Virtual reality in Education. Broken promises or new hope?

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Virtual reality in one form or another has been around for over 50 years, most notably in entertainment and business environments. Technology-focused teachers have been leading the way with attempts at utilising and integrating virtual reality into K-12 and Higher Education. However, as quickly as technology changes so does the enthusiasm for the use in educational contexts. Much of this is due to the high-level cost (time and money) with no evidence-based educational return. In 2020 the global pandemic forced the education sector to innovate to provide authentic learning environments for students. The time is right for virtual reality to take centre stage. Over 171 million people worldwide currently use virtual reality, and the market in education is expected to grow by 42% over the next five years. This paper focuses on a range of virtual reality literature encompassing work across the spectrum of software and hardware, identifying where more educational implementation and research needs to be done and providing a perspective on future possibilities focusing on current affordances.

Keywords: virtual reality, co-presence, teacher, learning

Background

Practically overnight, a shift in education delivery occurred when the COVID-19 pandemic forced the closure of physical schools and universities. Online, remote, and digital teaching and learning were not new, but suddenly all teachers, students, parents and carers had a vested interest in online learning. It has also emerged in research such as that by Orlov et al. (2021) that students of digitally savvy teachers performed better than their peers with less savvy teachers during the lockdowns of 2020. Education, across sectors, was prompted to do what it often resists: innovate quickly in a manner that can be applied to the realities of teaching and learning. Due to the multi-layered variables of policy, politics, and the need for evidence-based change, innovation is more commonly slow-moving. But proactive changes were required in the dynamic situation necessitated by a pandemic. The conservative nature of education is well documented (Apple, 2014; Fullan, 1993; Vrasidas & Glass, 2005) and has become more endemic as the 21st century progresses (Goodman, 2012). There was a collision between the way educational institutions usually respond and how they had to respond.

The snap decisions by governments to go into lockdown meant that educators had little time to prepare. Most moved to online learning through duplication of their lesson plans intended initially for in-person delivery. Importantly, there should be no blame placed on the educators who were busy dealing with the well-being of students, staff, and their communities, leaving very little time to focus on the learning. However, the topic of conversation in the mainstream media quickly became focused on learning loss. The World Bank estimated the monetary cost of learning loss on the current generation of students to be more than $10 trillion in lost earnings (World Bank, 2021).

Virtual Reality (VR) has been lauded as a technology poised to change the face of education, not dissimilar to many emerging technologies to come before. In 2019 the Educause Horizon report (Alexander et al., 2019) estimated the VR market to be worth up to $200 billion by 2022, with $7 billion specifically in the education sector. Gartner (Lowendahl, 2013) predicted that globally, by 2022, 70% of education organisations will experiment with VR or augmented reality (AR). In countries such as the UK, up to 96% of universities are already using AR or VR (Say, 2019). Williams (2019) claimed that VR was in the top 5 technologies impacting contemporary education, and Brown et al. (2020) stated that VR provides equity of education for learners and reduces institutional costs. With VR standing on the shoulders of other emerging technologies (for example, Virtual Worlds), one might assume that barriers would be superseded in response to the necessity to provide authentic, interactive learning environments in the time of forced remote learning.

It would not be a stretch to consider that in a year when institutional spending was tightened, digital delivery dramatically increased, and remote education became the norm, VR should have served a higher purpose. Instead, it seems to have been left at the starting gate (Roose, 2020). In preparing the education sector for future disruption, have we moved beyond considering VR as a realistic potential, or is VR ready to fulfil the transformational space as predicted? Online forums and emerging literature reveal that teachers and learners are ready for VR but lack skills and knowledge to link the technology with the curriculum to ensure sustainable integration.

Method

This paper presents some of the literature that has already emerged in relation to VR. While not an exhaustive literature review, the choice of papers provides a picture of what has gone before and what we might expect in the future. The authors present the idea of co-presence as one affordance of VR that is starting to emerge in real terms, offering insights through current literature. They acknowledge the importance of more evidence based real-world research into the use of VR in educational settings to shift the focus towards embedding VR as part of the teaching-learning landscape.

The Changing Nature of Virtual Reality

The history of VR is surprisingly long. As far back as the 1800s and the invention of photography and film, people began to play with the notion of simulating realities, but it was not until the 1960s that the first computer-aided virtual experience was realised (Mazuryk & Gervautz, 1999). This first machine was the Sensorama, a 3D wide-angle film accompanied by movement, wind, and smells to provide a multi-sensory experience for the user. It was not long before the impacts of computer-generated virtual experience interventions on learning outcomes became the subject of educational studies, with research from the 1970s showing an increased interest (Hamilton et al., 2021).

The technology has evolved significantly, due to the reduced cost of producing high-powered computing hardware. Current head-mounted VR comes in three types: tethered, such as the HTC Vive, where the headset is connected to a computer via cable; standalone, including headsets like the Oculus Quest 2 by Facebook, where the headset itself does the computing and relies on no cables or connections; and mobile, where the headset houses a separate mobile device, such as a smartphone. Processing power, graphic fidelity, and ability to track spatially, is usually superior in tethered headsets and standalone devices often offer the best performance for money (Greenwald, 2021).

The VR market surged forward in 2013 when Oculus released the Rift, one of the first affordable, high fidelity personal headsets backed by a large company with the resources to support app development and market the headset. Once the Rift hit the market, other companies, including Samsung, Sony, and HTC, began producing their versions. Sony launched their PlayStation VR (PSVR) in 2016, which has become the highest-selling tethered VR headset (Horwitz, 2019). In 2016 Oculus launched the first Oculus Quest to developers and later to consumers in 2019 (and in 2020, the Quest 2). The Quest was the first popular low-cost, high-fidelity headset which reinvigorated the market, with competitors following suit launching wireless or untethered standalone devices soon after. A 2021 literature review (Hamilton et al., 2021) of educational studies using head-mounted display VR found that more than 40% of studies used an Oculus HMD, while the next most-used headset was the HTC Vive at below 25%.

The processing power and graphical fidelity play a role in the user's positive experience in VR, as does the method in which the user engages with the virtual environment. Hamilton et al. (2021) suggests that "the increased levels of immersive content that stimulate multi-sensory engagement can ultimately lead to more effective learning outcomes" (p. 24). The Oculus Quest, particularly the Quest 2, was the first standalone headsets. The Quest 2 provides a 4k-resolution screen, a high ability to track real-world objects, and the processing power to display high-graphic, immersive applications untethered from a computer. While VR has been set to revolutionise education for some time, it may be due to the late emergence of standalone devices that contribute to their low uptake in tertiary education as a remote-learning device. Before standalone devices became low-cost and popular, the reliance on users to have a high-end PC to connect a tethered headset to or the low-immersive and low-graphical fidelity mobile VR versions produced less-than-optimal experiences.

Virtual Reality and Education

Affordable VR headsets, that offer highly immersive experiences, have only entered the consumer market in the last few years. Therefore, educators have not had an extensive opportunity to study or embed VR in teaching and learning. Furthermore, the fast-changing nature of the technology potentially creates a barrier when educators need to learn the 'logic' of each headset and application (Fransson et al., 2020). When a computer is improved by a manufacturer, the performance increases, the visual layout may change, but how a user engages with the device remains relatively static: a keyboard, a mouse, a touch screen. In contrast, as VR improvements are made, the very nature of the interaction may also change. The first Oculus Quest required two hand controllers to engage with the virtual world. By the next iteration, the Quest 2 was able to track a user's fingers individually, and no controllers are necessary (though the device does ship with controllers for some applications). New headsets are currently being developed to track eye movements and other ways to engage with these environments. Unlike with a computer where an educator may plan for a long-term program to be delivered in a specific way year on year, VR may require a different, dynamic approach that allows the delivered programs to be engaged in multiple ways, depending on the technology available at the time. As Scavarelli et al. (2021) write:

> the future of VR/AR in education will involve the use of a platform, not unlike current LMS/CMS systems… built with more significant consideration of accessibility and the interplay between the virtual and physical, social, and individual, in mind. Note that a VR/AR platform need not be mutually exclusive from current LMSs and could extend their existing functionality (p. 272).

VR use requires specific competencies, and a significant amount of time may need to be invested to master the application for the classroom. The time and competency requirement presents as an issue that has influenced integration of immersive environments in education (Carr et al., 2008). Without mastery of the device, errors may occur, leading to reduced 'learning time' and sub-optimal experiences for students and teachers. Research has shown that most errors occurring in VR use are related to the user's ability to use the headset rather than the headset or software itself (Gregory et al., 2015).

While the educational research into the current use of VR is still in an emergent phase, it is prudent to draw on research from similar technologies such as virtual worlds. Suh and Prophet (2018) identified two main categories of research: 1) an understanding of what impact a unique system or function of VR, such as haptic feedback or graphical quality, has on user experience; 2) how VR affects user performance, such as seen in teaching or learning outcomes. Several affordances of VR, including interactivity, immersion, and presence, provide positive outcomes for learners (Radianti et al., 2020). Research helps to objectively measure how a specific variable, such as interactivity, impacts learning outcomes. What research has shown is that while there is no consistently accepted scale to measure a user's experiences of immersion, interactivity, or presence, (Suh & Prophet, 2018), when a learner is more engaged through interactivity, and has a higher sense of presence, they score higher on cognitive, psychomotor, and affective skill tests (Jensen & Konradsen, 2018).

Webster (2016, p. 1321) concurs that research was focused on "factors that affect the interaction experience, such as immersion, presence, engagement, motivation, and usability; or human factors issues, such as cognitive workload, motion sickness, and aftereffects", but very little research looked directly at declarative knowledge acquisition and the relationship specifically between traditional instruction and VR-instruction. More recently, Radianti et al. (2020) found that the largest groups of studies in higher education were in engineering, computer science, and astronomy, with a much smaller number in non-science fields, such as language and architecture. They suggest that very few studies have focused on learning outcomes or educator and/or learner perceptions of effectiveness.

Jensen and Konradsen (2018) completed a review looking at VR educational use from 2013 to 2018. They revealed a slow shift from desktop VR to head-mounted display VR was occurring as the technology began to be applied more broadly to the education sector. Interestingly, they found that as immersive VR use increased, interactions between VR use and applied educational theories and practices also increased. As an example, Makransky and Lilleholt (2018) applied motivational theory to eLearning to investigate the impact on academic outcomes of the emotional response by learners, and Plass and Kaplan (2016) developed a cognitive affective model of learning with multimedia, including VR. Jensen and Konradsen (2018) conclude that there was limited evidence of improved cognitive, psychomotor, or affective acquisition while using head-mounted displays, but also noted that the quality of the studies was such that firm conclusions could not be drawn.

Research by Lei and Zhao (2007) also relied on the idea of embedding learning theories reflecting that how we use technology was more important than how much we use it and outlined that technology must be selected for its meaningful application to the content. An extension of this is that the technology's benefits must outweigh its drawbacks (Lei & Zhao, 2007). Aguayo et al. (2020) state that educational technologies such as MR/VR have the transformative ability to change attitudes and behaviours in individuals and the community (Aguayo et al., 2020, p. 1). They believe that mobile devices, such as HMD-VR systems, enable learning from anywhere and provide the opportunity for content to be shaped to fit individual learners. When the learning takes full advantage of the affordances of the technology, the learning can be transformative (p. 4). Specifically, Aguayo et al. (2020) discuss the advantages of using immersive technology to shift from a pedagogical to a heutagogical approach, outlining that MR gives learners specific tools which enable self-directed learning. The shift to a different style of learning was harder for educators and parents but worked well to engage the children in their experiment.

A recent literature review in the field of immersive reality by Hamilton et al. (2021) revealed that "For I-VR (immersive VR) to gain wide-spread acceptance as a reliable pedagogical method, it must be shown to confer a tangible benefit in terms of learning outcomes over less immersive or traditional teaching methods" (p. 16). Their review included 24 studies that focused on the cognitive domain with a majority reporting an improvement when using VR (pp. 16-17); 3 of the 4 studies focused on procedural skills and showed an advantage in using VR (p. 20); and one study focused on affective skills and showed that VR was useful but no significant difference between desktop VR or head mounted VR was evident (p. 21). Hamilton et al. (2021) conclude that the number of studies is low, and the quality of the studies is still not sufficient to make conclusive remarks regarding HMD-VR impacts on learning outcomes. They did note that around half of the literature showed that HMD-VR was beneficial to learning outcomes, with the majority of the remainder showing no difference. Only a small percentage found an HMD-VR intervention detrimental to learning (p. 26-27).

Many of the studies cited in Hamilton et al. (2021) took a specific task and sought to understand whether completing the task in VR had objectively higher or lower learning outcomes. Very few of the studies aimed to create social, engaging classrooms in a virtual space.

The Future of Virtual Reality – Co-presence

In 2006 social analytical company founder Jan Řežáb estimated that there would need to be approximately 50 million VR users in a single ecosystem (e.g., Oculus, PSVR, SteamVR) for it to be sustainable, and Facebook CEO Mark Zuckerberg believes 10 million is a sustainable number (Chaykowski, 2016). While Facebook does not reveal the number of headsets or users, business analysts have estimated approximately 5 million Quest 2 headsets are currently being used by end-users. Adding to the Quest 1 and Rift users, the Oculus ecosystem may be inching closer to the user milestone. The highest-selling VR platform to date has been the PSVR, which in its 5-year lifespan has only sold 5 million units, meaning the Quest 2 may have now overtaken it (Mailk, 2021). As more applications are developed for these headsets, more social experiences are entering the market and challenging a once-held notion that VR is a solo experience.

This idea of VR being an individual experience was raised as a concern for the technology in the 2019 Educause Horizon Report (Alexander et al., 2019). VR was listed as a top 5 technology impacting education (Williams, 2019), but the Educause Horizon Report was critical of the educational potential of mixed reality (MR) stating:

> Reflection and self-assessment are also critical aspects of experiential learning but are not necessarily enabled by MR technology. In general, learning goals that can be effectively met using MR are those that benefit from repetition (such as developing clinical skills) or even from simple exposure (such as fear extinction). (p. 25)

Alexander et al. (2019) suggested that a way around the issues of low social interaction and limited reflection was to use experiential learning as the starting point for embedding VR in the classroom. Such embedding would allow learners to experience locations or events they would have otherwise been unable to attend—a clear and practical use of an investment in the technology. However, they would still be in the immersive space alone.

Since the 2019 Horizon Report, the shared experiences afforded by VR has progressed in response to increased consumer demand for social environments. Driven in part by the Oculus, as the leading standalone headset on the market, that is owned by a social media company (Facebook). Ultimately, humans are social by nature and the ability to share these experiences has been an identified gap in the market. Overwhelmingly we experience education in social environments such as school classrooms that also leads to the desire to continue to be able to participate in socially connected learning experiences. Regardless of the cause, huge efforts have been made in very recent years to overcome the singular nature of a HMD-VR experience. Many applications in VR now have either remote or social abilities or co-presence built in.

Co-presence is the ability to see and interact with peers in the virtual environment so that it feels like they are present while they are not located in the same room. Bulu (2012) defines co-presence as having two dimensions: the ability to perceive other users in the virtual space and the sense that others are perceiving you simultaneously. It is important to not confuse this with co-location, which has also been a focus, where people in the same room can also see each other in-place in VR; or with social presence, which is the ability to interact with another, which can occur via pure audio, or visual, and does not rely on co-presence (Bulu, 2012). Co-presence allows natural social interaction, where users can move around, see, hear, and in some cases feel each other. Headsets such as the Quest have advanced haptic feedback engines in their controllers, which can mimic certain physical sensations, adding to the presence and immersiveness of the environments. Co-presence software also generally includes affordances such as spatial audio, meaning audio is not only three dimensional but louder or softer depending on the direction you face and your proximity to the sound source, mimicking reality. This co-presence means that, for example, a class could meet virtually and interact naturally as if they were in a real classroom. Users can interact with objects together and socially, writing on the same board, seeing each other's work, even picking up and engaging with digital objects together. They can do this remotely, from all over the world, and interact as if they were physically sitting in the same classroom, talking, listening, and interacting naturally. Unlike telepresence, such as Zoom, where there is low-immersiveness, no spatial audio, no ability to interact with objects together, and no control over a shared environment or experience, co-presence while using a HMD-VR allows a high-fidelity remote learning experience that is little explored in the literature.

A 7-week 2020 study (Yoshimura & Borst, 2021) conducted during COVID-19 lockdown looked at a university course delivered via low immersiveness (Desktop) and high immersiveness (VR headset) simultaneously. Students who used the VR headsets reported a higher degree of co-presence (Yoshimura & Borst, 2021). The study revealed that some students preferred the desktop and others the VR. The method replicated a real-world lecture with the lecturer doing the majority of the talking and the students passively watching and listening to the lecture. The class had little need for true co-presence, and, as the study's authors note, the students using the VR headsets had a variety of headset devices with different technical capabilities. This is a prime example of education designed for real-world delivery being transposed into the digital space when instead it could be transformed to make better use of the affordances of the digital tools available. As Scavarelli et al. (2021) write, “the greatest challenge will lie in determining how best to utilise this technology to better enhance students' learning in a manner that is not merely recreating, or replacing, the physical classroom but also enables activities, and access to facilities, that are not possible in physical settings” (p. 273).

Conclusion

Virtual reality has progressed significantly over the last decade. Appearing on the Gartner Hype Cycle in 1995 and remaining in the *trough of disillusionment* for nearly 23 years, just as it transitioned to the *slope of enlightenment* in 2018 it was removed from the Hype Cycle altogether (Bresciani & Eppler, 2021). It remained as a piece of technology touted to change the face of education (Williams, 2019) but, for the most part, has failed to live up to its expectations. Studies have investigated emerging technologies and asked why they have not lived up to expectations. Time after time, the same barriers to integration and sustainable use emerge that include cost, ease of use, usability, and support from the system within which the user works (or learns). Literature that does bring VR into focus often looks at specific tasks or applications and asks whether there are excellent learning outcomes instead of looking at VR as a whole system that enables transformational shifts in pedagogy and lesson delivery. In the past 18 months the world has seen unprecedented change in the expectations of what learning and teaching looks and feels like. Here is the opportunity to rethink the barriers and make swift progress in integrating meaningful, authentic, immersive learning environments. A concerted effort by the manufacturers of VR and the end-users in education (teachers and learners) needs to be reconciled to facilitate the latest emerging technology.

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