3D technology to support teaching and learning in health care education – a scoping review

Abstract

This scoping review aimed to describe the use of three-dimensional (3D) technology to support teaching and learning in health care education and the outcomes related to 3D technology from the perspective of teaching and learning. The study identified 31 articles that met the inclusion criteria. The results are presented in four categories: *3D environment, 3D image, 3D holograms and 3D print*. There were multiple pedagogical contexts, including the teaching of anatomy. All categories were connected to positive learning outcomes and outcomes that supported learning, e.g. satisfaction. Positive learning outcomes were related to skills, knowledge, students' perceptions and emotions. These findings describe multiple uses of 3D technology, which can have a positive effect on student learning in health care education.

Keywords: 3D technology, Health care education, Literature review

1 Introduction

Digital technology has a dominant role in international guidelines for education, and these guidelines also require developmental needs (European commission 2018). Health care education is no exception, and technology stands high in priority for future education (NLN 2016). One promising technology is three-dimensional technology (3D technology). 3D technology is used in multiple areas, for example, in astronomy (Su, Wang, Wang, & Song, 2019), biochemistry (Lohning, Hall, & Dukie, 2019) and engineering (Chien, 2017). 3D technology is usually connected to visualization (Carbonell Carrera, Avarvarei, Chelariu, Draghia, & Avarvarei, 2017) and is used in images (Silén, Wirell, Kvist, Nylander, & Smedby, 2008) and printing (Cornwall, 2016). In the area of learning, 3D technology can have a positive impact on actual learning outcomes and the motivation to learn (Sung, Hwang, Wu, & Lin, 2018). In health care education, different 3D technologies have a dominant usage: teachers supporting students' learning with augmented realities (Zhu, Hadadgar, Masiello, & Zary, 2014), 3D printing (Garas, Vaccarezza, Newland, McVay-Doornbusch, & Hasani, 2018; Langridge et al., 2018) and 3D pictures (Brown, Hamilton, & Denison, 2012) with positive learning outcomes (Triepels et al., 2020). Despite the multiple 3D technologies used in medical education, more thought should be given to a wider perspective on health care education. Health care education is an entity that consists of many professions that basically should work together (Mikkonen et al., 2018).

There is not yet much research on health care education from the perspective of supporting teaching and learning with 3D technology. The most common 3D technology is made by Linden Lab's Second Life ®, which also has a dominant role in the field of virtual reality (Irwin & Coutts, 2015). To improve understanding of the different 3D technologies that can support teaching and learning in health care education, it is necessary to have a more scoped description of the current state of the 3D technology in use. We also need a more structured definition of the multiple contents of 3D technology. This description could help teachers recognize the actual possibilities of using 3D technology in education to support teaching and learning. With these kinds of actions, we can promote learning outcomes.

2 Background

2.1 3D technology

3D technology can be part of different technologies, which makes a structured definition challenging (Hackett & Proctor, 2016; Geng, 2013). From the perspective of display technology, 3D technology is related to visualization. A two-dimensional (2D) image can be seen as a flat object, while a 3D image provides a deeper effect and challenges our brains to better understand. 3D technology can also include different levels of interactions with the users. For example, users can do something that has causation in a 3D image or the 3D world (Geng, 2013). 3D technology can be displayed in a monoscopic, stereoscopic and autostereoscopic way. In addition, 3D technology can be defined as an augmented or mixed reality display. Monoscopic display is a technology for which additional equipment (e.g. 3D glasses) is not needed to see the image in three dimensions. Stereoscopic display refers to technology where additional equipment is needed (e.g. 3D glasses) to obtain a full 3-dimensional experience. Autostereoscopic display refers to technology with multiple ways to provide a multi-view experience in three dimensions (e.g. 3D prints). Augmented and mixed realities utilize 3D technology to give real-life experiences with digital information (Hackett & Proctor, 2016; Geng, 2013). 3D technology can also be defined together with certain other technologies. 3D technology occurs also when using mobile devices with 3D applications (Hamm, Money & Atwal, 2019) or 3D printers (Verner & Merksamer, 2015) to support teaching and learning.

The hyponym of 3D technology, 'virtual reality', can also be defined from different perspectives (Geng, 2013). Basically, different kinds of virtual realities use 3D technology, although this definition is used to describe other technology as well, for instance, social media tools (Kardong-Edgren, Farra, Alinier, & Young, 2019). To connect the definition of 3D technology to mixed realities, the concepts of "virtual reality" and "augmented reality" need to be clarified in more detail. The most common virtual reality is Second Life ®, which is clearly defined 3D technology through its licensing of the technology is. This technology has also been the subject of a considerable amount of research (Irwin & Coutts, 2015; Schaffer, Tiffany, Kantack, & Anderson, 2016). Virtual reality has been defined as a "virtual world" (de Gagne, Oh, Kang, Vorderstrasse, & Johnson, 2013), "virtual learning environment" (Tavares, Leite, Silveira, Santos Brito & Camacho, 2018), "virtual patient" (Moule, Pollard, Armoogum, & Messer, 2015) and "virtual simulation" (Cant & Cooper, 2014), which are not unequivocal 3D technologies. Because of the primary interest in the scope of knowledge on the actual 3D technology, the definition "virtual reality" needs a clear criterion to be included.

2.2 Health care education

Health care education can be defined with medical education (Hackett & Proctor, 2016; Hamilton, 2011) or without it (Mikkonen et al., 2018). Medical education differs from other health care educations because the content and goals of the education are unique (Hamilton, 2011). Health care education in Finland spans vocational (secondary) education and higher education. This review uses the definition of health care education by the Finnish National Supervisory Authority for Welfare and Health (2020) because we need a wide and structured description of different educations, and the content of education varies considerably in different countries (Salminen et al., 2010). The definition is structured from the perspective of legalization of the following health care professions: practical nurses, registered nurses, osteopaths, dental hygienists, dental technicians, medical technologists, midwives, naprapathic practitioners, occupational therapists, opticians, paramedics, physical therapists, podiatrists, prosthetists, public health nurses, radiographers and rehabilitation counsellors.

3 Materials and method

The aim of this scoping review was to explore the use of 3D technology to support teaching and learning in health care education and the outcomes related to 3D technology from the perspective of teaching and learning. A scoping review was chosen for the methodology for this review because of the characteristics and nature of the main theme, 3D technology (Grant & Booth, 2009). Since 3D technology is a new area in health care education, a method that enabled ongoing studies and the grey literature to be included in the review was best suited for the purposes of this review (Grant & Booth, 2009; Levac, Colquhoun, & O'Brien, 2010). The methodological framework used in this study was Arksey and O'Malley's (2005) framework for scoping reviews. The framework is structured in five phases:

1. Identifying research questions
2. Identifying relevant studies
3. Study selection
4. Charting the data
5. Summarizing the data

(Hacking & Hacking, 2012; Arksey & O'Malley, 2005)

3.1. Identifying research questions

This scoping review identified three different research questions to fulfil the aim of the study:

1. What kinds of 3D technologies are used to support teaching and learning in health care education?
2. In what kinds of pedagogical contexts are 3D technologies used in health care education?
3. What are the outcomes related to 3D technology from the perspective of teaching and learning in health care education?

3.2. Identifying relevant studies

For a wide-scoped perspective on the theme, the following seven databases are included in this review: Cinahl (Ebsco), PubMed (MEDLINE), Eric (Ebsco), APA PsychInfo (Ebsco), Cochrane Library (Wiley), Teacher Reference Center (Ebsco) and Education Research Complete (Ebsco). The search string included the following terms: ('three dimensional' or '3 dimensional' or '3D' or '3-D' or 'VR' or 'AR' or 'virtual realit*' or 'augmented realit*') and ('health care education' or 'healthcare education' or 'allied health education' or 'health science education' or 'nursing education' or 'practical nurse education' or 'nurse education*' or 'nursing education' or 'dental hygienist education' or 'dental technician education' or 'medical technologist education' or 'midwife education' or 'naprapathy education' or 'occupational therapist education' or 'optician education' or 'osteopath education' or 'paramedic education' or 'physical therapist education' or 'podiatrist education' or 'prosthetist education' or 'public health nurse education' OR 'radiographer education' or 'rehabilitation counselor education'). The search was carried out in January 2020.

This scoping review utilizes the PICO process to identify the inclusion and exclusion criteria (Table 1). Outcome is not defined, because it can exclude relevant descriptive articles for different 3D technologies (CDR 2009).

Table 1.

PICO strategy to identify the studies

PICO elements	Inclusion criteria	Exclusion criteria
P (population)	Undergraduate health care students with the following education: practical nurse, registered nurse, osteopaths, dental hygienist, dental technician, medical technologist, midwife, naprapathy, occupational therapist, optician, paramedic, physical therapist, podiatrist, prosthetist, public health nurse, radiographer or rehabilitation counsellor.	Postgraduate health care professionals. Medical students or physicians.
I (intervention)	A technology that aims to support teaching and learning with 3D technology. A technology described as 3D technology.	Any other digital technology. The Second Life ®

	Displaying the way 3D technology has to be described as monoscopic, stereoscopic or autostereoscopic. Virtual or augmented reality, which utilizes 3D technology as an environment or platform, and the connection is clearly described. 3D printing	Virtual or augmented reality that utilizes technology but with no clear description as 3D technology.
C (context)	Health care education.	Patient education. Medical education. Continuing education.
O (outcome)	-	-

Second Life ® was excluded because it is owned by a company and works like a virtual entity on the Internet (Irwin & Coutts, 2015). Even though a body of research exists related to Second Life ®, this scoping review is interested in a wider perspective on actual 3D technology usage. From the educational perspective, medical education and continuing or postgraduate education have been excluded to ensure homogeneous data on basic health care education.

3.3. Study selection and analysis

First, two independent researchers agreed on the inclusion and exclusion criteria. Then a search was made using the seven databases. After completing the search, the researchers identified relevant studies through headlines and abstracts. When the researchers reached a consensus, the full texts of the relevant studies were read before proceeding to the next selection phase. Possible disagreements were discussed after each phase. Because of the various ways to define 3D technology, the number of articles in the full text analysis was expected to be high (n=140). The challenge of describing the actual technology accurately in the abstract can mislead researchers to exclude unclear articles, although the technology in the article might actually use 3D technology. This challenge can be minimized by screening the full text in the analysis. The grey literature was also done with an additional search. The grey literature was defined as different kinds of reports or working papers (Adams et al., 2016). The additional search was made from the reference lists of the full text papers; however, it did not produce new articles for review (Figure 1).

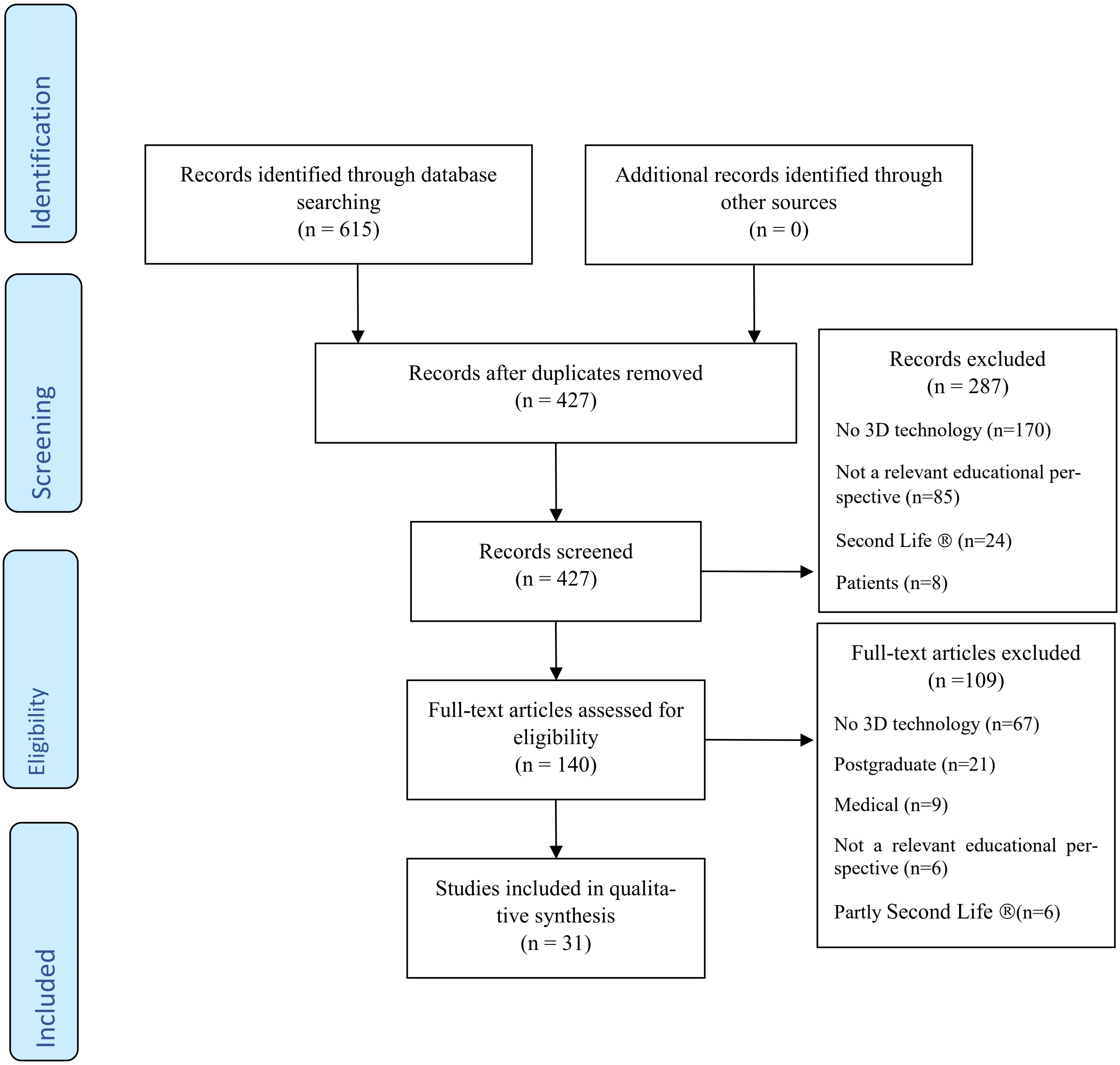

Figure 1. Study selection process

3.4. Charting and summarizing the data

According to Arksey & O'Malley (2005), the included studies should be organized by a structured method; consequently, this scoping review utilized a narrative and thematic approach. After screening the full text of the articles (n=31), they were then organized with a narrative approach to give a general view of the scope. The following information was retrieved from the articles: country, study design, article type and educational perspective. After a narrative description, a thematic approach was used to organize the data into different categories according to the 3D technology used, the pedagogical context and the outcomes. The categories reflected the level of interaction (Geng, 2013), the nature of the user interface (Verner & Merksamer, 2015) and the learning outcome that can support learning.

4 Result

4.1. Description of selected studies

In this scoping review, 140 articles were included for a full text analysis, and 31 of these met the final inclusion criteria. All the articles were from the years 2011 to 2019. Most of the articles were research articles (n=27) with several designs, most of which were quasi-experimental (n=8). Geographically, the articles were mostly from the USA (n=10). The studies were conducted in different health care education contexts: nursing, midwifery, community health nursing and physiotherapist undergraduate education (tables 2 and 6).

Table 2.

Descriptive overview of the articles

Country	Health care education	Article type and possible designs
USA	Nurse education	Research article (N=10) *quasi-experimental (n=5, of which two are pilot studies)* *mixed method (n=3)* *randomized control trial (n=1)* *descriptive qualitative (n=1)*
Australia	Nurse education and midwife education	Research article (N=4). Nurse education: *mixed methods (n=2)* *experimental (n=1)* Nurse and midwife education together: *Mixed method (n=1)*
Australia	Midwife education	Issue of debate (N=1)
Finland	Nurse education	Research article (N=3) *Cross-sectional descriptive study (n=1)* *Mixed methods (n=1)* *Design-based with qualitative methods dominant (n=1)*
Spain	Nurse education	Research article (N=2) *Randomized control trial (n=1)* *Quasi-experimental (n=1)*
United Kingdom	Nurse education	Research article (N=2) *Quasi-experimental (n=2)*
Canada	Nurse education	Research article (N=1) *Exploratory action research (n=1)*

Canada	Community health nurse education	Professional publication (N=1)
Turkey	Nurse education	Research article (N=1) *Quasi-experimental (n=1)*
Korea	Nurse education	Research article (N=1) *Randomized control trial (n=1)*
Taiwan	Nurse education	Research article (N=1) *Qualitative study (n=1)*
Israel	Nurse education	Research article (N=1) *Quasi-experimental (n=1)*
Ireland	Midwife education	Contemporary Issues (N=1)
Denmark	Physiotherapist education	Research article (N=1) *Experimental (n=1)*
China	Nursing education	Overview (N=1)

4.2. 3D technologies used to support teaching and learning in health care education

The use of 3D technologies in healthcare education can be divided into four categories (Arksey & O'Malley, 2005): *3D environment, 3D image, 3D holograms and 3D print.*

A *3D environment* means that the students interact with a completely 3D environment at some level. Student interaction means that students can concretely do something that has causation in a 3D environment (Smith, Farra, Ulrich, Hodgson, Nicely & Mickle, 2018). The following concepts are related to using a 3D environment with concrete interaction: virtual reality, augmented reality, gaming and virtual reality simulation. There were a total of 19 articles concerning 3D environments. The user interface for 3D environments were computers mobile phones, headsets or glasses, and haptic devices (for example, hand control devices) (Table 3).

A 3D environment was used in different pedagogical contexts, such as teaching unique skills and knowledge in medical administration (Dubovi, Levy, & Dagan, 2017), cardiopulmonary resuscitation (CPR) (Boada et al., 2015), skills in disaster environments (Smith et al., n.d.), decontamination skills (Farra, Smith, & Ulrich, n.d.), clinical reasoning (Koivisto, Multisilta, Niemi, Katajisto, & Eriksson, 2016) and concept understanding (Foronda Schubec et al.) It was also used to support wider skills in evaluating patients in a clinical practicum laboratory (Dang, Palicte, Valdez, & O'Leary-Kelley, 2018; Garrett, Jackson, & Wilson, 2015). The 3D environment included different cases (Boada et al., 2015; Foronda et al. 2016) for students to solve. A 3D environment was used to support teaching and learning from the perspective of gaming (Gallegos, Tesar, Connor, & Martz, 2017; Hogan, Kapralos, Cristancho, Finney, & Dubrowski, 2011; Koivisto et al., 2016; Koivisto, Niemi, Multisilta, & Eriksson, 2017). A 3D environment was also utilized in an evaluation process capturing the moves of students who were moving patients with a possible spinal injury (Gordillo Martin, 2017) (Table 3).

3D image means used visualizations while teaching students with or without student interaction. The students' possible interaction was not connected to any causation, but the aim was to affect students' thinking while they see or hear something in 3D. A 3D image can be related to pictures, sounds, small animations or videos (e.g. Everson et al., 2018). There were a total of 10 articles concerning 3D images. The user interfaces used for 3D images were computers, mobile phones applications, 3D headsets or glasses, and a 360-degree camera (Table 3).

A 3D image was used in different pedagogical contexts, such as teaching about certain treatments (Ulrich, Helms, Frandsen, & Rafn, 2019), EKG rhythms (Holthaus & Wright, 2017), pharmacology (Hanson, Andersen, & Dunn, 2019) and anatomy (Rutty et al., 2019). 3D images were used for teaching intravenous treatments (Jung et al., 2012). 3D images were also used to affect students' thinking, such as empathic concerns (Everson et al., 2018) and cultural empathy (Everson et al., 2015). A mix of different 3D images was used for animations and images in a mobile application (Holthaus & Wright, 2017) (Table 3).

A *3D hologram* has a visualization to a 3D image, but it can include a deeper interaction with students. To interact with holographic technology, students need certain digital equipment. The interaction was also for a short period, aiming, e.g., at viewing a subject from different angles by using students' head or hand movements (Chang & Lai, 2018; Hackett & Proctor, 2018). There were two articles concerning 3D holograms. The user interface used for this 3D image was a holographic platform and headset or glasses (Table 3).

The pedagogical context of 3D holograms was connected to the teaching of anatomy, specifically the structure of the heart (Chang & Lai, 2018; Hackett & Proctor, 2018). Student interactions occurred only with the head moves (Hackett & Proctor, 2018) or with preplanned hand gestures (Chang & Lai, 2018), and these moves allowed students to have a different and interactive perspective of the heart's structure (Table 3).

3D prints mean that the subject has been modelled or scanned in a 3D format and then 3D printed as a concrete item. The level of interaction is concrete because of the possibility to touch the item. One article concerned the use of 3D printing. The user interface used for a 3D print was all pre-work because the modelling and printing were not done by students. They only used the final items, not the actual 3D technology. The pedagogical context was connected to the teaching of anatomy. The 3D printing was meant to support the students' knowledge of bone fractures (Rutty et al., 2019) (Table 3).

Table 3.

Description of the use of 3D technology in health care education

Category of the 3D technology and number of articles	User interface that is possibly needed and pedagogical context
3D environment (n=19)	Mobile phone Pedagogical context: Clinical skills/clinical practicum laboratory Computer (keyboard and mouse) Pedagogical context: Clinical skills/clinical practicum laboratory, concept understanding, fire safety, CPR, medical administration Different levels of headsets Pedagogical context: Clinical skills/clinical practicum laboratory Different haptic devices Pedagogical context: Clinical skills/clinical practicum laboratory, disaster environment, decontamination
3D image (n=10)	Mobile phone Pedagogical context: EKG rhythm Computer (keyboard and mouse) Pedagogical context: Pharmacology, anatomy Different levels of headsets Pedagogical context: intravenous treatment, emphatic concerns, empathy towards culturally diverse patients 360-degree camera Pedagogical context: Treatment understanding
3D hologram (n=2)	Holographic platform Different levels of headsets Pedagogical context: Anatomy

3D print (n=1)	3D printer Pedagogical context: Anatomy

There were also mixed 3D technologies in three articles. The mix of 3D holograms and 3D images was related to the teaching of anatomy (Hackett & Proctor, 2018) as well as the mix of 3D images and 3D printing (Rutty et al., 2019). The mix of a 3D environment and a 3D image was related to gaming and included different areas used in the teaching and learning of, for example, utilizing research (Gallegos et al. 2017).

4.3 Outcomes after using 3D technology

Outcomes of using 3D technology were divided into learning outcomes and outcomes that supported learning. Eight experimental studies reported learning outcomes with a statistically significant difference. These learning outcomes are described in four categories: *skills, knowledge, students' perceptions and emotions* (Table 4).

Table 4.

Positive learning outcomes

Approved learning outcome	**3D technology and author**	**Research details**	**Specific outcome**
Skill	3D environment (Boada et al., 2015)	Design: Randomized control trial. Three control groups (n=42) and five experimental groups (n=67). Pretest and posttests. Participants: Nursing students (N=109) Experimental groups used several times 3D technology for one week before posttests.	CPR skills
Skill	3D environment (Rossler, Sankaranarayanan, & Duvall, 2019	Design: Pilot study. Experimental group (n=13) and control group (n=13). Pretest and posttests. Participants: Nursing students (N= 26) Experimental group used 3D technology one time before posttests.	Fire safety skills
Knowledge	Hologram and 3D image (Hackett & Proctor, 2018)	Design: Randomized control trial. Two experimental groups (n=120) and one control group (n=59). Pretest and posttest.	Anatomy knowledge

		Participants: Nursing students (N=179) Experimental groups used 3D technology one time for seven minutes.	
Knowledge	3D environment (Dubovi, Levy & Dagan, 2017)	Design: Quasi-experimental. One experimental (n=82) and one control group (n=47). Pretest and posttests. Participants: Nursing students (N= 129) Experimental group used 3D technology for three hours before posttests.	Pharmacology knowledge
Knowledge	3D environment (Hanson et al., 2019)	Design: mixed method. Pretest and posttests. Participants: Nursing and midwifery students (N=202) Experimental group used 3D technology one time before posttests.	Pharmacology knowledge
Students perceptions	3D image and 3D printing (Rutty et al., 2019)	Design: Quasi-experimental. One group. Posttests. Participants: Nursing students (N=59) Group used 3D technology one time for 1.5 hours.	Students' perceptions about their own learning
Emotion	3D image (Everson et al., 2018)	Design: Mixed methods multisite study. One group. Pretest and posttests. Participants: Nursing students (N=530) Group used 3D technology one time for 10 minutes.	Emphatic concern
Emotion	3D image (Everson et al., 2015	Design: Experimental study. One group. Pretest and posttests. Participants: Nursing students (N=460) Group used 3D technology one time for 10 minutes.	Cultural empathy

Outcomes that supported learning were compiled into the following categories: *User experience* (satisfaction with the 3D technology), *motivation* (motivation to learn), *attitudes* (self-confidence to learn) and *emotion* (feedback, presence experienced, feeling of interactivity and emotional feelings) (Table 5).

Table 5.

Positive outcomes that supported learning

Outcome	3D technology
User experience	3D image (Courtney-Pratt et al., 2015; Vaughn, Lister, & Shaw, 2016; Jung et al., 2012; Hanson et al., 2019; Farra et al., n.d.) 3D environment (Günay İsmailoğlu, & Zaybak, 2018)
Motivation	Hologram (Chang & Lai, 2018)
Attitude	3D environment (Vaughn et al., 2016)
Emotion	3D environment (Garrett et al., 2015; Foronda et al., 2016; Koivisto et al., 2016; Dang et al., 2018; Günay İsmailoğlu & Zaybak, 2018; Butt, Kardong-Edgren & Ellerton, 2018; Farra et al., n.d.; Keskitalo, 2012) 3D image and 3D printing (Rutty et al., 2019)

A description of all the data is in Table 6.

Table 6.

Description of the articles

Study	Design	Participants (students)	Aim and technology	Implementation	Possible outcomes
(Holthaus & Wright, 2017). United Kingdom.	Quasi-experimental study. One experimental and one control group, pretest and posttests.	N=50 Nursing students	**Test 3D application on nursing students to support EKG rhythm interpretation.** **3D technology: 3D images with 3D application**	Study group (n=25) completed an interactive 3D learning session on an iPad. The 3D application included animations, sound and images. Control group (n=25) was in classroom teaching. Duration of implementation: one time.	Measured categories: knowledge Knowledge: 3D application did not have a positive effect on learning outcomes.
(Everson et al., 2018) Australia.	Mixed methods multisite study. One group pretest and posttest.	N= 530 Nursing students	**Test 3D simulation on nursing students to support students' empathic concerns.** **3D technology: 3D image with video**	Students watched 10 minutes of 3D video with glasses and headphones to fulfil the 3D experience. Duration of implementation: 10 minutes and one time.	Measured categories: emphatic concern. Empathic concern: Significant increase after using 3D technology.
(Dang et al., 2018) USA.	Quasi-experimental. A (control)-B (experimental)-A (control) design with three different tracks and conditions. Pretest and posttests.	N=58 Nursing students	**Assess virtual reality among high fidelity simulation and TV modalities in clinical training in the field of active participation.** **3D technology: 3D environment with smartphone-powered VR stereoscope headsets and earphones.**	Track and conditions were in different sessions in a different order. The bases were all-sim track, TV track and virtual reality track. During the simulation, the camera was capturing 360 degrees for students to observe the training in the other room through their smartphone-powered VR stereoscope headsets and earphones. Duration of implementation: one time.	Measured categories: presence experienced. Presence experienced: VR observers felt moderately present while the concrete simulation was the best, and the TV observers were the worst.
(Garrett et al., 2015) Canada.	Exploratory action research. One group.	N= 160 Nursing students	**Test mobile augmented reality technology to enhance clinical skills learning in a laboratory lesson.** **3D technology: 3D environment with a mobile phone.**	During clinical skills lab, the environment also consists of attractions to scan (for example, QR codes or images), which include augmented reality resources (e.g. videos). Duration of implementation: one time.	Measured categories: the student perspective Mobile augmented reality had positive elements from the student perspective in the following areas: implementation and value of AR, and preferred media, although the technical issues were challenging.

(Hogan et al., 2011) Canada.	Descriptive article.	Community health nursing education	**To describe a serious game in community health nursing education.** **3D technology: 3D environment with a computer.**	A serious game with a 3D environment can be played with a computer, mouse and keyboard.	-
(Courtney-Pratt et al., 2015) Australia	Multi-site mixed methods study. Posttest.	N = 497 Nursing students	**To implement and test nursing students' satisfaction with 3D immersive simulation.** **3D technology: 3D image with video.**	Students watched a 3D video with glasses to fulfil the 3D experience. Duration of implementation: one time	Measured categories: satisfaction. The students described high satisfaction with 3D immersive simulation.
(Jung et al., 2012) Korea.	Randomized control trial. Three experimental groups, pretest and post-test.	N = 119 Nursing students	**To implement and test intravenous simulators incorporating virtual reality / haptics device technologies.** **3D technology: 3D images to observe with Polaroid glasses.**	Group A used only a plastic arm (n=41) Group B used VR simulator (n=40) Group C used both (n= 38) Duration of implementation: One time.	Measured categories: state and visual anxiety, venipuncture performance and satisfaction. **State and visual anxiety**: No statistical difference. **Venipuncture performance**: No statistical differences, although Group C scored the highest points. **Satisfaction:** highest satisfaction was among Group C.
(Foronda et al., 2016) USA**.**	Mixed method study. Pre-test and posttest. One group.	N= 6 Nursing students	**Test virtual simulation to teach the concepts of disaster triage to nursing students.** **3D technology: 3D environment with a computer.**	Students enrol in the 3D simulation with a computer, mouse and keyboard. 3D environment is a different kind of disaster case. Duration of implementation: 30 minutes and one time.	Measured categories: knowledge and students' experiences. **Knowledge:** No significant difference. **Students' experiences:** Four themes issued. Fun, appreciation for immediate feedback, better than reading and technical issues. Positive experiences for all but technical issues.
(Smith et al., 2018) USA.	Quasi-experimental study. Two experimental and one control group, pretest and posttest. Also follow-up at 6 months	N= 197 Nursing students	**Test virtual reality simulation to support learning in a disaster environment.** **3D technology: 3D environment with a computer screen. Interaction using hand controllers.**	Experimental group 1 (n=59) used a web module and a head-mounted device. Experimental group 2 (n=58) used a web module and mouse and keyboard. Control group (n=55) web module and written instructions Duration of implementation: one time	Measured categories: skills, knowledge, performance 3D virtual reality simulation had no significant effect on skills, knowledge or performance. It had positive elements for initial skill development and time consumed.
(Koivisto et al., 2016) Finland.	Cross-sectional descriptive study. One group, posttest	N= 166 Nursing students	**Describe nursing students' experiences of 3D simulation game in clinical reasoning.** **3D technology: 3D environment with a computer.**	Students played a serious game with a 3D environment, which included different cases.	Measured categories: experiences Experiences: 3D environment correlated with student learning

				Duration of implementation: 30–40 minutes. Students can enrol in it more than once.	experiences. Students described good learning experiences when using a 3D game.
(Everson et al., 2015) Australia.	Experimental study. One group pretest and posttest.	N=460 Nursing students	**Test the effect of 3D simulation on nursing students' empathy towards culturally and linguistically diverse patients.** **3D technology: 3D image with video.**	Students watched a 3D video with glasses to fulfil the 3D experience. Duration of implementation: one time, 10 minutes.	Measured categories: cultural empathy. 3D simulation had a significant effect on students' cultural empathy scores.
(Chang & Lai, 2018) Taiwan.	Qualitative study. Posttest.	N= 90 Nursing students.	**To implement the combination of 3D holographic imaging and hand gestures in anatomy teaching.** **3D technology: 3D holographic image with hand gestures.**	Students used holographic technology in anatomy lessons and gave reflective feedback. Duration of implementation: one time	Measured categories: experiences The holographic technology enhanced the convenience of teaching and had a positive influence on students' motivation to learn. The following categories were analysed: Rescue imagination, conquer the abstract, transform 2D into 3D, facilitate self-controlled learning, and dynamically understand memory.
(Ulrich et al., 2019) Denmark.	Experimental study. Three treatment groups, pretest and posttest.	N= 81 Physiotherapy students	**Test the 360-degree video in health care education.** **3D technology: 3D image with 360-degree camera.**	Group one (n=28) used 360-degree video with virtual reality head-mounted set about the treatment to be learned. Group two (n=26) used regular video. Group three (n=27) got the traditional lesson with an instructor without technology.	Measured categories: academic performance, perceived user satisfaction, perception of learning climate 360-degree video did not have an effective influence compared to other methods, except the students' feelings about the learning climate.
(Butt et al., 2018) USA.	Mixed method pilot study. One experimental and one control group. Post and follow-up tests (2 weeks after posttest).	N= 20 Nursing students.	**Describe and evaluate the use of virtual reality game in teaching urinary catheterization.** **3D technology: 3D environment with headgear and haptic gloves.**	Control group (n=10) got the traditional laboratory teaching. Experimental group (n=10) got the simulation in a 3D environment. Duration of implementation: During one lesson.	Measured categories: skills and perceptions. **Skills:** The actual skills were identical in both groups. The experimental group used more time practising and completed more procedures. **Perception:** Experimental group described the method as engaging and enjoyable.
(Boada et al., 2015) Spain.	Randomized control trial. Three control groups and five experimental groups, pretest and posttest.	N= 109 Nursing students.	**Evaluate the effectiveness of a 3D game while teaching CPR skills.** **3D technology: 3D environment with a computer.**	Experimental groups got the 3D gaming with different scenarios before the laboratory sessions. Control groups got the traditional teaching (theory reading) before the laboratory sessions.	Measured categories: skills. Skills: Experimental groups had significantly better learning outcomes compared to those that received the traditional teaching.

				Duration of implementation: During one week, more than once.	
(Farra et al., n.d.) USA.	Mixed method study (focus-group dominant). Two experimental groups and one control group.	N= 100 Nursing students	**Describe students' experiences and satisfaction with two different levels of virtual reality simulation in teaching decontamination.** **3D technology: 3D environment with goggles and 3D display technology.**	Experimental group A (n=36) received 3D simulation with goggles. Experimental group B (n=36) received 2D simulation with keyboard and mouse. Control group (n=28) got written instructions.	Measured categories: experience and satisfaction. Analysis was conducted in the following categories: simulation of learning experience educational strategies, simulation of design, participant outcome and participant experience of simulation. Both experimental groups' experiences were mainly positive in every category, although the design was also mentioned as a barrier.
(Hackett & Proctor, 2018) USA.	Randomized control trial. Two experimental groups and one control group. Pretest and posttest.	N= 179 Nursing students	**Evaluate the effect of different 3D modalities while teaching anatomy.** **3D technology: Autostereoscopic 3D visualization (holograms) and monoscopic 3D visualization (3D image**).	Experimental group 1 (n=60) used autostereoscopic 3D modality. Experimental group 2 (n=60) used monoscopic 3D modality. Control group (n=59) used 2D printed images.	Measured categories: knowledge. Knowledge: Learning outcomes of anatomy knowledge were significantly better in experimental Group 1. The following areas were significantly better with 3D than with 2D: cognitive load and instructional efficiency.
(Rutty et al., 2019) United Kingdom.	Quasi-experimentalstudy. One group, posttest after each session.	N= 59 Nursing students	**Evaluate post Mortem Computed Tomography in teaching anatomy to nursing students.** **3D technology: 3D image and 3D printing.**	Students initially got the traditional teaching in anatomy and then the same teaching using 3D tools. Duration of implementation: One time 1.5 hours.	Measured categories: Students' perceptions of their own learning. Students' perception about their own learning: Significantly approved with 3D tools in all the following questions: Be stimulating, link theory to practice, be helpful for learning, be good quality, have good clarity, assist understanding of anatomy, assists in increasing knowledge base and identify whether they felt needed additional learning opportunities. The students highlighted themes of visual learning, realism, patient empathy.
(Vaughn et al., 2016) USA	Pilot study. One group, posttests	N= 12 Nursing students.	**Describe using augmented reality in high fidelity simulation while teaching clinical care.**	Students used glasses in the simulation room and interacted with a mannikin with augmented reality.	Measured categories: satisfaction and self-confidence in learning.

			3D technology: 3D environment with Google glasses.	Duration of implementation: one time.	**Satisfaction**: 3D environment was scored favourably. The technology was also mentioned as a barrier. **Self-confidence**: Students reported growth of self-confidence in learning.
(Koivisto et al., 2017) Finland	Design-based design with qualitative methods dominant. One group.	N= 8 Nursing students	**Describe students' experiences of 3D simulation game connected to the learning process.** **3D technology: 3D environment with a computer.**	Students enrolled in the 3D game in four sessions. They played as groups or as an individual. Duration of implementation: Four sessions, 10–20 minutes each.	Measured categories: experiences. Experiences: Students' experiences revealed that the authentic 3D environment could support the learning process. Following areas were analysed: Audiovisual authenticity, authenticity of patient scenarios, interactivity, patient observation, feedback during the game, feedback after the game, application of nursing knowledge, internalizing procedures, exploring and decisions making.
(Dubovi et al., 2017) Israel	Quasi-experimental study. One experimental and one control group, pretest and posttest.	N= 129 Nursing students	**Evaluate the pharmacology Interleaved Learning Virtual Reality in nursing education** **3D technology: 3D environment with a computer.**	The experimental group (n=82) enroled in the 3D environment as an avatar. The 3D environment had different scenarios targeting medical administration. The control group (n=47) got the lecture-based teaching. Duration of implementation: three hours.	Measured categories: knowledge Knowledge: The students that enroled in the 3D environment revealed significantly higher scores from conceptual and procedural knowledge.
(Choi, 2017) China	Overview.	Nursing education.	**Describe using virtual reality in nasogastric tube placement training simulator.** **3D technology: 3D environment with a computer.**	3D environment, that works in collaboration with a plastic mannikin. The route of the nasogastric tube is shown in a 3D environment.	-
(King et al., 2018) Ireland	Contemporary Issues.	Health care education, midwives.	**Describe the potential of virtual reality in health care education.** **3D technology: 3D environment with multiple ways to use.**	3D environments with multiple uses with mobile devices, tablets, computers or with headset and haptic devices.	-
(Gallegos et al., 2017) USA	Descriptive qualitative study. One group.	N= 59 Nursing students.	**Describe nursing student experiences with 3D gaming.** **3D technology: 3D environment with a computer and 3D image with videos.**	The students used 3D GameLab and reported their experiences. Duration of implementation: six weeks, more than once.	Measured categories: experiences Student experiences were mainly critical and consisted of

					six themes: navigation, motivation, gaming concept, knowledge, technology and target population.
(Günay Ismailoğlu et al., 2018) Turkey.	Quasi-experimental study. One experimental and one control group, pretest and posttest (after 15 days).	N= 65 Nursing students	**To compare the effectiveness of a virtual simulator to plastic arm in teaching intravenous catheter insertion skill.** **3D technology: 3D environment with a haptic device that finally converts the arm-image and students' movements to virtual reality images.**	Experimental group (n=33) used a virtual simulator (3D environment). Control group (32) used a plastic arm. Duration of implementation: One time	Measured categories: skills, knowledge, satisfaction, self-confidence and fear symptoms. **Skill:** No statistically significant difference. **Knowledge:** No statistically significant difference, although psychomotor skills were higher in the experimental group **Satisfaction:** No statistically significant difference, although satisfaction was higher in the experimental group. **Self-confidence**: No statistically significant difference. **Fear symptoms**: No statistically significant difference, although the fear symptoms were higher in the control group.
(Smith et al., n.d.) USA.	Quasi-experimental study. One experimental group and one control group, pretest and posttest. Follow-up test after five months.	N= 106 Nursing students	**Assess virtual reality simulations to teach decontamination skills.** **3D technology: 3D environment with head-mounted display and hand controls (stereoscopic 3D technology).**	Experimental group (n=57) used a web module and stereoscopic 3D technology. Control group (n=51) utilized a web module and written instructions. Duration of implementation: one time, about 10 minutes.	Measured categories: knowledge and skills. **Knowledge:** No significant differences between groups, although the experimental group scored higher points than the control group. **Skills:** No significant differences between groups, although the experimental group's performance was significantly faster than the control group's.
(Hanson et al., 2019) Australia.	Mixed method study. Pretest and posttest.	N= 202 Nursing and midwifery students	**To compare the effectiveness of 3D visualization and 2D visualization for nursing and midwifery students to learn pharmacology.** **3D technology: 3D image with 3D visualization studio.**	Two rooms were students enrolled, depending on the situation. Room 1 had a 3D visualization studio. Room 2 had the 2D perspective. Duration of implementation: One time.	Measured categories: knowledge, discomfort and satisfaction. **Knowledge:** Room 1 and 3D visualizations improved students' correct answering statistically significantly. **Discomfort and satisfaction**: Room 1 was comparable to Room 2 while both results were better.

(Gordillo Martin et al., 2017) Spain.	Quasi-experimental study. One group, pretest and posttests.	N= 35 Nursing students	**Test the clinical simulation among nursing students with patients with possible spinal injury.** **3D technology: 3D environment with 3D capturing tool VICON 3D motion, which captures possible misalignments of the spine during training with multiple cameras.**	A 3D capturing tool was the instrument of the research that measured the results and supported the evaluation.	-
(Rossler et al., 2019) USA.	Pilot study. Experimental group and control group, pretest and posttest.	N= 26 Nursing students.	**Test virtual reality among students to teach fire safety in a perioperative environment.** **3D technology: 3D environment with a computer.**	Experimental group (n=13) used a 3D environment that included five different sessions on fire issues. This was used after the theory session. Control group (n=13) only used the theory session. Duration of implementation: one time.	Measured categories: knowledge, skills **Knowledge:** No significant differences were found from the perspective of learning outcome in knowledge. **Skills:** From the perspective of skills, the intervention group had significantly better results in the area of one emergency procedure.
(Keskitalo, 2012) Finland.	Mixed method. Pretest.	N=97 Health care students.	**Describe students' expectations about virtual reality in the learning process.** **3D technology: 3D environment with projector and handheld device**	Students' expectations were measured before using the 3D technology.	Measured categories: experiences Three named variables described that overall, the students' experiences with the 3D environment was quite high. Variables were named following: inspiring and individually tailored teaching, individual and competence-based studying, transferable learning outcomes and competent and well-prepared instructor.
(Williams, Jones & Walker, 2018) Australia.	Issue for debate	Midwife education.	**Describe the potential use of virtual reality in midwife education in neonatal resuscitation.** **3D technology: 3D environment with different uses.**	The 3D environment can be used in many ways, and it can be a potential way to teach neonatal resuscitation.	-

5 Discussion

The aim of this scoping review was to explore the use of 3D technology to support teaching and learning in health care education and the outcomes related to 3D technology from the perspective of teaching and learning. The use was related to 3D environments (e.g. Dang et al., 2018), 3D images (e.g. Ulrich et al 2019), 3D holograms (Chang & Lai, 2018; Hackett & Proctor, 2018) and 3D printing (Rutty et al., 2019). The use of 3D technology was also connected to positive outcomes from the perspective of learning outcomes (e.g. Boada et al., 2015) and outcomes that supported learning for example students' motivation (e.g. Chang & Lai, 2018). All outcomes were connected to different kinds of pedagogical contexts, for instance, the teaching of anatomy (e.g. Rutty et al., 2019) or pharmacology (Hanson et al., 2019).

As an entity, the 3D environment was dominant, when using 3D technology to support teaching and learning in health care education (e.g. Dang et al., 2018). This can be connected to a wide definition of concepts like virtual reality and augmented reality (Geng, 2013). However, it does not explain the minor usage of 3D images (e.g. Ulrich et al 2019), 3D holograms (Chang & Lai, 2018; Hackett & Proctor, 2018) and 3D prints (Rutty et al., 2019), when, for example, other studies present a wide use of 3D printing (Shah & Chong, 2018; van Doormaal, Mensink, & van Doormaal, 2018; Warsi, Yusuf, Robaian, Khan, Muheem & Khan, 2018) and 3D images (de Boer, Vesselink & Vervoom, 2016). This was interesting because there are possibilities of using 3D technology in more ways. The unbalanced use can be related to different levels of actual technology because, for example, holographic technology is quite new (Chang & Lai, 2018; Hackett & Proctor, 2018) and 3D environments have been possible for several years (Hogan et al., 2011). 3D holograms and 3D printing were used only in teaching anatomy (Rutty et al., 2019; Chang & Lai, 2018; Hackett & Proctor, 2018). However, the pedagogical contexts when using these technologies can be wide (Shah & Chong, 2018; van Doormaal et al., 2018; Warsi et al., 2018). Nevertheless, an anatomical context is also used in medical education when using 3D printing (Weidert et al., 2019).

The positive learning outcomes were in multiple areas and included improved skills (e.g. Rossler et al., 2019), knowledge (e.g. Hackett & Proctor, 2018) and empathic concerns (e.g. Everson et al., 2018), which are in line with studies in medical education (Shah & Chong, 2018; van Doormaal et al., 2018; Warsi et al., 2018; de Boer et al., 2016). The positive learning outcomes cannot be generalized because of the small amount of research (n=8) and the various characteristics of research. The research designs were not homogenous and there were only a few randomized control trials. Because all of the different 3D technologies were also connected to positive learning outcomes, the connection of a single 3D technology is not clear. An interesting element in this study was the number of articles (n=14) that presented positive outcomes that supported the actual learning process. This highlights the possibilities of using 3D technology to support teaching and learning in health care education if the teacher wants to visualize something that can be hard to understand (Günay Ismailoğlu et al., 2018; Butt et al., 2018). Students reported also very positive satisfaction with using 3D technology in teaching and learning (e.g Courtney-Pratt et al., 2015).

From the perspective of the user interface, the results of this scoping review describe content that is in line with medical education (Shah & Chong, 2018). The use of technology demands different kinds of competence from teachers, because it can be characteristically simple with only mobile phones (Garrett et al., 2015) or quite complex including a computer, haptic devices and glasses (Smith et al., n.d.) or a 3D printer (Rutty et al., 2019). The results highlight that 3D technology (3D printers, for example) can also be used in the planning and pre-work of teachers (Rutty et al., 2019). However, there were no articles about teachers using 3D printers with students or only students using 3D printers, which occurs in medical education and adds to students' technological understanding (Shah & Chong, 2018).

According to this scoping review, it is not possible to describe a systematic connection between different 3D technologies in teaching and learning in health care education, as the research articles included multiple designs. There were only three articles that were designed as randomized controlled trials (Hackett & Proctor, 2018; Boada et al., 2015; Jung et al., 2012), and the dominant part included qualitative elements, at least with a mixed-method design (e.g. Farra et al., n.d.). The results are not unequivocal from an educational perspective because this scoping review only used the definition of health care education by the Finnish National Supervisory Authority for Well and Health (2020). In contrast, the results can be considered to be global, as the data came from multiple countries (n=13). This reflects that 3D technologies can be used to support teaching and learning, although the educational content varies in different countries (Salminen et al., 2010).

The results present challenges to the conceptualization of 3D technology. The challenge of conceptualization was also reflected in the amount of included data (n=140) in the full-text analysis phase, when the uncertainty about losing relevant articles was considerable. The analysis was guided by Arksey and O'Malley's (2005) framework, which helped in controlling the data.

3D technology can be a promising possibility for teachers to use as support for teaching and learning (Hackett & Proctor, 2018). Although the connection to positive learning outcomes is not unequivocal, teachers can think of 3D technology as a concrete help to enhance actual learning outcomes. Different 3D technologies have many positive elements from the perspective of students that can be also be related to the concrete learning process (e.g. Dang et al., 2018). It is also part of a teacher's professionalism to know the different possibilities of technology (NLN 2016) such as 3D technology. In that situation, the teacher can plan different methods and perspectives on teaching, while the actual content is the same (for example, pharmacology). This will make the entity richer, and multiple ways of teaching make learning more accessible for different types of learners. This can encourage students to be more engaged in learning and obtain better learning outcomes.

5.1. **Limitation**

This scoping review has limitations concerning the whole process. The first limitation is the conceptualization of 3D technology. Although the aim was a structured conceptualization, the unclear descriptions could have led to some articles being excluded. That means that the actual 3D technology could have been utilized and reported in some other way. Secondly, the study was limited by the exclusion of the 3D environment technology Second Life® because of the already existing wide knowledge about the technology. Including Second Life® could have created the problem of a too-heavy focus on a certain technology, and the dominance of a virtual reality or 3D environment could have been clearer. Thirdly, a quality assessment was not included in this scoping review. This could affect the validity of the results. Although the data also included the grey literature, it is not possible to assess the quality of this literature with validated tools (Daudt, Van Mossel, & Scott, 2013). This means that the quality assessment could have been a limitation on the performance of the scoping review's results (Pham et al., 2014). This review utilized the ethical guidelines of the Finnish Advisory Board for Research Integrity (2012) in every phase to make sure that the quality was good and no misconduct occurred.

CONCLUSION

The main result of this scoping review is the finding that there are several different 3D technologies that teachers can use to support their teaching in health care education. It also seems that using 3D technology can have a positive effect on learning outcomes and students perceptions, although the amount of research was small. This reflects a promising element of using 3D in multiple ways in health care education. This study highlights the important meaning of a structured conceptualization of 3D technology. This can help researchers to target studies more relevantly, thus affecting the reliability of the studies. With a structured conceptualization of 3D technology, teachers can also evaluate their methods more widely and support their teaching with richer content. This scoping review also tentatively presents a structured conceptualization of the main concepts of 3D technology. Future research is needed on this conceptualization. More validating research also has to be done from the perspective of learning outcomes.

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