BEME PROTOCOL

Title of review

Augmented reality and virtual reality techniques for ultrasonography education – a systematic review

NAME OF LEAD REVIEWER
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1. COVER SHEET

Abstract
Background:

According to the British Health Committee, about 10% of patients treated by the National Health System (NHS) suffer from potentially preventable injuries. Inadequate medical training remains the main reason. The use of virtual reality (VR) and augmented reality (AR) ultrasound simulators, started respectively in 2000s trying to answer the practical problems responsible for above injuries. Both techniques used simulation, a technique consistently associated with high impact in improving knowledge, skills and attitudes, to create an artificial and manipulated environment in an attempt to project interactive aspects of real life, safely and effectively. The main differences for previous traditional methods are: the possibility for a high number of trials until performance is achieved by the trainee; no patient is needed; the trainer may observe the trainee from a distant location. The aim of the current systematic review is to identify and summarize the evidence concerning the use of VR and AR to accelerate the learning of ultrasonography. **Objectives:** The objectives are to identify the effectiveness of teaching ultrasonography, in undergraduate, postgraduate and continuous professional development, using AR and VR independently of medical specialties, when compared with the so-called traditional methods as well as needed human and financial resources. **Methods:** A systematic literature search using major electronic databases following PRISMA guidelines will be performed. 'Effectiveness' will measure trainees' capacity to establish a correct diagnosis and the number of trials needed to achieve such a diagnosis. We expect that the majority of the studies included in this review will demonstrate heterogeneity in study design and outcome measures. If so, we will qualitatively analyse data where appropriate to draw comparisons. The impact of the intervention will also look at outcomes according to Kirkpatrick's hierarchy. If so, we will qualitatively analyse data where appropriate to draw comparisons. The impact of the intervention will also look at outcomes according to Kirkpatrick's hierarchy. The BEME (Best Evidence Medical Education methodology will be applied by two independent authors to all studies identified by literature search (no limitation of publication date). Any divergence will be solved by a third author. The quality of included studies will be evaluated using the

Buckley (2009) quality indicators. Meta-analysis: If suitably homogenous outcome data are presented which include any form of evaluation (considering educational and methodological heterogeneity as highlighted in the quality assessment), meta-analysis may be employed to consider the impact of the intervention using Kirkpatrick's hierarchy. We will group similar outcomes to allow for comparison. However, this is felt to be unlikely. Apparently, teaching by this methodology presents learning similar to the traditional technique - direct to the patient. **Expected Results:** With this Systematic Review we expect to get evidence to support stakeholders' (students, and teachers, trainees and trainers, sonographers, radiologists, physicians, educators and patients) in all health professions decisions in terms not only of the most effective technique to teach ultrasonography but also on the necessary human and financial resources. The review is expected to support academic and health institutions when deciding on the most effective technique to teach/train ultrasonography in any health profession, especially radiology residents.

Group members

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2. BACKGROUND TO THE TOPIC

According to the British Health Committee, about 10% of patients treated by the National Health System (NHS) suffer from potentially preventable injuries. Inadequate medical training remains the main reason (Cohen et al. 2010). The use of virtual reality (VR) and augmented reality (AR) ultrasound simulators, started respectively in 2000s trying to answer the practical problems responsible for above injuries. Both techniques used simulation, a technique consistently associated with high impact in improving knowledge, skills and attitudes, to create an artificial and manipulated environment in an attempt to project interactive aspects of real life, safely and effectively.(Brigham 2017; Jensen et al. 2017)

The main differences for previous traditional methods are: the possibility for a high number of trials until performance is achieved by the trainee; no patient is needed; the trainer may observe the trainee from a distant location. The aim of the current systematic review is to identify and summarize the evidence concerning the use of VR and AR to accelerate the learning of ultrasonography. Ultrasonography is a portable, sensitive, radiation-free, operator-dependent, non-invasive technique available in many areas where traditional imaging – computed tomography (CT) scan and magnetic resonance imaging (MRI) – is too expensive or completely unavailable. The ultrasound technique is a difficult skill to learn and maintain because the only indication for the location and orientation of the image plane concerning the organ is the appearance of the organ in the image. More and more medical schools, mainly

European, are incorporating ultrasound training in their curricula, especially in the discipline of medical emergencies (Hempel et al. 2016).

Ultrasonography requires not only theoretical and anatomical knowledge, which can be learned online but also, visual and sensorimotor perceptual skills, and the ability to integrate ultrasound findings into clinical contexts in real-time to support the decision-making process. Ultrasonography improves the initial diagnosis in up to 52% of cases, with a change in medical treatment by up to 46%. The levels of technical performance and accuracy for diagnosis by *FAST* ultrasonography (focused assessment with sonography for trauma), for example, are controversial, and the existing estimates vary between 10 and 200 exams before achieving the correct diagnosis, while in obstetric ultrasonography that number increases to 200-300 exams (Chalouhi et al. 2016).

The so-called "traditional methodology", in which most of the techniques have been used for the last century to teach ultrasonography, includes:(Sendra-Portero et al. 2013)

- Classroom models using PowerPoint.
- Practical classes such as anatomy and pathology.
- DICOM system (Digital Imaging and Communications in Medicine).
- Lectures.
- Multidisciplinary discussions are also part of the day-to-day learning process.

All the above techniques allow students to take notes or to learn from teachers' verbalizations.

In the 2000s the use of simulators in training started to gain ground in educational environments for health professionals (Chalouhi et al. 2016). Simulation is consistently associated with favourable effects for results of knowledge, skills, and attitudes. The simulation allows an artificial and manipulated environment in an attempt to project interactive aspects of real life, safely and effectively. The term "practice makes perfect" reflects a daily scenario where students and professionals need a certain amount of procedures to be performed to then perform them unambiguously and judiciously (Konge et al. 2015).

In the 1940s, rudimentary elements of AR were proposed and used (Brigham 2017). AR represents the concept of digital overlapping of virtual objects to physical objects in real space so that individuals can interact with both at the same time. Today, AR is one of the main technologies used in medical learning, seeking to diminish surgical complications through quality education. The recently increasingly common mobile AR (mAR) technology allows students to enjoy flexible learning or to learn in the places they choose based on their preferences. The concept of just-in-time training allows a student or professional to practice a skill (in which they have already demonstrated competence) in mobile technology before doing it on a 'real patient' in practice. AR is an immersive experience based on economical and easily available technology to improve the learning process and its accessibility, reducing the possibility of negatively influencing the patient´s physical or emotional well-being, which is often already psychologically fragile (Aebersold et al. 2018).

In the late 1980s and early 1990s the concept of VR was introduced. Virtual reality creates an immersion of the user in a given environment, controlled or not, by depriving the perception of the local environment with a computerized scenario or previously captured by video, and experiencing an environment as if it existed (Brigham 2017). The use of VR simulators has gained popularity in various specialties and various types of clinical procedures. VR ultrasound simulators present beginning operators with various types of disorders and provide hands-on experience with little faculty involvement (Jensen et al. 2017). Konge et al. concluded that training in the virtual reality simulator is more effective than traditional learning (didactic, simulation without the use of virtual or augmented reality, hands-on experience) training in the initial part of the learning curve (Konge et al. 2015).

Problem statement and financial implications

Radiologists capable of reducing predictable complications, such as infection at the central venous catheter site, have a positive impact on hospital expenses. In 2006, at Northwestern Medical University - USA, residents completed a simulation course on central venous access using ultrasound, before proceeding to the intensive care unit stage. After a year, the catheter-related infections fell from 4.2 cases per 100 patients with central venous access, to 0.42 cases in 100 patients, establishing significant savings. In this study, Cohen et al also reported a significant reduction in patients' spending during hospital interaction, such as less need for ICU, medications - notably costly - and the discount in the hospital stays as a whole (Cohen et al. 2010). From an economic point of view, the impact of simulation courses would be about $ 390,000 savings every five year. (Berry et al. 2008).

Theoretical implications

Much of simulation benefits have an example in aviation. Pilots train extensively for hours on aircraft simulators and therefore there is a reduction in the number of accidents. At first, students experience some difficulties in dealing with help for AR or VR. However, a few minutes were enough to acquire the necessary handling skills. The introduction of AR in non-academic environments, mainly in recreational elements, demonstrates that, progressively, students need less time to adapt to handling.(Ferrer-Torregrosa et al. 2016).

Practical implications

Direct patient training presents some significant threats, at least a reduction in the number of training opportunities available, as the number of trainees increases, the revenue of companies running hospitals increases, and the time available for training decreases or unforeseen events of any amount. The phantom, which is expensive, needs the ultrasound device but the use of virtual reality is a viable alternative. Time flexibility, representation of various cases, and the opportunity to engage in self-directed learning are the most attractive components of virtual reality simulation training (Arya et al. 2018).

Simulation training is an efficient tool in several current areas, such as medical education, (namely training residents and surgeons' improvement), and research. Considering that technical learning about a given procedure is directly related to the number of procedures performed, the use of simulators implies a new way of acquiring them. In this way, the operator can learn the procedure safely and effectively, valuing the integrity of the patient's life. As already mentioned, reduced procedure time, as well as technical errors (iatrogenesis, which occur in 2.9-3.7% of hospitalized patients, are the most expected effects of this new resource. (Vignon et al. 2018).

The use of virtual or augmented simulators has expanded considerably in recent years and is becoming increasingly realistic. Using again the aviation example this training method allows the operator to move the transducer in standard directions, identify the correct plane, and demonstrate relevant findings. A virtual or augmented simulator allows training without pressure and repeated interventions as needed, accelerating the learning curve. It reproduces real-life conditions without time limitations, patient discomfort, and student shame, ensuring regular and standardized teaching for everyone in the institution, without causing stress to the patient or examiner. (Chalouhi et al. 2016)

The results of a preliminary scoping search indicate that there are no systematic reviews on the use and effectiveness of virtual or augmented reality used in ultrasound teaching.

3. REVIEW TOPIC QUESTION(S), OBJECTIVES, AND KEYWORDS

Teaching techniques evaluated

<u>Augmented reality or Virtual reality:</u> Use of simulators for learning, improvement, and, also, for minimally invasive procedures in ultrasound.

The aim of the current systematic review is to identify and summarize the evidence concerning the effectiveness of using VR or AR versus traditional techniques to teach ultrasonography, as well as the human and financial resources.

This review will address the following questions concerning ultrasonography teaching in under and post-graduate teaching as well as continuous professional development independently of health specialties**:**

- What methods have been used?
- Which is the effectiveness of VR and AR compared with traditional techniques?
- Are VR and AR cost-effective techniques?
- How do trainers and trainees evaluate AR and VR techniques namely in terms of strengths and barriers/difficulties?

The review questions were formulated according to PICO framework (Richardson et al. 1995), reporting on Population/ participants, Intervention, issue or activity under investigation, Comparison and Outcomes.

The PICO for this research is:

P = Undergraduate health care students / postgraduate trainees / continuous professional development training – independent of the specialities.
I = Augmented reality / Virtual reality to teach ultrasonography.
C = Traditional methodology versus AR and VR.
O = Improve ultrasound skills to achieve an accurate diagnosis.

The objectives of the review are to identify in the teaching of ultrasonography the:

- Techniques used
- Effectiveness of VR, AR, and traditional techniques*
- Learning outcomes of traditional, AR and VR techniques
- Human and financial resources required by above techniques.
- Teachers/trainers and trainees/students' views in AR and VR.

* To measure 'Effectiveness' will the following trainees' outcomes will be used:

a) Capacity to establish a correct diagnosis.
b) Time and number of trials to establish a correct diagnosis.
c) Intra-reliability of an established diagnosis at a later moment.

Type of review: A systematic review.

Keywords: Ultrasonography; Virtual Reality; Augmented Reality; Video Games; Computer Simulation; Education, Medical; Teaching; Simulation Training.

Stakeholders (who would benefit from this review): healthcare trainees/students, and trainers/teachers; curriculum planners; quality assurance and safety committees; sonographers; radiologists; physicians; patients and care teams; educators.

4. SEARCH SOURCES AND STRATEGIES

We aim to summarise the existing literature in medical education about the use of VR and AR versus traditional teaching in ultrasound training. A dedicated librarian from Brazilian Cochrane Center (MESP) was consulted and searches were performed.

The following key databases will be searched:

- MEDLINE (via PubMed)
- Embase
- Cochrane Library
- LILACS
- CINAHL
- Trip Database
- ERIC
- Scielo

Cross referencing, and grey literature (namely the proceedings of the World Education Congress (http://www.worldeducationcongress.com/), World Congress on Education (https://worldconedu.org/), and International Congress on Education Sciences and Learning Technology (https://www.education.gen.tr/), will also be searched.

The detailed search strategy is presented in Appendix 1.

Search Period: The search will be performed in June 2021 with no limitation of publication date.

The selection process of studies will be carried out applying the Rayyan platform (Ouzzani et al. 2016) (https://rayyan.qcri.org).

5. STUDY SELECTION CRITERIA

The following inclusion criteria will be used:

- Studies of any design, comparing outcomes of VR or AR versus any traditional technique used to teach ultrasonography.
- Studies in any kind of ultrasound speciality.
- Studies in undergraduate, post-graduate or continuing professional development.
- Studies on all health professions.
- Studies with no limitation of publication date.
- Studies regardless their publication status (article approved or published).
- Studies in any language.

Outcomes analysed

- Capacity to establish a correct diagnosis.
- Time and number of trials to establish a correct diagnosis.
- Intra-reliability of an established diagnosis at a later moment.

- Requested AR and VR human and financial resources.

Exclusion criteria

Ultrasonography teaching studies will be excluded if they do not:

- Compare traditional with AR and VR techniques.
- Report on intervention outcomes (opinion pieces, commentaries, editorials, perspectives, and preprints).

Identification of included studies

Following the duplication exclusions, MLD and LRS will independently screen (the review authors were not blinded to the journal or to the authors) and review all titles and abstracts, a random selection of 20% will jointly checked by WI, and ASBO. Any disagreement will be resolved by discussion with MESP or MSP. To facilitate this process, the Rayyan QCRI Systematic Review software will be used (Ouzzani et al. 2016) (https://rayyan.qcri.org).

Then, selected full texts will be read again by third reviewer (MLD) before final inclusion.

6. PROCEDURES FOR EXTRACTING DATA

Two authors will use an EXCEL data extraction form to record all included studies. Any divergence will be solved by a third author. The following data will be extracted:

- Paper information: title, authors, journal, year, publication status, and study design.
- Context (geographic location, responsible organization, education level, setting, number of learners)
- Population/participants: number of participants.
- Education level
- Study design.
- Intervention: technique used and brief summary of teaching.
- Outcomes (effectiveness indicators, Kirkpatrick´s results (see table below) and other outcomes) Kirkpatrick´s (Kirkpatrick and Kirkpatrick 2006; Steinert et al. 2006).
- Summary of results.
- Human and financial resources.
- Lessons learnt as stated by trainers and trainees.
- Summary of conclusions.
- Other information.

Table 1: Kirkpatrick's Hierarchy (Kirkpatrick and Kirkpatrick 2006)

Level	Feature	Evaluation
1	Reaction	Participants' opinions about the learning experience, its organization, presentation, content, teaching methods and quality of instruction
2A	Learning - Change in attitude	Changes in attitudes or perceptions among participating groups concerning teaching and learning
2B	Learning - Modification of knowledge or skills	For knowledge, this refers to the acquisition of concepts, procedures, and principles.

		For skills, it refers to the acquisition of thinking / problem solving, psychomotor and social skills
3	Behaviour - Behaviour change	Documents transfer of learning to the workplace or students' willingness to apply new knowledge and skills
4A	Results - Change in the organizational system / practice	Refers to broader changes in the organization, attributable to the educational program
4B	Results - Change between participants, students, residents or colleagues	Refers to the improvement in learning / performance of students or residents as a direct result of educational intervention

Inter-rater reliability will be calculated using Cohen's Kappa when analyzing the title and abstract. The data extraction form is presented in appendix 2.

7. QUALITY APPRAISAL OF STUDIES

Included studies will be evaluated using Buckley et al. quality indicators (2009) presented in BEME GUIDE 11 (Buckley et al. 2009). It consists in 11 quality 'indicators' concerning to the appropriateness of the study design, conduct, results analysis and conclusions. Please see Appendix 3.
The following question will be added to the questionnaire: Is the source of funding identified?

8. SYNTHESIS OF EXTRACTED EVIDENCE

The EXCEL data table constructed in Microsoft Excel spreadsheets detailing the dimensions presented above in section 6 (procedures for extracting data) is the basis for producing a descriptive coherent picture of the effectiveness of AR and VR compared with ultrasound traditional technics as well as the necessary human and financial resources. To synthesize and summarize qualitative data we will collate evidence from the published studies to be related to effectiveness.

We predict that the majority of the studies included in this review will demonstrate heterogeneity in study design and outcome measures. If this is so, we will qualitatively analyze data where appropriate to draw comparisons. As such, a method to synthesize evidence of quantitative data is not described. There will be an internal appraisal of the review prior to submission to BEME for peer-review.

When doing the synthesis, we will be attentive to the need of translation evidence into practice. This was why we decide to look to qualitative date to allow the authors to understand the 'meaning' frequently hidden behind quantitative data. The lead reviewer, MLD, will synthesize extracted data in a manuscript form from these tables.

If accepted by the BEME Collaboration, this would be published in a highly read and impactful forum. This study is designed to be a useful tool for educators to apply modern teaching technologies to their practice, and researchers in identifying current trends and gaps in the literature. We expect such a systematic review, summarizing current evidence to answer the research questions, to be useful by generating an update curriculum that could be employed at local, national or international settings namely to optimize ultrasound teaching or other areas where a deficit appears to exist.

Expected outcomes and implications for education research and practice

Expected results

Descriptive: Describes what was done or presents a new conceptual model. Asks: 'What was done?' There is no comparison group. May be a description without assessment of outcomes, or a 'single-shot case study' (single-group, post-test only experiment).

Justification: Makes comparison with another intervention with intent of showing that 1 intervention is better than (or as good as) another. Asks: 'Did it work?' (Did the intervention achieve the intended outcome?). Any experimental study design with a control (including a single-group study with pre- and post-intervention assessment) can do this. Generally, lacks a conceptual framework or model that can be confirmed or refuted based on results of the study.

Clarification: Clarifies the processes that underlie observed effects. Asks: 'Why or how did it work?' Often a controlled experiment, but could also use a case–control, cohort or cross-sectional research design. Much qualitative research also falls into this category. Its hallmark is the presence of a conceptual framework that can be confirmed or refuted by the results of the study.

Implications for education research:

The review was designed to analyse the effectiveness of different teaching techniques to guide decisions when deciding on curricula concerning ultrasonography teaching. We expect that results and conclusions will stimulate additional research namely to find evidence on other radiology techniques namely in terms of 'computed tomography' and ´magnetic resonance imaging medical specialties.

This review is crucial in education as an urgent contribution for moving from ultrasonography teaching based on opinion to ultrasonography teaching based on evidence.

9. TRANSLATIONS INTO PRACTICE

The review was designed to identify the evidence on the most effective method to improve ultrasound education curricula, namely in terms of AR and VR when compared with the so-called 'traditional methods. Finding evidence is of utmost importance to support schools' decisions to better cope with current demands of radiology teaching namely to assure the acquisition and development of learners' competencies.

Findings will also support schools under scrutiny in terms of social accountability.

10. PROJECT TIMELINE

ACTIVITY	TIMELINE
Electronic and database search and protocol development	June 2021
Protocol submission to BEME	July 2021
Completion of screening titles, abstracts and relevant full text articles	August 2021
Piloting of data extraction sheet Search updated	September 2021
Data extraction of studies completed	October 2021
Quality assessment completed	October 2021
Data analysis and synthesis	November 2021
Writing of manuscript complete	December 2021

11. CONFLIT OF INTERES STATEMENT

There is no conflict of interest to disclose.

12. PLANS FOR UPDATING THE REVIEW

We intend to update the systematic review after three years of the date of publication date.

APPENDICES
Appendix 1 – Search Strategy

DATABASE	SEARCH STRATEGY
Cochrane Library	1: MeSH descriptor: [Ultrasonography] explode all trees #2: MeSH descriptor: [Virtual Reality] explode all trees #3: MeSH descriptor: [Augmented Reality] explode all #4: MeSH descriptor: [Video Games] explode all trees #5: MeSH descriptor: [Computer Simulation] explode all trees #6: MeSH descriptor: [Education, Medical] explode all trees #7: MeSH descriptor: [Simulation Training] explode all trees #8: MeSH descriptor: [Teaching] explode all trees #9: #1 AND #2 OR #3 OR #4 OR #5 AND #6 OR #7 OR #8
TRIPDATABASE	(title:Ultrasonography)(title:Virtual Reality OR Augmented Reality OR Video Games OR Computer Simulation)(title:Education, Medical OR Simulation Training OR Teaching)
MEDLINE	#1: "Ultrasonography"[Mesh] OR (Echotomography) OR (Diagnostic Ultrasound) OR (Diagnostic Ultrasounds) OR (Ultrasound, Diagnostic) OR (Ultrasounds, Diagnostic) OR (Sonography, Medical) OR (Medical Sonography) OR (Ultrasound Imaging) OR (Imaging, Ultrasound) OR (Imagings, Ultrasound) OR (Ultrasound Imagings) OR (Echography) OR (Ultrasonic Imaging) OR (Imaging, Ultrasonic) OR (Echotomography, Computer) OR (Computer Echotomography) OR (Tomography, Ultrasonic) OR (Ultrasonic Tomography) OR (Diagnosis, Ultrasonic) OR (Diagnoses, Ultrasonic) OR (Ultrasonic Diagnoses) OR (Ultrasonic Diagnosis) #2: “Virtual Reality” [MeSH] OR (Reality, Virtual) OR (Virtual Reality, Educational) OR (Educational Virtual Realities) OR (Educational Virtual Reality) OR (Reality, Educational Virtual) OR (Virtual Realities, Educational) OR (Virtual Reality, Instructional) OR (Instructional Virtual Realities) OR (Instructional Virtual Reality) OR (Realities, Instructional Virtual) OR (Reality, Instructional Virtual) OR (Virtual Realities, Instructional) OR “Augmented Reality“[MeSH] OR (Augmented Realities) OR (Realities, Augmented) OR (Reality, Augmented) OR (Mixed Reality) OR (Mixed Realities) OR (Realities, Mixed) OR (Reality, Mixed) OR “Video Games”[MeSH] OR (Game, Video) OR (Games, Video) OR (Video Game) OR (Computer Games) OR (Computer Game) OR (Game, Computer) OR (Games, Computer) OR “Computer Simulation”[MeSH] OR (Computer Simulations) OR (Simulation, Computer) OR (Simulations, Computer) OR (Computerized Models) OR (Computerized Model) OR (Model, Computerized) OR (Models, Computerized) OR (Models, Computer) OR (Computer Models) OR (Computer Model) OR (Model, Computer) OR (In Silico) OR (In Silicos) OR (Silico, In) OR (Silicos, In)

	#3: "Education, Medical"[MeSH] OR (Medical Education) OR "Teaching"[MeSH] OR (Training Techniques) OR (Technique, Training) OR (Techniques, Training) OR (Training Technique) OR (Training Technics) OR (Technic, Training) OR (Technics, Training) OR (Training Technic) OR (Pedagogy) OR (Pedagogies) OR (Teaching Methods) OR (Method, Teaching) OR (Methods, Teaching) OR (Teaching Method) OR (Academic Training) OR (Training, Academic) OR (Training Activities) OR (Activities, Training) OR (Training Activity) OR (Techniques, Educational) OR (Technics, Educational) OR (Educational Technics) OR (Educational Technic) OR (Technic, Educational) OR (Educational Techniques) OR (Educational Technique) OR (Technique, Educational) OR "Simulation Training"[MeSH] OR (Training, Simulation) OR (Interactive Learning) OR (Learning, Interactive) #4: "Ultrasonography"[Mesh] OR (Echotomography) OR (Diagnostic Ultrasound) OR (Diagnostic Ultrasounds) OR (Ultrasound, Diagnostic) OR (Ultrasounds, Diagnostic) OR (Sonography, Medical) OR (Medical Sonography) OR (Ultrasound Imaging) OR (Imaging, Ultrasound) OR (Imagings, Ultrasound) OR (Ultrasound Imagings) OR (Echography) OR (Ultrasonic Imaging) OR (Imaging, Ultrasonic) OR (Echotomography, Computer) OR (Computer Echotomography) OR (Tomography, Ultrasonic) OR (Ultrasonic Tomography) OR (Diagnosis, Ultrasonic) OR (Diagnoses, Ultrasonic) OR (Ultrasonic Diagnoses) OR (Ultrasonic Diagnosis) AND ""Virtual Reality" [MeSH] OR (Reality, Virtual) OR (Virtual Reality, Educational) OR (Educational Virtual Realities) OR (Educational Virtual Reality) OR (Reality, Educational Virtual) OR (Virtual Realities, Educational) OR (Virtual Reality, Instructional) OR (Instructional Virtual Realities) OR (Instructional Virtual Reality) OR (Realities, Instructional Virtual) OR (Reality, Instructional Virtual) OR (Virtual Realities, Instructional) OR "Augmented Reality"[MeSH] OR (Augmented Realities) OR (Realities, Augmented) OR (Reality, Augmented) OR (Mixed Reality) OR (Mixed Realities) OR (Realities, Mixed) OR (Reality, Mixed) OR "Video Games"[MeSH] OR (Game, Video) OR (Games, Video) OR (Video Game) OR (Computer Games) OR (Computer Game) OR (Game, Computer) OR (Games, Computer) AND "Education, Medical"[MeSH] OR (Medical Education) OR "Teaching"[MeSH] OR (Training Techniques) OR (Technique, Training) OR (Techniques, Training) OR (Training Technique) OR (Training Technics) OR (Technic, Training) OR (Technics, Training) OR (Training Technic) OR (Pedagogy) OR (Pedagogies) OR (Teaching Methods) OR (Method, Teaching) OR (Methods, Teaching) OR (Teaching Method) OR (Academic Training) OR (Training, Academic) OR (Training Activities) OR (Activities, Training) OR (Training Activity) OR (Techniques, Educational) OR (Technics, Educational) OR (Educational Technics) OR (Educational Technic) OR (Technic, Educational) OR (Educational Techniques) OR (Educational Technique) OR (Technique, Educational) OR "Simulation_Training"[MeSH] OR (Training, Simulation) OR (Interactive Learning) OR (Learning, Interactive)
EMBASE (OvidSP)	#1: Echography/exp #2: Virtual reality/exp #3: Augmented reality/exp #4: video game/exp #5: computer simulation/exp #6: medical education/exp #7: simulation training/exp #8: teaching/exp

	#9: #1 AND #2 OR #3 OR #4 OR #5 AND #6 OR #7 OR #8
LILACS	#1: mh:"Ultrassonografia"/exp OR (Ultrasonografía) OR (Ultrasonography) OR (Ecografia) OR (Ecotomografia Computador) OR (Sonografia Médica) OR (Ecografia Médica) OR (Tomografia Ultrassônica) OR (Diagnóstico Ultrassom) OR (Imagem Ultrassônica) OR (Imagem Ultrassonográfica) OR (Imagem Ultrassom) OR (Imagem Ultrassom) OR (Ecotomografia) OR (mh:E01.370.350.850$) #2: mh: "Realidade Virtual"/exp OR (Realidad Virtual) OR (Virtual Reality) OR (Educational Virtual Realities) OR (Educational Virtual Reality) OR (Instructional Virtual Realities) OR (Instructional Virtual Reality) OR (Realities, Instructional Virtual) OR (Reality, Educational Virtual) OR (Reality, Instruc*tional Virtua*l) *O*R (Reality, Virtual) OR (Virtual Realities, Educational) OR (Virtual Realities, Instructional) OR (Virtual Reality, Educational) OR (Virtual Reality, Instructional) OR (mh:L01.224.160.875$) OR (mh:L01.296.555$) OR (mh:SP4.011.127.428.806.030$) #3: mh: "Realidade Aumentada"/exp OR (Realidad Aumentada) OR (Augmented Reality) OR (Augmented Reality for Health) OR (Augmented Reality in Clinical Simulations) OR (Augmented Reality in Health Care Education) OR (Augmented Reality in Health) OR (Augmented Reality in Healthcare Education) OR (mh:SP4.011.127.428.806.020$) #4: mh: "Jogos de Vídeo"/exp OR (Juegos de Video) OR (Video Games) OR (Computer Game) OR (Computer Games) OR (Game, Computer) OR (Game, Video) OR (Games, Computer) OR (Games, Video) OR (Video Game) OR (mh:I03.450.642.693.930$) OR (mh:L01.224.900.930$) #5: mh: "Simulação por Computador"/exp OR (Simulación por Computador) OR (Computer Simulation) OR (Computer Model) OR (Computer Models) OR (Computer Simulations) OR (Computerized Model) OR (Computerized Models) OR (In Silico) OR (In Silicos) OR (Model, Computer) OR (Model, Computerized) OR (Models, Computer) OR (Models, Computerized) OR (Silico, In) OR (Silicos, In) OR (Simulation, Computer) OR (Simulations, Computer) OR (mh:L01.224.160$) #6: mh: "Educação Médica"/exp OR (Educación Médica) OR (Education, Medical) OR (Education, Undergraduate Medical) OR (Medical Education) OR (mh:I02.358.399$) #7: mh: "Treinamento por Simulação"/exp OR (Entrenamiento Simulado) OR (Simulation Training) OR (Interactive Learning) OR (Learning, Interactive) OR (Training, Simulation) OR (mh:I02.903.847$) #8: mh: "Ensino"/exp OR (Enseñanza) OR (Teaching) OR (Academic Training) OR (Activities, Training) OR (Educational Technic) OR (Educational Technics) OR (Educational Technique) OR (Educational Techniques) OR (Method, Teaching) OR (Methods, Teaching) OR (Pedagogies) OR (Pedagogy) OR (Teaching Method) OR (Teaching Methods) OR (Technic, Educational) OR (Technic, Training) OR (Technics, Educational) OR (Technics, Training) OR (Technique, Educational) OR (Technique, Training) OR (Techniques, Educational) OR (Techniques, Training) OR (Training Activities) OR (Training Activity) OR (Training Technic) OR (Training Technics) OR (Training Technique) OR (Training Techniques) OR (Training, Academic) OR (mh:I02.903$) #9: #1 AND #2 OR #3 OR #4 OR #5 AND #6 OR #7 OR #8

CINAHL	#1: Ultrasonography or ul*tr*asound or sonography or echography #2: Virtual reality or vr or augmented reality OR video games OR computer simulation #3: Education medical OR simulation training or simulation education or simulation learning OR teaching #4: #1 AND #2 AND #3
ERIC	#1: MeSH descriptor: Ultrasonography #2: MeSH descriptor: Virtual Reality #3: MeSH descriptor: Augmented Reality #4: MeSH descriptor: Video Games #5: MeSH descriptor: Computer Simulation #6: MeSH descriptor: Education, Medical #7: MeSH descriptor: Simulation Training #8: MeSH descriptor: Teaching #9: #1 AND #2 OR #3 OR #4 OR #5 AND #6 OR #7 OR #8
SCIELO	#1: MeSH descriptor: Ultrasonography #2: MeSH descriptor: Virtual Reality #3: MeSH descriptor: Augmented Reality #4: MeSH descriptor: Video Games #5: MeSH descriptor: Computer Simulation #6: MeSH descriptor: Education, Medical #7: MeSH descriptor: Simulation Training #8: MeSH descriptor: Teaching #9: #1 AND #2 OR #3 OR #4 OR #5 AND #6 OR #7 OR #8

Results of the scoping search
Search Period: no limitation of publication date. The search will be performed in June 2021. The selection process of studies will be carried out applying the Rayyan platform (Ouzzani et al. 2016) (https://rayyan.qcri.org).

SCOPPING SEARCH
A scoping search was conducted to test the strategy using one database (Cochrane Library). The following search strategy was input into the database:
#1: MeSH descriptor: [Ultrasonography] explode all trees
#2: MeSH descriptor: [Virtual Reality] explode all trees
#3: MeSH descriptor: [Augmented Reality] explode all
#4: MeSH descriptor: [Video Games] explode all trees
#5: MeSH descriptor: [Computer Simulation] explode all trees
#6: MeSH descriptor: [Education, Medical] explode all trees
#7: MeSH descriptor: [Simulation Training] explode all trees
#8: MeSH descriptor: [Teaching] explode all trees
#9: #1 AND #2 OR #3 OR #4 OR #5 AND #6 OR #7 OR #8

A total of 4,939 search items were identified.
An initial list of 5 studies identified using the search criteria were extracted (Chao et al. 2015; Ebner et al. 2019; Moult et al. 2013; Rosen et al. 2017; Tolsgaard et al. 2015) after reviewing the first 4,000 search items, identifying relevant titles and then reviewing the abstracts.

As a pilot, MLD and LRS will independently code five papers to validate the data sheet for utility and completeness. Two reviewers will then code all papers identified in the search strategy. The reviewers will identify references cited in these papers that may of interest to the review and obtain these if appropriate. For any disagreements regarding coding of data, MSP will arbitrate and make a final decision.

Appendix 2 - The data extraction form

Title, author(s), date	
Geographic location	
Institution	
Number of learners	
Educational level of the participants	
Study design	
Kind of ultrasound	
Teaching method (Intervention)	
Comparison	
Risk of Bias	
Learning outcomes (Results)	
Requested human resources	
Requested financial resources	
Teachers' views on barriers, facilitator factors and lessons learned	
Trainees' views on barriers, facilitator factors and lessons learned	
Any level of Kirkpatrick outcome and other results	
Conclusions presented by the authors	
Other comment by the coder	

Appendix 3 – Quality indicators from Buckley et al.,2009 (BEME GUIDE 11)

The 11 questions in BEME GUIDE nº11 are as follows:

1. Are the research question (s) or hypothesis clearly defined?
2. Is the group of participants appropriate for the study being carried out (number, characteristics, selection, and homogeneity)?
3. Are the methods used (qualitative or quantitative) reliable and valid for the research question and context?
4. Did the participants drop out? Is the dropout rate below 50%? For questionnaire-based studies, is the response rate acceptable (60% or more)?
5. Have several factors / variables been removed or accounted for whenever possible?
6. Are the statistical methods or other methods of analysing the results used appropriately?
7. Is it clear that the data justify the conclusions drawn?
8. Could the study be repeated by other researchers?
9. Does the study look forward in time (prospective) and not backward (retrospective)?
10. Have all relevant ethical issues been addressed?
11. Were the results supported by data from more than one source?

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