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Virtual Reality and Augmented Reality in Education: A review

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Virtual Reality and Augmented Reality in Education. A review.

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Abstract

The emerging field of Virtual Reality (VR) and Augmented Reality (AR) systems and solutions lead to new opportunities for learning and education. In this review we investigate how and why VR/AR tools and applications contribute to the learning of new knowledge and skills, using a core set of literature reviews, and we also look at the research and development of VR/AR within the Utrecht University. We draw some conclusions and propose recommendations. The report is the result of a cooperation between teachers and researchers of the Utrecht University.

Content

Chapter 1 – Context and definitions

Context - A continuum of realities

There are many innovations in research and technology that may have strong influence on education and training. The rapid growing area of Virtual Reality (VR) and Augmented Reality (AR) promises to add quality to educational settings. In autumn 2019 it was decided to write a review on the use of VR and AR to have an internal report for Educate-it. Although definitions exist for the terms VR and AR, they are not unique and sometimes rather vague and ambiguous. Therefore, we start with a short review of the field and specification of the terminology, while focusing on how these may relate to applications and usages in an educational context. We start from a continuum of realities, the virtuality continuum (Milgram et al., 1994). The virtuality continuum is a continuous scale ranging between the completely virtual, a virtuality, and the completely real, reality (Figure 1).

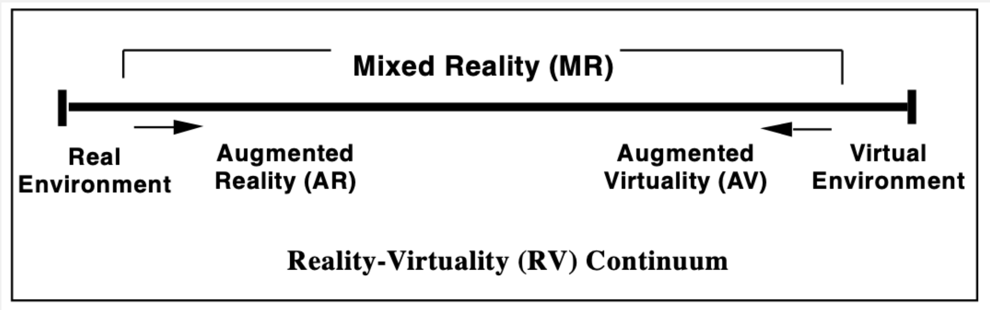


Figure 1 – The Reality-Virtuality Continuum (Milgram et al., 1994).

The reality–virtuality continuum encompasses all possible variations and compositions of real and virtual objects. It has been described as a concept in new media and computer science, but in fact it could be considered a matter of anthropology. Having this continuum as a starting point we look at the two important stages in this continuum, VR and AR (Figure 2).

Virtual Reality	Augmented Reality
A simulated system or digital representation that can be similar to or completely different from the real world.	A system that fulfills three basic features: • a combination of real and virtual worlds; • real-time interaction; • accurate 3D registration of virtual and real objects.
Kavanagh et al., 2017	Wu et al., 2013

Figure 2 – Definitions of Virtual Reality and Augmented Reality.

Let’s go into more detail.

Virtual reality

Virtual reality is basically the creation of a realistic or believable virtual world with a computer that users can explore and interact with in an immersive way. Kavanagh et al. (2017) describe it as “a simulated system or digital representation that can be similar to or completely different from the real world.”. We give some examples.

Example 1 - Replicas of existing worlds that match them as closely as possible.

Virtual supermarket

The virtual supermarket is a VR implementation that is used for the treatment of stroke patients (Knowledge Center Revalidation Medicine Utrecht; based on earlier research, e.g. Spreij et al, 2014). Using a head-mounted virtual reality display (HMD), users are placed into a familiar supermarket environment. They can train everyday life situations and their behavior can be analyzed by the neuroscientists running this training. It is a good example for a simulated virtual world that looks like and reacts like a real environment. Using HMD technology allows us to “virtually place” patients into this alternative world.


Example 2 - Real worlds with extended “functionality” or unreal extensions.

Tree VR Experience

A VR simulation by New Reality Co (treeofficial.com). Using HMDs, a user can experience the life of a tree in the rainforest via a time lapsed simulation from its “birth” from a seed, to its growth to a full tree, and its tragic death when the rainforest is burned down. At the Faculty day on July 4, 2019, at the Science Faculty of Utrecht University, we showed this program as an example to demonstrate how VR technology can be used to teach and create awareness. It is also a nice example where VR is used to create a realistic world, but unrealistic extensions and modifications of this world can be used for education (here, to create stronger awareness to protect the rainforest by experiencing it from the perspective of a tree).

Example 3 - Fantasy worlds that have no real counterpart but are still believable.

3D painting education in primary schools

In a collaboration with Kleur in Cultuur and ING, people from the Multimedia Group at the Department of Information and Computing Science explored the opportunities of using VR in primary education. They developed exercises for 3d painting that allowed children to draw in 3d and evaluated, among other things, the impact on developing a better spatial understanding. This is an example where a virtual world is created that does not resemble a real world, nor does if follow common physical rules, yet is still believable insofar as people experiencing it feel like they are really present in this virtual world and can interact with it in a natural way. (Bolier et al,, 2019)

Characteristics
Although these worlds can be realistic, they do not have to, as long as they are, as we called it in the last example above, believable, that is, people can experience them as being a real part of them. This is also why the notions of immersion and presence are central aspects when it comes to VR research and usage. A good VR generally increases presence, i.e., the feeling of being in in this virtual world and being a part of it. Non-surprisingly, VR worlds are therefore based on 3D graphics and generally provide a first person view, although examples where users are represented by an avatar in the VR simulation exist.

Technology
Computer-generated 3D graphics that can be updated in real-time are an essential necessity to create believable virtual worlds. Concrete implementations of VR systems can be distinguished by what type of display technology is used. In its simplest form, the 3D VR simulation can run on a standard desktop computer screen. While being less immersive and thus less “real-world like”, such simple forms of VR can still be quite powerful. See for example the Communicate! project.

Example 4 - A simple, yet powerful desktop-based VR environment

Communicate!

communicate.sites.uu.nl

Communicate shows that sophisticated systems are not always needed to achieve a certain goal.

More advanced and immersive realizations of VR include so-called CAVE systems, where the virtual world is projected around the user with data projectors, and the now omnipresent head-mounted displays (HMDs), where a display is placed in front of the users eyes, thus creating the visual illusion of being in a different space. See the first three examples mentioned above.

Other, non-visual modalities

The visual virtual world created with VR is commonly complemented with audio, from simple mono sound to sophisticated, real-world-like 3d surround sound. Other modalities are less used these days, but provide promising opportunities for future systems. Different devices and technologies are being used to create haptic feedback, for example, when people are interacting with the virtual world. Making VR more interactive provides a shift from rather passive experiences to active participation in the virtual world and thus has a high relevance for teaching and education. Other advanced technology includes machines that simulate walking in the virtual world (similarly to walking on a treadmill) or the controlled usage of odors to simulate smell, which is an important trigger in relation to memory.

In Chapter 2 (review) we dive into the (recent) literature on VR in order to get a better idea of the different attempts and successes to use VR in education.

Augmented reality

In contrast to VR, where the whole environment is simulated, Augmented Reality (AR) simulates only parts of it and integrates these virtual elements seamlessly with the real environment of a user, thus virtually “augmenting” it. Like VR though, AR systems have certain identifying characteristics, but lots of variations exist. Milgram et al. (1994) see AR as subsection of Mixed Reality (MR), which is basically everything between pure real and pure virtual reality (see Figure 1). Individual implementations along this continuum represent the level of integration of the real and simulated virtual elements.

Characteristics

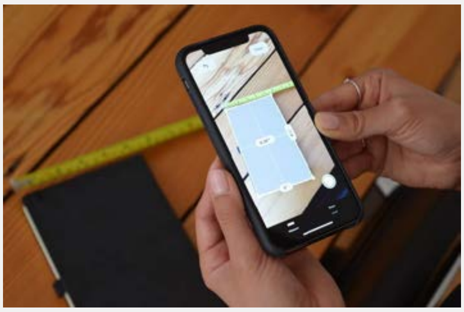
Like with VR, different AR implementations exist depending on the used display technology (see below). Yet, all AR systems commonly share certain characteristics. In an attempt to abstract from the actual technology, Azuma (1997) defined an AR system using the following three characteristics:

- Combines real and virtual
- Interactive in real-time
- Registered in 3d

"Registration" in this context means the accurate placement of a virtual 3d object at a dedicated space in our 3d world (in contrast to, for example, just superimposing it to our real-world view).

Example 5 – Measurement App

Apple iOS (and other mobile platform)



In this basic example you see the combination of real and virtual, it changes when you move the camera (real-time) and there is registration (the virtual 'object' is locked to a the real world).

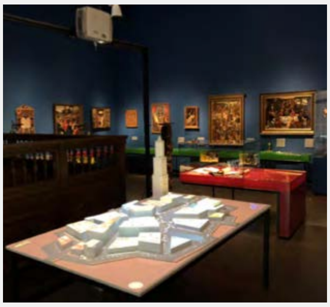
Technology
While researchers commonly agree on the characteristics of Azuma for AR systems, which are independent of the used technology, the used type of display has a high impact in practice. E.g., some goals can only be achieved with a certain technology, and likewise, some technologies might be better for achieving certain goals).

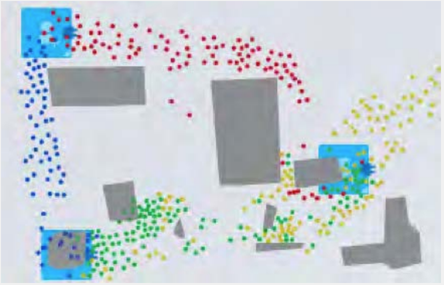
Creation of virtual visuals: requires display that is either naturally integrated into the environment (reality) or "blended" with it. Options can be categorized by where this display is placed:

- At the eye (contact lenses)
- Right in front of the eyes (AR HMDs, e.g., HoloLens)
- Handheld
- Desktop (see through or special case of "magic mirrors")
- Spatial / projected (see example 6)

Example 6 – Spatial/projected

CrowdAR – Utrecht University





AR table installation with data projector and video camera on the ceiling and projections onto a fixed city mode. The other picture is a contour map of the physical objects placed on the table

This was a short introduction to the two techniques VR and AR and we repeat the two central definitions (Figure 2).

Virtual Reality	Augmented Reality
A simulated system or digital representation that can be similar to or completely different from the real world.	A system that fulfills three basic features: • a combination of real and virtual worlds; • real-time interaction; • accurate 3D registration of virtual and real objects.
Kavanagh et al., 2017	Wu et al., 2013

Figure 2 – Definitions of Virtual Reality and Augmented Reality.

In Chapter 2 we will look for educational use of those two techniques VR and AR.

Chapter 2 – Review

Methodology

In order to integrate the findings regarding the use of AR and VR in education, we conducted a search for the most relevant and recent systematic literature reviews and meta-analyses regarding this topic. Only articles written in English that focused on the use of VR and AR in education, were included. We conducted the search in October 2019 and included all articles published after 2010 and prior to October 2019, so that the found articles would contain relevant and currently used VR and AR technology for general education purposes. Also, we excluded articles that did not specify the educational implications of the use of VR and AR, articles that are domain-specific regarding the topic (e.g., virtual reality for orthopedic surgery), and that were not reviews or meta-analyses.

We conducted the literature search using the scholarly search engines ERIC, Scopus, and Web of Science in all journals and using the search terms as presented in Table 1 – Search Terms Used. Based on our predetermined inclusion and exclusion criteria, we studied the titles and, if needed, the abstracts of those articles to judge whether each article was relevant to include. After applying the inclusion and exclusion criteria, four articles about AR, four articles about VR and one article about both AR and VR, were selected to be included, see Table 2 - Key Publications on the next page.

Table 1 - Search Terms Used

Search term		Search term		Search term
“Virtual Reality” OR “Augmented Reality”	(AND)	“Education” OR “Learning”	AND	“Review” OR “Meta-Analysis”

Note. Search limits included English, and publication date between January 1, 2010, and October 2019

Key Publications
Nine recent scholarly publications including recent research articles on the use of AR and VR for education were selected for this review. Table 2 describes the titles and authors of these publications.

Table 2 - Key Publications selected for this review on AR and VR

Augmented Reality	Virtual Reality
Akçayır, M. et al. (2017). Advantages and challenges associated with augmented reality for education.	*Concannon et al. (2019).* Head-Mounted Display Virtual Reality in Post-secondary Education and Skill Training.
Garzón & Acevedo. (2019). Meta-analysis of the impact of Augmented Reality on students' learning gains.	*Jensen & Konradsen (2018).* A review of the use of virtual reality head-mounted displays in education and training.
Hedberg, H. et al. (2018). A systematic review of learning through mobile augmented reality. Interactive mobile technologies, 12(3).	*Kavanagh, S. et al. (2017).* A systematic review of Virtual Reality in education.
Papanastasiou, et al. (2018) Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills.	*Merchant, Z. et al. (2014).* Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education.
Saltan & Arslan (2017) The use of augmented reality in formal education: a scoping review.	*Papanastasiou, et al. (2018)* Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills.

AR and VR are part of a virtuality-reality continuum (Milgram, 1994) as stated in Chapter 1, but they imply different technologies, as well as different advantages and disadvantages for education. Therefore, in the following section, we describe AR and VR separately including details about the pedagogical methods, field, and level of education, educational goals and learning outcomes obtained by using each one.

Augmented Reality

In order to understand the state-of-the-art on the use of AR in education, three literature reviews, and one meta-analysis were analyzed (i.e., Garzon & Acevedo, 2019; Hedberg, et al., 2018; Akçayır & Akçayır, 2017; Papanastasiou, et al., 2018). These articles include studies from 2000 to 2018, selected through extensive literature searches.

Educational levels

As shown in Table 3, primary and secondary education (i.e., grades 1-12), as well as higher education, are the main targets for the use of AR with educational purposes (Garzon & Acevedo, 2019; Hedberg, et al., 2018; Akçayır & Akçayır, 2017). Garzon and Acevedo (2019), found AR technologies to be effective, according to their educational goals, in all target groups.

Table 3 - Distribution of AR studies, regarding the level of education

	Garzon & Acevedo (2019)	**Hedberg, et al. (2018)**	**Akçayır & Akçayır (2017)**
Early childhood education (K)	0	6	1
Primary education (grades 1-6)	19	18	35
Secondary education (7-12)	25	17	
Higher education	20	34	19
Adult education	NA	NA	7
NA	NA	2	6

Fields of education

According to Garzon and Acevedo (2019), the majority of research papers focused in the field of natural sciences, mathematics, and statistics (32/64), followed by arts and humanities (11/64) and in a less extent by health and welfare (7/64), social sciences (5/64) and engineering, manufacturing and construction (5/64). Similarly, Hedberg and colleagues (2018) found natural sciences to be the field that was mostly mentioned in the articles they reviewed (20/73), followed by language and history (8/73) and history (8/73).

Pedagogical methods and learning approach

Many of the studies reviewed do not explicitly describe a pedagogical approach for their development (Hedberg & et al., 2018; Saltan & Arslan, 2017). From the studies that did specify a pedagogical approach or instructional strategy, interactive and situated learning were mainly mentioned (Hedberg & et al., 2018; Saltan & Arslan, 2017). Both refer to the

construction of knowledge, through continuous interaction with the environment and in real-life situations. In this case, the use of AR enables the opportunity to interact with virtual and real objects together to foster students' learning and motivation (McLellan, 1996).
Another mentioned approach is inquiry-based learning, this approach aims at constructing knowledge by following a research procedure to discover new causal relations. In this approach, the students define hypotheses and test them by conducting experiments or by making observations (Pedaste et al., 2015). With the use of AR, students are able to develop the research process by observing both virtual and real objects that can serve them to answer their questions. An example that involves both situated learning and inquiry-based learning is described by Chang, Wu, & Hsu (2013). Their study develops a mobile AR activity in which students define a research question about the impact of nuclear accidents. With the AR device, students are hypothetically situated in a school near a power plant that had a nuclear accident. The students have to find and measure AR superimposed radioactive objects from their surroundings to analyze the radiation values and answer their research question (Chang et al., 2013).
To a lesser extent, other pedagogical approaches mentioned include collaborative learning and game-based learning. Collaborative learning is mainly described when the learning activities are planned to be solved in groups or teams. In this way, students use AR to develop the activity and, at the same time, participate in teams or groups (e.g., Han, Jo, Hyun & So, 2015). Furthermore, game-based learning implies the use of AR within a game with educational purposes. For example, Crandall and colleagues (2015), developed a game in which students, with the use of an AR application, solve challenges in a gamification mode to learn about food chemistry.
In sum, AR is used to combine virtual and real objects to situate students in a specific context in which they can learn by interacting with the newly created environment. These situations or learning environments can incorporate inquiry-based practices, collaborative activities or game-based learning according to the instructional goal.

Learning Outcomes

According to Garzon & Acevedo (2019), interventions using AR technologies are more effective in attaining the educational goals, than using only traditional lectures, pedagogical tools, and multimedia resources. As mentioned in the previous section, AR facilitates the knowledge construction by providing a unique and learner-centered experience that allows students to interact, at their own pace, with the virtual and real objects (Papanastasiou, et al., 2019).
Numerous studies report that AR enhances learning achievement and performance (Akçayır & Akçayır, 2017; Hedberg et al., 2018; Saltan & Arslan, 2017). As described by Akçayır and Akçayır (2017), some explanations for this effect include: (1) the use of AR designed videos and 3D images can help students' explore new ideas and visualize intangible concepts to fully understand the content; (2) AR allows the provision of well-integrated and organized relevant materials in different modalities (e.g., written text, images, videos, auditory stimuli) which avoids the cognitive overload; (3) The use of AR triggers students' positive attitudes towards the learning activities which helps to maintain their attention and interest; (4) The students' interaction with the environment, promotes active participation and responsibility as well as learning by doing, which facilitates the knowledge construction and retention.
However, as explained by Akçayır & Akçayır (2018) and Hedberg et al. (2018), the main contributions of AR to educational settings rely on increasing the students' motivation, satisfaction, and engagement, which at the same time enhance positive learning outcomes (Akçayır & Akçayır, 2017; Hedberg et al., 2018; Saltan & Arslan, 2017). In this case, AR make instruction more entertaining and AR-based games make learning more fun, AR

increases the students' interest and attention on the topic, allows students to be responsible and make decisions for their own learning (Akçayır & Akçayır, 2017).
In a lesser extent, some studies found AR-enhanced instruction aimed at improving the students' problem-solving, creativity, communication, collaboration and emotional skills (Akçayır & Akçayır, 2017; Hedberg et al., 2018; Papanastasiou et al., 2019). For example, an AR video-modeling storybook helps children with ASD to understand facial expressions and emotions. This tool attracts the attention of the child to mimic the nonverbal content and feel the presented emotions, showing an improvement in social and emotional awareness (Huang, et al., 2016 cited by Papanastasiou et al., 2019). However, AR applications focused on supporting the development of students' higher-order thinking skills are still lacking (Saltan & Arslan, 2017).

Challenges

Even though AR seems to enhance many advantages for education, some studies have reported their challenges when incorporating these tools into instructional programs. One of the main challenges when testing the AR tools was the difficulties students experience when using AR (i.e., usability, application-related and technical problems), which may increase the time required for learning and the cognitive load of the students, hampering their motivation and performance (Akçayır & Akçayır, 2017). Additionally, these tools are not suitable for large groups of students and are not accessible in places without the devices and internet connection (Akçayır & Akçayır, 2017). Furthermore, the use of AR may create a novelty effect in the learning advantages presented in the previous section. It is still unknown if the positive outcomes such as motivation or students' interest are still high after students become familiar with the tool (Saltan & Arslan, 2017).

Conclusion

In conclusion, the use of AR for educational purposes enhances the students' learning by interacting with a created environment, which includes both real and virtual objects. This technology allows the use of pedagogical approaches such as inquiry-based learning, game-based learning or collaborative learning which promote the students' active participation increasing their interest, attention, and motivation. Additionally, the use of different stimuli (e.g., images, videos, text and auditory stimuli), attracts the students and avoids cognitive overload. In sum, these effects increase the students' achievement and performance, however, the development of skills such as creativity, problem-solving and collaboration as well as higher-order thinking skills are still underrepresented in the research findings. Furthermore, because AR is such a new technology, some challenges are still encountered by the users when looking to adopt it in real educational settings.

Virtual Reality

In order to explore the current use of virtual reality in education, we reviewed three systematic literature reviews and one meta-analysis (i.e., Concannon, Esmail, & Roduta Roberts, 2019; Jensen & Konradsen, 2018; Kavanagh, Luxton-Reilly, Wuensche & Plimmer, 2017; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014). These studies include articles from 1999 to 2018, identified through extensive literature searches.

Educational levels

VR environments developed for educational purposes, target mainly higher education. To a lesser extent, some VR solutions have been developed to target secondary and primary education. Specific details regarding the two studies reviewed that explicitly mention the target groups can be found in Table 4.

Table 4 - Distribution regarding VR per level of education

	Kavanagh et al. (2017)	Merchant et al., (2014)
Early childhood education (K)	4	NA
Primary education (grades 1-6)	6	8
Secondary education (grades 7-12)	9	24
Higher education	52	35
Other (e.g., museums, general tools)	21	NA

Fields of education

VR environments have been mainly used in the STEM (i.e., Science, Technology, Engineering, and Mathematics) field, Health Sciences education, and to a lesser extent, for arts and humanities (Concannon et al., 2019; Kavanagh et al., 2017; Merchant, et al., 2014). See Table 5.

Table 5 - Distribution regarding VR per fields of education

	Concannon et al., 2019	Kavanagh et al., 2017	Merchant, et al., 2014
STEM (Science, Technology, Engineering, and Mathematics)	55	26	24
Health Sciences	49	35	10
Arts and humanities	16	7	NA
Others (e.g., museums and general tools)	4	31	13

Pedagogical methods and learning approach

Even though the reviewed studies did not usually refer to a specific pedagogical approach, three main approaches were found to be explicitly or implicitly used to develop VR learning environments. First, the majority of the studies describe learning to be acquired from a constructivist perspective, where students develop knowledge through active experimentation and experience process (Kavanagh et al., 2017). This was also referred to as experiential learning or situated learning, where students are able to use the virtual environments to simulate their actions as if they were in the real-world (Concannon et al., 2019). Other studies exploit the collaborative potential of the VR environments aligning to the social constructivism perspective. In this case, the interaction within the VR environment with other students or teachers is possible which also enables learning (Concannon et al., 2019; Kavanagh et al., 2017). Last, another use of VR is for gamification or game-based learning purposes, in this case, the VR technology is utilized to recreate an environment in which the users play and learn at the same time. For example, a marine game life designed for children with down syndrome, where students watch virtual marine life and participate in game-type, fun exercises and tests (Afonseca et al., 2013 cited by Kavanagh et al., 2017).
Additionally, Concannon and colleagues (2019), emphasize the importance of student-centered instruction through virtual environments. This means that the students are active participants and responsible for their own learning by constantly interacting with the environment, which, at the same time provides feedback and adaptive challenges (Concannon et al., 2019).

Reasons to use VR

Kavanagh and colleagues (2017) as well as Concannon and colleagues (2019), reviewed the studies' rationale to use VR as an instructional tool. From a pedagogical perspective, the VR immersion factor enables a learner-centered instruction in which the students actively lead their own learning process. Students are required to interact directly with the recreated environment, explore and develop knowledge from their experience. Additionally, VR can facilitate multi-sensory learning stimuli, simulations for skill training, access to intangible concepts as well as personalized learning experiences that adapt to the students' interests and cognitive ability providing different levels of challenge and real-time feedback (Concannon et al., 2019). From a motivational perspective, since VR is a new technology, making use of it can improve the students' engagement, enjoyment and motivation to learn the content by developing interesting learning activities as well as game-based learning models (Kavanagh et al., 2017).
Lastly, from a practical perspective, Concannon et al (2019) found that the use of VR provides other benefits compared to training the same skills in the real world. First, VR can be used to train skills in interaction with objects that in real-life could be unsafe or inaccessible. Second, the resources required to train the same skills in the real world such as time, location and cost. For example, the VR environment can provide a cost-effective solution to train surgical skills that in the real world can be very costly (Mathur, 2015 cited by Concannon et al., 2019). Collaboration in a common virtual space with people in different locations can be enhanced through a VR system (Concannon et al., 2019). Also, regarding time, the use of a VR lab may allow more lab availability hours, as well as reduce the preparation and clean-up time required (Lau et al., 2017 cited by Concannon et al., 2019).

Learning outcomes

The VR environments' immersive property allows students to experience learner-centered conditions that make learning more flexible and a unique experience to discover and construct knowledge at their own pace (Papanastasiou et al., 2019). Many studies that use VR for education are based on the assumption that more immersion is related to better learning outcomes (Jensen & Konradsen, 2018). Overall, virtual-reality instruction, in its three formats simulations, virtual worlds, and games, has been shown to be quite effective (Merchant et al., 2014). However, some results may vary according to the instructional design features (i.e., type of feedback, collaboration, teacher availability, among others), outcome measurements, retention intervals, level of immersion and repetition (Jensen & Konradsen, 2018; Marchant et al., 2014).

One of the main learning outcomes includes knowledge acquisition and skills training (Concannon et al, 2019; Jensen & Konradsen, 2018; Papanastasiou et al., 2019). Regarding the cognitive skills or knowledge acquisition, the VR systems studied, mainly focused on helping students remember and understand facts (low-level cognitive skills; Bloom et al., 1965). For example, a VR system featured a 360-degree view of Kaaba to teach about Islamic History, the users can visit different learning points and receive audio information (Yildirim et al., 2018). Nevertheless, no studies reported the use of VR to help students develop other higher-level cognitive skills such as critical thinking (Jensen & Konradsen, 2018).

Other studies focused on the development of psychomotor skills, using simulators in which the learner can repeatedly practice. In order to consider this type of training as effective, the skills should transfer to the real world (Jensen & Konradsen, 2018). For example, a training simulator designed to teach people to juggle three balls was tested after the intervention in the real world to assess the transferability of the skills acquired (Kahlert et al., 2015 cited by Jensen & Konradsen, 2018). It was shown that the simulators' effectiveness depends mainly on their fidelity to recreate the real-world (Jensen & Konradsen, 2018).

Furthermore, few studies investigate the use of VR to develop interpersonal or affective skills (Jensen & Konradsen, 2018; Papanastasiou et al., 2019). Similar to the psychomotor skills training, this type of training requires repetition and high fidelity to simulate a virtual human or social situation that may evoke an emotional response from the learner (Jensen & Konradsen, 2018). An example of this training is a VR simulator created to train health professionals to perform diagnostic interviews in eating disorders through psychopathological explorations of virtual patients (Gutierrez-Maldonado et al., 2015 cited by Jensen & Konradsen, 2018). Other VR environments are used to develop collaboration and communication skills by facilitating the interaction and collaboration between people from different locations or with communication difficulties (e.g., people in the autistic spectrum; White et al. 2007 cited by Papanastasiou et al., 2019) (Papanastasiou et al., 2019).

Another often mentioned goal is increasing the users' motivation or engagement to learn the subject content by prompting the users' interest in the VR environment (Concannon et al., 2019). VR encourages students' active participation in learning by doing activities (Papanastasiou et al., 2019). Also, VR may recreate real worlds where the students can be motivated and engaged to freely participate (Lorenzo et al. (2013) and Wallace et al. (2010) cited by Papanastasiou et al., 2019). In this regard, Jensen and Konradsen (2018) found that participants perceived the VR models to be useful and exciting. Nevertheless, users' in some studies found the VR model to be discouraging as it may provoke physical discomfort, feeling of unsafety and loneliness (Jensen & Konradsen, 2018).

Challenges

Despite the advantages VR environments can imply to educational settings, there are some challenges or disadvantages that have been found in the different studies included in this review. According to Kavanagh and colleagues (2017), they categorized the disadvantages in four main issues. First, the setup time, software and hardware costs, as well as training for teachers and students required to use the VR software in education. Second, the VR solutions often require a specialized solution that may present inaccuracies regarding recognition or hardware usability which hampers the learning process. Third, a lack of engagement or ineffective for the learning goal. Lastly, the output problems include the insufficient realism employed by the VR environment, software usability and motion sickness (Kavanagh et al., 2017). Regarding this latter, Jensen and Konradsen (2018), found eight out of 21 studies that reported physical discomfort and cybersickness symptoms when using the VR models. These symptoms influenced the learner's attitude towards the VR environment and were correlated with lower learning outcomes (Jensen & Konradsen, 2018).

Conclusion

In conclusion, VR technology creates a 3D spatial experience where the user immerses into a virtual simulation, game or world where he or she can experience different stimuli to learn. In this regard, the learning process is often described as situated or experiential learning, from a constructivist perspective. This means that the users construct knowledge from their experience and interaction with the environment.

Most research studies carried out on the use of VR for educational purposes focus mainly on the teaching of STEM and health sciences in higher education. From a pedagogical perspective, VR prompts the users' active participation and interaction to develop their own knowledge and skills. VR can provide multi-sensory stimuli and simulations for skill training as well as personalized learning experiences utilizing fewer resources than with real-world interventions. In addition, VR has been mainly used to develop low order cognitive skills, with an interesting research gap in using VR for higher-order skills development. Psychomotor, affective and interpersonal skills are also developed through simulations in VR, but high-fidelity and immersion ability are required. Finally, students' motivation and engagement is also attained by the use of VR, mainly in games used for learning purposes. However, these advantages may be also hampered by the physical and emotional discomfort VR can provoke and by the challenges that the use of this technology may cause.

Chapter 3 – General conclusions and recommendations

First we draw conclusions from the previous chapter and what we can learn from the literature review. In Table 6 both VR and AR results are compressed.

Table 6 – Most frequently mentioned issues in the literature review (sorted from most frequent to less frequent per category).

Category	Augmented Reality	Virtual Reality
Educational levels	• higher education • secondary education • primary education	• higher education • secondary education • primary education
Fields of education	• STEM • Arts and humanities • Health and welfare	• STEM • Health and welfare • Arts and humanities
Pedagogical methods and learning approach	• Interactive learning • Inquiry-based learning • Collaborative learning	• Inquiry-based learning • Gamification • Collaborative learning
Learning outcomes	Enhancing enjoyment, raising the level of engagement and the learning interest, which suggests that students will, therefore, perform better.	Increase in user skills and increase in engagement/motivation. Small effect: Game-based instruction has more impact than simulation-based instruction.
Challenges	• Technical problems • Availabilty for bigger groups	• High costs and setup time • Insufficient realism • Physical discomfort

Recommendations

This literature review included a comprehensive overview of the use of VR and AR in education. After analyzing the already published literature on this topic, we recommend considering the following ideas when deciding to implement an AR or VR solution for instruction.

Table 7 - Recommendations

1	Be clear about your **educational purpose**	The use of AR or VR for educational purposes is very interesting. However, it is important to understand what the main and secondary educational goals are, in order to decide which solution better fits the educational purpose. AR combines virtual and real objects with a specific purpose. If the educational purpose includes exploring certain objects, disregarding the setting, AR may be a good solution. VR is aimed at immersing the user partially (non-immersive VR) or completely (immersive VR) to a new world. In the new world, the user has the opportunity to experience a totally different setting or learning environment. Many different solutions can be created in a VR environment such as skills simulators, learning from a new or different world, etc.
2	Don't underestimate the role of **technology**	Technical considerations must be taken into account before developing an AR or VR solution for education, considering the target group and accessibility of resources. For example, usually, the AR solutions require a smartphone or tablet with an internet connection to be able to function. Also, immersive VR solutions require googles to be completely immersive
3	The central issue remains: **good instruction and learning activities**	It is important to consider that the use of AR and VR has mainly shown the potential to motivate students to engage in the learning content. Currently, the students' motivation may be higher because of an uncontrolled novelty effect which drives students' motivation and attitudes. However, the novelty effect may diminish over time, affecting the reported positive outcomes. Regarding learning, it depends on the instruction and learning activities the tool integrates whether the student is able to learn more or equally as in traditional instruction. Therefore, a combination of good technology with effective instruction is required to benefit from the use of VR or AR tools
4	Start a **SIG** VR/AR within the UU	Continue and enhance the collaboration within UU by starting a special interest group: • Exchange of Research and Development • Start/continue experiments with both formative and summative assessment as a main goal

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