre-service teachers ($n = 9$)	Physical—role play of student with disability	In this study, participants completed an assignment in which they were expected to live out and simulate a randomly chosen disability for a 24-h period. The purpose of this intervention was to provide students with a better appreciation and understanding of disabilities	Qualitative—participants recorded their experiences and wrote a reflective journal	Thematic analysis	Students' experiences resulted in statements supporting the learning of outcomes specific to teaching students with disabilities in the future as well as an overall greater appreciation of disabilities	5/5
Bautista & Boone	2015	USA	Early childhood education pre-service teachers' ($n = 62$)	Mixed—TeachLivE	This study investigated the impact of a mixed-reality teaching environment on early childhood education majors' science teaching self-efficacy beliefs	Mixed methods—survey and guided journal entries	The Science Teaching Efficacy Beliefs Instrument-b (STEBI-b). Thematic analysis	The results of this study suggest that this simulation is a worthwhile technology for learning to teach in teacher education. It enables pre-service teachers to improve their understanding and confidence related to teaching science	1/5
Dalinger et al.	2020	USA	Pre-service teachers ($n = 13$)	Mixed—Mursion TeachLive	This study explored the experiences of preservice teachers who participated in a session with mixed-reality simulation	Qualitative—interviews	Thematic analysis	Participants considered the mixed-reality simulation a more authentic form of practice than what their observations during field experiences afforded. Participants perceived transfer	5/5

TABLE 1 (Continued)

Author	Year	Country	Sample	Type of simulation	Study aims	Methods/design	Measurement/analysis	Outcomes	Quality appraisal score
								of learning from observations of peers during sessions with the mixed-reality simulation to performance during their own sessions. Some participants perceived increased confidence in applying skills practiced during the simulation to work with live students and parents	
Ferguson	2017	Canada	Pre-service teachers ($n = 65$)	Physical—Role play (students as actors)	This article presents the use of simulations as a method of instruction for teaching preservice teachers about reading assessment	Mixed methods—survey with quantitative and qualitative elements	Researcher developed questionnaire and thematic analysis	Overall, the assessment simulation activity was highly valued by preservice teachers and was a significantly different learning experience about literacy and assessments than they had experienced previously. Preservice teachers felt that they learned more about literacy and literacy assessments through the simulation than they had through other teaching methods	1/5
Gundel, et al.	2019	USA	Pre-service teachers ($n = 53$)	Mixed—Mursion TeachLive	The purpose of this study was to examine the effects of mixed-reality simulations on preservice teachers' sense of self-efficacy	Quantitative—quasi-experimental design	Teachers' sense of efficacy scale (Tschannen-Moran & Hoy, 2001)	Continued exposure within mixed-reality simulations may develop teaching self-efficacy. However, an initial drop in teaching self-efficacy occurring after 30 mins of exposure to the simulations was noted, which may warrant focused support	4/5
Hume	2012	New Zealand	Students in an optional second year teacher education science course ($n = 11$)	Physical—role play	This study sought to investigate an innovation involving a sustained simulation in an undergraduate science education course as a mediational tool to connect two communities of practice—initial teacher education and expert primary science teaching	Qualitative	Activity theory	Findings from the first trial indicate that the simulation was very effective in initiating science pedagogical content knowledge (PCK) development of primary student teachers	4/5
Ledger et al.	2019	Australia	Pre-service teachers ($n = 322$)	Mixed—Mursion TeachLive	This study sought to capture and classify preservice teachers' (PSTs) preferred teaching strategies and teaching confidences in conjunction with	Mixed methods		Results showed a positive impact of reflective practice and revealed that most preservice teachers preferred 'Questioning' and 'Direct Instruction' methods	4/5

(Continues)

TABLE 1 (Continued)

Author	Year	Country	Sample	Type of simulation	Study aims	Methods/design	Measurement/analysis	Outcomes	Quality appraisal score
					their levels of teaching quality while interacting in TeachLivE™ simulations			of delivering micro-teaching lessons. The authors offer a typology of teaching strategies, confidences and a quality measure for teacher educators	
Zach & Ophir	2020	Israel	Physical education student teachers' ($n = 23$)	Physical—role play	This study examined the influence of simulation on flexible and reflective thinking in student teachers (STs), and appraised how they evaluate its potential contribution to teacher education programs	Qualitative—video analysis and written reflections	Content analysis	Participants not only increased their flexible and reflective thinking, but they gained an understanding of how to do it independently. As they were learning how to be more open-minded, they were able to feel, think, and behave authentically, and to over a variety of solutions regarding conflictual situations	5/5
Peterson-Ahmad	2018	USA	Pre-service, special educaiton teachers ($n = 8$)	Mixed—TeachLive	This study investigated the extent to which virtual simulations combined with instructional coaching impacted the way pre-service educators learned how to provide opportunities to respond (OTR) to the avatar students through the repeated teaching of a lesson over four sessions	Mixed methods—quasi experimental. Observation and self-reflection	Researcher developed measures and thematic analysis	Providing opportunities for pre-service special educators to practice such strategies within a virtual simulation environment offers teacher preparation programs a way to individualize the teaching and practice of various pedagogical aspects needed when new educators enter their first classroom. Coupling such simulations with specific instructional coaching allows for increased and individualized remediation of the way instruction is given, classroom management practices, or getting to know your student population	0/5
Piro & O'Callaghan	2018	USA	Pre-service teachers ($n = 29$)	Mixed—TeachLivE	This study explored liminal learning in a teacher education program that used mixed-reality simulations prior to and within clinical placements	Qualitative—video data	Thematic analysis	The integration of mixed-reality simulations within initial teacher preparation core courses facilitated the journey of preservice teachers toward professional identities as they faced instructional and behavioural challenges over the course of three semesters	5/5

TABLE 1 (Continued)

Author	Year	Country	Sample	Type of simulation	Study aims	Methods/design	Measurement/analysis	Outcomes	Quality appraisal score
Dotger et al.	2015	USA	Undergraduate teacher trainees ($n = 6$), graduate teacher trainees ($n = 2$)	Physical simulation	This study describes and evaluates a mathematics simulation, reporting data from prospective mathematics teachers' interactions with a standardized student on the issue of iconic interpretation	Qualitative—survey response, video data and group debrief	Not stated, however all data was 'coded' and analysed	Results explore participant decision making within the simulation	5/5

study was published in 2012, however most studies were published from 2017 onwards.

3.3 | Textual narrative synthesis results

3.3.1 | Physical simulation

The seven studies that utilized or evaluated physical simulation employed a diverse range of approaches to simulation and studied a range of outcomes. While one study utilized a relatively novel approach (Baghurst, 2014), all other studies that utilized physical simulation, used role-play like scenarios. Overall, these studies suggest that simulation could be used as a tool to enhance a range of teacher trainees' skills and knowledge.

Ferguson (2017) utilized simulation as a means to develop teacher trainees' skills related to reading assessment. The simulation used was a type of role-play that is, students wrote a script for a fictional student and then acted out the roles of students and teachers related to reading assessment. Students indicated that they found this experience helpful and novel. Among other benefits students suggested that the simulation helped them develop teaching and learning strategies for reading and develop empathy for readers. Participants also reported an increase in confidence in being able to conduct reading assessment. Similarly, Hume (2012) also engaged a role-play like simulation. That is, teacher trainees participated in lessons as students and then reflected on their learning experiences and the actions of their 'teacher' (the course lecturer). The majority of participants found value in the simulation, gaining insight into the teacher (lecturers) pedagogic strategy. Other benefits included increased confidence about teaching with the simulation providing a means to reflect on some of the potential issues they may face as teachers in the classroom. Dotger et al. (2015) also employed a role-play like simulation. Actors played the role of students while teacher trainees took on the role of a mathematics teacher. This study also provided positive results in trainees' development of diagnostic, explanatory, mathematical, and instructional repertoires. The stimulation also helped illuminate the teacher trainees' knowledge, abilities and areas that needed improvement. Amador (2017) developed a video simulation Task which required pre-service teachers to engage in tasks to create three simulations, leading to collaborative activities, which developed both the delivery of teaching and learnings aspects with reference to mathematics. The activities required that participants played the role of both teacher and student in recorded videos, which were scripted. Each participant in turn viewed the simulated videos of other participants over the course of several weeks. The findings of this study suggest that preservice teachers primarily focus on the classroom elements when teaching, that is, the lessons are structured according to how they believe discussion is facilitated, whereas viewing the simulation from the student perspective, participants were able to analyse the contents of the created simulations to consider specific teacher comments and behaviours in a classroom setting. Overall, results suggest that pre-service teachers had trouble in viewing learning from a

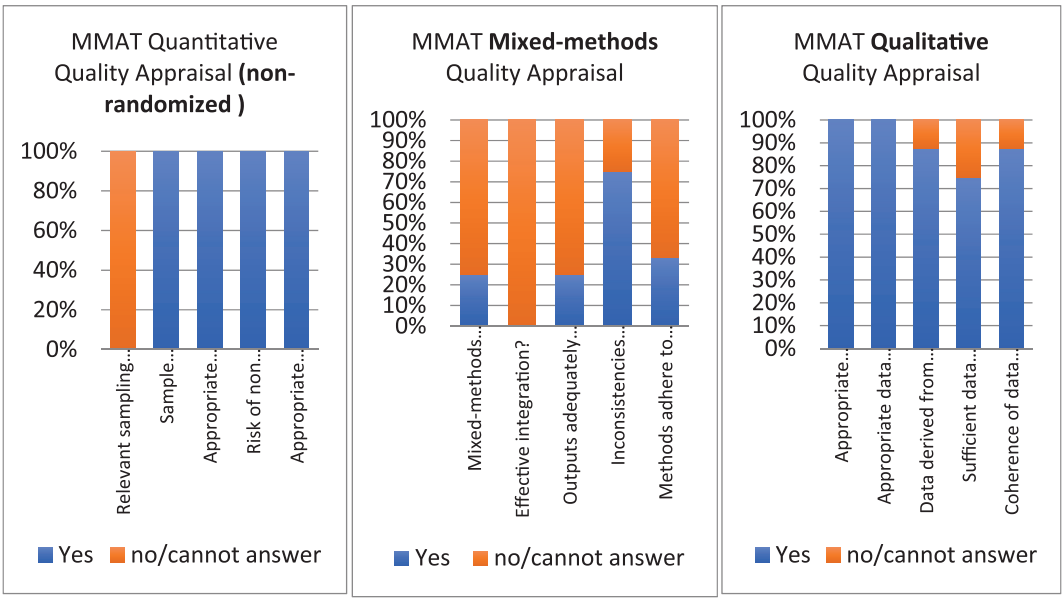

FIGURE 2 Quality appraisal diagram

student's perspective. In a follow-up study, Amador (2018) explored pre-service teachers' perception of the process of creation and collaboration of a scripted video simulation process. Preservice teachers considered the technology to be beneficial in developing pedogeological skill and as well as developing a better understanding of the student's perspective. This study's main finding is the use of video simulation tasks could be incorporated into teacher education programmes. Zach & Ophir (2020), took a similar approach. In this study students, who were physical education teacher trainees, were briefed on a scenario, which they then acted out. This scenario was recorded and then presented to the class for discussion. The student in the scenario then offered further reflections on their involvement in the simulation. The results of this study suggest that this simulation not only increased participants' flexible and reflective thinking but also helped them gain an understanding of how to do this independently. Baghurst (2014) also engaged physical education teacher trainees, but in a very different way. This study sought to explore how simulated experience of living with a disability would affect nine physical education teacher trainees' awareness of living with a disability. Participants completed an assignment in which they were expected to live out and simulate a randomly chosen disability for a 24-h period. The simulated disabilities included blindness (use of a blindfold), loss of dominant arm/hand function (arm in sling), loss of leg function (use of a wheelchair), and loss of speech. A major theme that emerged from this data was how this experience would inform future teaching, with multiple participants noting they had a better understanding of living with a disability and how difficult life could be made day to day.

3.3.2 | Mixed-reality simulation

Five studies utilized mixed-reality simulation that is simulation where real and simulated environments were combined in such a way virtual and real objects interacted with each other in real time (Milgram & Kishino, 1994). The simulation types utilized by the studies in this category all used the simulated virtual environment TLE TeachLivE, which is specifically designed for the educational development of preservice teachers. In this context, it is important to note that in 2015, the US research team of TLE TeachLivE entered a private public partnership with *Mursion* to licence the commercial rights to develop further the simulator technology (Ferrante, 2017).

Bautista and Boone (2015) explored the use of 'The TLE TeachLivE simulation software. The TLE TeachLivE is a mixture of virtual computer created environment and "puppetry" where teachers play the role of students in the simulation. This study assessed levels of self-efficacy in preservice teachers as well as its usefulness in teacher training education. The use of the mixed simulated environment provided a means to generate a highly individualized and tailored experience. Levels of self-efficacy and understanding about science teaching improved with the anticipation that this learning could be translated to a physical classroom environment. Likewise, Gundel et al. (2019) focussed on the effects of a mixed-reality simulation on preservice teachers' self-efficacy, utilizing TeachLive. Repeated exposure to the simulation found that self-efficacy initially decreased before showing an overall increase by the end of the study in keeping with the results obtained by Bautista and Boone (2015) and that the use of these types of simulation help pre-service teachers develop their "professional identities" whilst managing challenging scenarios.

Peterson-Ahmad (2018) also used TLE TeachLivE alongside "live" instructional coaching to assess the usefulness of such practices in developing teaching strategies and pedagogical thinking. Participants were also required to reflect on the experience and the role of instructional coaching in the development of their teaching. The results suggest that repeated exposure to mixed-reality environments helped to develop teaching practice and self-efficacy, which is

in keeping with the previous studies in this review, which utilized TeachLive. Dalinger et al. (2020) incorporated the Mursion TLE TeachLive software into their teacher education programme and sought to examine its effectiveness prior to teachers delivering live sessions with students. Thirteen participants were recruited, and a qualitative analysis revealed four themes. Participants stated that the mixed-reality simulation offers more learning affordances than those offered through the traditional observations during field experiences. The participants recognized where the transfer of learning occurred from the observation of their peers during simulated sessions with TeachLive. Some participants expressed an increase in their level of confidence when applying skills practiced during the simulation and transferring this to real classroom settings. Piro and O'Callaghan (2019), also focused on the participants' experience of using the TeachLive simulation and focused on the processes involved in learning and interacting with the TeachLive software. The findings from this study suggest the that participants underwent experiences reflective of the behaviour of pre-service teachers such as troublesome learning characterized by mimicry when in the presence of others. As participants continued to interact with the simulation, they became more confident and were able to improvise and language more consistent with their profession. Ledger et al. (2019) intended to measure preservice teachers' (PSTs) preferred teaching strategies, record participants personal reflection when engaging with simulated teaching environments, their confidences, and PST ability to transfer knowledge to the physical space whilst using the Mursion TeachLive simulation. Results showed that pre-service teachers adopted 'Questioning' and 'Direct Instruction' strategies whilst using the simulation. Teachers who were orientated to student focused strategies tended to possess high levels of self-efficacy, and increased competence. Ledger et al. (2019) suggest that these students could be further supported by a range of teaching strategies such as microteaching and reflective practice, which could be applied in conjunction with PST educational programmes to support their confidence.

Overall, the message emerging from these studies is that mixed-reality simulation offers the potential for greater learning affordances in various contexts when compared to the traditional practice, which is limited to promoting similar learnings through observation during field experience or placements.

4 | DISCUSSION

Before discussing the summary of our findings from these studies, it is important to highlight our views about the quality of the studies. This is important in the context of the potential for generalization and replicability that this study can induce. As shown in our quality appraisal (See Figure 2), the quality of studies varied substantially with qualitative studies generally of higher quality and mixed methods studies reflecting deficits. This calls for a level of caution in responding to the findings of this review.

The studies that explore the use of simulation in pre-service teacher training suggest that simulation can be used as a tool to develop pre-service teacher skills in a safe and controlled fashion. The studies reported improvements in specific areas such as confidence, self-efficacy and communication among other skills. A further benefit of simulation noted in a number of studies was that it allowed students to reflect on their behaviour within a classroom setting; results were seen across both physical and mixed-reality simulations. This provides an indication that simulation has a huge potential for contributing to the delivery of ITT as it has been demonstrated in other areas such as health and engineering. The challenge is how teacher educators might draw on this potential to develop a comprehensive simulation-informed teacher education delivery.

It is notable in our results that only one software, namely TeachLive, offers the possibility of mixed-reality simulations in pre-service teacher education. In fact, during the literature search other software were identified such as SIMschool (Christensen et al., 2011), SIMUl@b (Dominguez Garcia et al., 2017), DTkid (Randell et al., 2007) and Classroom SIM (Bradley & Kendall, 2014). However, research with pre-service teachers to evaluate or develop a teaching skill or when it was used as a pedagogical tool had not been carried out and therefore not included in this literature scoping review. About those excluded studies it is noteworthy to mention that the execution of simulated students or the environment was ultimately not convincing to those participants in the studies. Hence the use of mixed-reality simulations, where fellow pre-service trainee teacher play the counter part in the simulation are likely to be more convincing than a fully automated simulation, which at the current state of development seems to repeat predictable phrases and actions. This limitation, however, should not deter educators from exploring the potential use of simulation including automated simulation. The range of simulation options simply highlights the possibility of taking an eclectic approach, which should harness the strengths available in individual types or in a combination of different types of simulation.

Considering the online learning and teaching conditions during the recent pandemic it is inevitable to include more technology in the pre-service teacher training studies. Firstly, to expose the pre-service trainee teachers to similar experiences school pupils have recently endured and therefore develop a holistic albeit reflective view of the learning cycle. Secondly, to protect trainees and their teachers in any other emergency situations. Thirdly, in the world of remote learning, the learning experience itself can be a lonely experience, but by employing mixed-reality simulation or physical simulation played out with online video connectivity tools such as Zoom© or Skype©, the interaction with fellow pre-service teachers will provide a sense of collaboration and human connectivity. The latter point is likely to support mental health and well-being of any learners. In spite of this tremendous advantage, we neither prioritize nor express a preference for an exclusive use of online and digital only learning tools and their positive features such as 24-h accessibility.

Another notable finding of this review is the complete absence of reported academic research around physical and mixed-reality simulation research in the UK, or at least the results did not qualify to be included in this review. Education research in the UK and in fact in any other country has now the opportunity to contribute

fundamentally with the advancement of this topic in the field of education. That is not only by producing and creating tools for pre-service teacher trainees, but also by leading a critical discussion on developing frameworks for integration into the curricula, addressing ethical concerns and by specifying the opportunities in where simulation can make best difference in teacher training. This can be achieved by learning from other disciplines and their experiences, as experienced in nursing, paramedic science, medicine and aviation, for example, where simulation has been successfully integrated in the curricula to provide students with safe learning environments and where reality like scenarios can be repeated and practiced. German researchers, for example, have recently shown concerted effort in developing a framework and research agenda for facilitating diagnostic competences in simulations in medical and teacher education (Heitzmann et al., 2019). Education as a field can tap into these rich resources, academically and practically, to learn from their research and experience to avoid costly mistakes.

5 | CONCLUSION

Simulation in education appears to be a promising way to train pre-service teachers, having a number of practical and pedagogical advantages over traditional teaching placements. The evidence from this review suggests that simulation could be used as a tool to increase confidence, self-efficacy, classroom management skills and communication. In saying this however and in line with the broader literature, simulation in education appears to be in its infancy, with few large scale, high quality studies and a lack of conceptual clarity.

On this point, a number of major limitations should be noted in relation to this review. The literature is relatively small, and with the studies explored, there are few large scale high quality studies. Because of this, we suggest that the results should be interpreted with caution. Furthermore, there appears to be a number of fundamental areas that deserve greater investigation such as simulation fidelity. On this point, few studies outlined how they determined or defined fidelity and a number of the reviewed studies that self-identified as simulation could also be considered as essentially of the physical type such as role play. This speaks to a more fundamental need, namely that conceptual research is needed into simulation in education, how to conduct a simulation and what fidelity means in this context. This appears to be largely consistent with the findings of another systematic review (Theelen et al., 2019), which examined computer-based classroom simulations, that is, while studies reported that simulation had mostly positive effects, there were few large-scale studies as evidenced with this review in which 10 of the 15 studies that were included were case studies.

In relation to our research question, 'Is there any evidence that different simulation types, different features of simulation or a combination of simulation features can facilitate its use in the development of teacher education? ', there is evidence that simulation types, particularly the mixed simulation variety, do have the potential for contributing to teacher education. The obvious limitation highlighted in this study is the limited experimentation with the various simulation types. In our view, this might constitute a form of missed opportunity. COVID-19 and the attendant lockdown has presented us with a vision of what the future might look like in an emergency such as this - the removal of face-to face learning context. In such a situation, we suggest that simulation will come to its own. Given what the literature revealed, we argue that the evidence suggests that different simulation types have the potential to offer replacements for various aspects of face-to-face teacher education. It is, therefore, important that the potential effectiveness of simulation be explored further, and concerted efforts be made to develop teacher education programmes into which different forms of simulation are embedded.

Regarding our subsidiary questions: 'What does the literature tell us about the effectiveness of simulation in replacing face to face elements of ITT and, to what extent can simulation facilitate the comprehensive delivery of ITT without or in combination with the face-to-face element?' the literature does not offer us any conclusive evidence in answering these subsidiary questions. While there is evidence of targeted skill development, there is little to enable us to make judgements in terms of the comprehensive delivery of teacher education. In a way, this speaks to the paucity of studies in teacher education in the context of simulation and may be seen as an indication of the limited engagement of teacher trainers with this opportunity. It might ultimately be sounding a clarion call for professionals in the field of teacher education to begin to engage more robustly with this option.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conception of manuscript, *drafting and editing of manuscript*: Gordon O. Ade-Ojo. *Literature review*, *data extraction & presentation*, *review and editing of manuscript*: Marianne Markowski. *Literature search & review*, *data extraction & presentation*, *critical appraisal*, *editing of manuscript*: Ryan Essex. *Literature review*, *data extraction*, *editing of manuscript*: Marlon Stiell. *Literature appraisal*, *review of manuscript*: Jill Jameson.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/jcal.12653.

DATA AVAILABILITY STATEMENT

Reaseach data are not shared.

ORCID

Gordon O. Ade-Ojo https://orcid.org/0000-0002-1098-0765

REFERENCES

Amador, J. (2017). Preservice Teachers' video simulations and subsequent noticing: A practice-based method to prepare mathematics teachers. *Research in Mathematics Education*, *19*(3), 217–235.

Amador, J. (2018). Video simulations to develop preservice mathematics teachers' discourse practices. *Technology*, *Pedagogy and Education*, *27*(1), 1–14.

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology*, *8*(1), 19–32.

Badiee, F., & Kaufman, D. (2014). Effectiveness of an online simulation for teacher education. *Journal of Technology and Teacher Education*, *22*(2), 167–186.

Baghurst, T. (2014). Encouraging disability appreciation among physical education, teacher education students through practical simulation. A Pilot Study. *Palaestra*, *28*(4), 44–47.

Bautista, N., & Boone, W. (2015). Exploring the impact of TeachME™ lab virtual classroom teaching simulation on early childhood education Majors' self-efficacy beliefs. *Journal of Science Teacher Education*, *26*(3), 237–262.

Beaubien, J. M. (2004). The use of simulation for training teamwork skills in health care: How low can you go? *Quality & Safety in Health Care*, *13*(suppl_1), 51–56.

Bradley, E. G., & Kendall, B. (2014). A review of computer simulations in teacher education. *Journal of Educational Technology Systems*, *43*(1), 3–12.

Campos, N., Nogal, M., Caliz, C., & Juan, A. A. (2020). Simulation-based education involving online and on-campus models in different European universities. *International Journal of Educational Technology in Higher Education*, *17*(1), 8.

Christensen, R., Knezek, G., Tyler-Wood, T., & Gibson, D. (2011). SimSchool: An online dynamic simulator for enhancing teacher preparation. *International Journal of Learning Technology*, *6*(2), 201–220.

Clark, D. B., Tanner-Smith, E., & Killingsworth, S. (2016). Digital games, design, and learning. *Review of Educational Research*, *86*(1), 79–122.

Cohen, J., Wong, V., Krishnamachari, A., & Berlin, R. (2020). Teacher coaching in a simulated environment. *Educational Evaluation and Policy Analysis*, *42*(2), 208–231.

Connolly, T. M., Stansfield, M. H., & Hainey, T. (2008). *Development of a general framework for evaluating games-based learning*. In Proceedings of the 2nd European conference on games-based learning. Universitat Oberta de Catalunya, .

Crookall, D. (2010). Serious games, debriefing, and simulation/gaming as a discipline. *Simulation & Gaming*, *41*(6), 898–920.

Dalinger, T., Thomas, K., Stansberry, S., & Xiu, Y. (2020). A mixed reality simulation offers strategic practice for pre-service teachers. *Computers & Education*, *144*, 103696.

Department for Education. (2021). *Guidance: Initial teacher training (ITT): Criteria and supporting advice*. DFE.

Dominguez Garcia, S., Sanromà-Giménez, M. & Mogas Recalde, J. (2017). Simul@b. 3D simulations laboratory for the digital competence for teachers development. Jornada d'investigadors Predoctorals Interdisciplinania (JIPI). 8th Feb 2017 Barcelona.

Dotger, B., Masingila, J., Bearkland, M., & Dotger, S. (2015). Exploring iconic interpretation and mathematics teacher development through clinical simulations. *Journal of Mathematics Teacher Education*, *18*(6), 577–5601.

Ferguson, K. (2017). Using a simulation to teach Reading assessment to preservice teachers. *The Reading Teacher*, *70*(5), 561–569.

Ferrante, D. 2017. Kickin' it new school. A cutting-edge classroom simulator at UCF is helping educators become better teachers. Pegasus The Magazine of the University of Central Florida.

Gundel, E., Piro, J. S., Straub, C., & Smith, K. (2019). Self-efficacy in mixed reality simulations: Implications for preservice teacher education. *The Teacher Educator*, *54*(3), 244–269.

Gutiérrez, F., Pierce, J., Vergara, V. M., Coulter, R., Saland, L., Caudell, T., Goldsmith, T., & Alverson, D. (2007). The effect of degree of immersion upon learning performance in virtual reality simulations for medical education. In J. D. Westwood (Ed.), *Medicine meets virtual reality 15* (pp. 155–160). IOS Press.

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*, *8*(1), 1–32.

Heitzmann, N., Seidel, T., Hetmanek, A., Wecker, C., Fischer, M. R., Ufer, S., Schmidmaier, R., Neuhaus, B., Siebeck, M., Stürmer, K., Obersteiner, A., Reiss, K., Girwidz, R., Fischer, F., & Opitz, A. (2019). Facilitating diagnostic competences in simulations in higher education a framework and a research agenda. *Frontline Learning Research*, *7*(4), 1–24. https://doi.org/10.14786/flr.v7i4.384

Hirt, J., & Beer, T. (2020). Use and impact of virtual reality simulation in dementia care education: A scoping review. *Nurse Education Today*, *84*, 104207.

Hong, Q. N., Fàbregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., … Pluye, P. (2018). The mixed methods appraisal tool (MMAT) version 2018 for information professionals and researchers. *Education for Information*, *34*(4), 285–291.

Hume, A. C. (2012). Primary connections: Simulating the classroom in initial teacher education. *Research in Science Education*, *42*(3), 551–565.

Jackson, B. N., Brady, A., Friary, P., Braakhuis, A., Sekula, J., & Miles, A. (2020). Educator–student talk during interprofessional simulation-based teaching. *BMJ Simulation and Technology Enhanced Learning*, *6*(4), 206–213.

Kaufman, D., & Ireland, A. (2019). Simulation as a strategy in teacher education. In *Oxford research encyclopedia of education*. Oxford University Press.

Kim, J., Park, J., & Shin, S. (2016). Effectiveness of simulation-based nursing education depending on fidelity: A meta-analysis. *BMC Medical Education*, *16*, 152.

Krath, J., Schürmann, L., & von Korflesch, H. F. O. (2021). Revealing the theoretical basis of gamification: A systematic review and analysis of theory in research on gamification, serious games and game-based learning. *Computers in Human Behavior*, *125*, 106963. https://doi.org/10.1016/j.chb.2021.106963

Lamb, R. L., Annetta, L., Firestone, J., & Etopio, E. (2018). A meta-analysis with examination of moderators of student cognition, affect, and learning outcomes while using serious educational games, serious games, and simulations. *Computers in Human Behavior*, *80*, 158–167. https://doi.org/10.1016/j.chb.2017.10.040

Ledger, S., Ersozlu, Z., & Fischetti, J. (2019). Preservice teachers' confidence and preferred teaching strategies using TeachLivE™ virtual learning environment: A two-step cluster analysis. *EURASIA Journal of Mathematics, Science and Technology Education*, *15*(3), 1–17.

Lindgren, R., Tscholl, M., Wang, S., & Johnson, E. (2016). Enhancing learning and engagement through embodied interaction within a mixed reality simulation. *Computers & Education*, *95*, 174–187.

Lucas, P. J., Baird, J., Arai, L., Law, C., & Roberts, H. (2007). Worked examples of alternative methods for the synthesis of qualitative and quantitative research in systematic reviews. *BMC Medical Research Methodology*, *7*(1), 4.

Makowski, D., Sperduti, M., Nicolas, S., & Piolino, P. (2017). 'Being there' and remembering it: Presence improves memory encoding. *Consciousness and Cognition*, *53*, 194–202.

Massoth, C., Röder, H., Ohlenburg, H., Hessler, M., Zarbock, A., Pöpping, D. M., & Wenk, M. (2019). High-fidelity is not superior to low-fidelity simulation but leads to overconfidence in medical students. *BMC Medical Education*, *19*(1), 29.

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems*, *77*(12), 1321–1329.

Munshi, F., Lababidi, H., & Alyousef, S. (2015). Low- versus high-Fidelity simulations in teaching and assessing clinical skills. *Journal of Taibah University Medical Sciences*, *10*(1), 12–15.

Noyes, J., Booth, A., Moore, G., Flemming, K., Tunçalp, Ö., & Shakibazadeh, E. (2019). Synthesising quantitative and qualitative evidence to inform guidelines on complex interventions: Clarifying the purposes, designs and outlining some methods. *BMJ Global Health*, *4*-((Suppl 1)), e000893.

Pantelidis, P., Chorti, A., Papagiouvanni, I., Paparoidamis, G., Drosos, C., Panagiotakopoulos, T., Lales, G., & Sideris, M. (2018). In G. Tsoulfas (Ed.), *Virtual and augmented reality in medical education, in medical and surgical education—Past, present and future* (pp. 77–97). IntechOpen. https://doi.org/10.5772/intechopen.71963, https://www.intechopen.com/chapters/58199

Peters, M., Godfrey, C., McInerney, P., Munn, Z., Trico, A., & Khalil, A. (2020). Scoping reviews. In *JBI Manual for Evidence Synthesis*. JBI.

Peterson-Ahmad, M. (2018). Enhancing pre-service special educator preparation through combined use of virtual simulation and instructional coaching. *Education in Science*, *8*(1), 10.

Pham, M. T., Rajić, A., Greig, J. D., Sargeant, J. M., Papadopoulos, A., & McEwen, S. A. (2014). A scoping review of scoping reviews: Advancing the approach and enhancing the consistency. *Research Synthesis Methods*, *5*(4), 371–385.

Piro, J., & O'Callaghan, C. (2019). Journeying towards the profession: Exploring liminal learning within mixed reality simulations. *Action in Teacher Education*, *41*(1), 79–95.

Pottle, J. (2019). Virtual reality and the transformation of medical education. *Future Healthcare Journal*, *6*(3), 181–185.

Randell, T., Hall, M., Bizo, L., & Remington, B. (2007). DTkid: Interactive simulation software for training tutors of children with autism. *Journal of Autism and Developmental Disorders*, *37*(4), 637–647.

Renganayagalu, S., Mallam, S. C., & Nazir, S. (2021). Effectiveness of VR head mounted displays in professional training: A systematic review. *Technology, Knowledge and Learning*, *26*, 999–1041.

Sauvé, L., Renaud, L., Kaufman, D., & Marquis, J. S. (2007). Distinguishing between games and simulations: A systematic review. *Educational Technology & Society*, *10*(3), 247–256.

Sawyer, B., & Smith P. (2008). Keynote address. In *The second European conference on games-based learning* (pp. 16–17). Universitat Oberta de Catalunya.

Sotille, J., & Brozik, D. (2004). The use of simulations in a teacher education program: The impact on student development. A Critical Review. Hawaii International Conference On Education.

Theelen, H., van den Beemt, A., & den Brok, P. (2019). Classroom simulations in teacher education to support preservice Teachers' interpersonal competence: A systematic literature review. *Computers & Education*, *129*, 14–26.

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C., … Straus, S. E. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine*, *169*(7), 467–473.

Tschannen-Moran, M., & Woolfolk Hoy, A. (2001). Teacher Efficacy: Capturing an Elusive Construct. *Teaching and Teacher Education*, *17*, 783–805. https://doi.org/10.1016/S0742-051X(01)00036-1

Vlachopoulos, D., & Makri, A. (2017). The effect of games and simulations on higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education*, *14*, 22. https://doi.org/10.1186/s41239-017-0062-1

Zach, S., & Ophir, M. (2020). Using simulation to develop divergent and reflective thinking in teacher education. *Sustainability*, *12*(7), 2879.

Zhonggen, Y. (2019). A meta-analysis of use of serious games in education over a decade. *International Journal of Computer Games Technology*, *2019*, 1–8.

How to cite this article: Ade-Ojo, G. O., Markowski, M., Essex, R., Stiell, M., & Jameson, J. (2022). A systematic scoping review and textual narrative synthesis of physical and mixed-reality simulation in pre-service teacher training. *Journal of Computer Assisted Learning*, 1–14. https://doi.org/10.1111/jcal.12653