Virtual reality in education: a tool for learning in the experience age

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Abstract: Educators face major challenges as a result of the shift from the *Information Age* to the *Experience Age* (Wadhera, 2016). For example, students are passive and disengaged (Capps and Crawford, 2013) and may struggle to see the relevance of what they are learning to their lives (Gee, 2009); also, important skills needed for 21st century learners – such as empathy, systems thinking, creativity, computational literacy, and abstract reasoning – are difficult to teach (Smith and Hu, 2013). Virtual reality, an immersive, hands-on tool for learning, can play a unique role in addressing these educational challenges. In this paper, we present examples of how the affordances of virtual reality lead to new opportunities that support learners. We conclude with a discussion of recommendations and next steps.

Keywords: virtual reality; virtual environments; experience age; education; technology.

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1 Introduction

We are now in the *Experience Age* – where 92% of teens are online daily, playing games, livestreaming memorable experiences, sharing ephemeral moments on Snapchat, or posting pictures of exciting daily occurrences on Instagram (Wadhera, 2016). Both informal and formal learning, as a result, have shifted again: from an *Industrial Revolution* model of education, where a teacher transmitted information to students via a 'one size fits all' mentality; to an *Information Age* model, in which access to and accumulation of information was the highest priority; and now onto the *Experience Age*, in which the ubiquity of interconnected mobile devices, gaming and social networking software have led to sharing and experiencing new points of view. By creating, sharing and participating in technology-mediated experiences, young people are becoming accustomed to rich new learning environments.

At the same time, formal education faces three major challenges in adapting to this shift to the *Experience Age*. First, teachers often still rely on transmissionist methods such as lectures, leading to passive, disengaged students (Capps and Crawford, 2013). Learning in this manner, when knowledge is isolated from context, causes many students to struggle to see the relevance to their lives (Gee, 2009). Second, authentic learning contexts require many factors that are either difficult to attain or simply absent from traditional teaching methods (Hill and Smith, 2005). Third, important skills needed for 21st century learners such as empathy, systems thinking, creativity, computational literacy, and abstract reasoning are difficult to teach (Smith and Hu, 2013). Each of these challenges is significant and though it may have been acceptable to ignore them in the past, will grow as obstacles if not addressed for the current generation of students.

Technological advances like tablet computers, Chromebooks, student-response-systems (i.e., 'clickers'), and smartphones have made incremental progress in keeping education and its tools relevant. One technology that is pushing its way into the mainstream is virtual reality (VR), defined as immersive, realistic, three-dimensional environments that involve visual feedback from body movement (Aarseth, 2001). VR technology is poised to be disruptive and vastly influential – projected to be a trillion-dollar industry by the year 2035 according to market researchers (Boyle, 2016). Already, developers have created compelling experiences allowing people to travel through the cells of the body, to explore the Solar System, and to encounter recreations of ancient battles in history (Hayden, 2015; Hamilton, 2016; Bienz, 2016). VR promises to provide more immersive, engaging experiences, with applications in many domains, including shopping, entertainment, training, and education.

There is evidence that VR can address the above educational challenges in the experience age (Dalgarno and Lee, 2010; Psotka, 2013; Bailenson et al., 2008). In particular, VR can: lead to increased student engagement; provide active, constructivist learning; increase frequency of authentic learning experiences; allow for empathetic experiences; enable students to exercise creativity; and provide an arena for visualising abstract concepts concretely. In this paper, we start with a brief overview of VR technology. Next, we present examples of how the affordances of VR lead to new opportunities that can address the three major challenges to formal education described above. Finally, we conclude with a discussion of recommendations and next steps.

2 Overview: the evolution of virtual reality

The concept of VR is not new; in the early 1990's speculation on its potential already existed. VR promised to bring an exciting future – where everyone would wave their hands to travel through strange neon geometric places, converse with virtual people, and experience adventures in perfectly simulated worlds or times (Steinicke, 2016). However, at the time, VR did not go far. Other than primarily military and industrial uses such as combat training and 3D visualisations (Cruz-Niera, 2016; Pollack, 1989), it was uncomfortable, not realistic, expensive and required immense amounts of computing power to render.

Today, we are greeted with a very different landscape; the technology that once was too expensive or impractical for consumers is now readily available. The popularity of several mainstream consumer products like the *Google Cardboard, Daydream View, Oculus Rift, HTC Vive*, *Samsung Gear VR, Playstation VR,* and *Microsoft HoloLens* (Figure 1) are evidence that technical developments have finally resolved many of the problems that previously doomed VR. In addition, the ubiquity of smartphones – used by 65% of the American population (Statista, 2017) – and their rapidly increasing capabilities has expanded VR's reach to more consumer bases. Development and investment in VR – including key players Apple, Microsoft, Facebook, and Google (Mason, 2016) – totalled over $2.3 billion in 2016 alone (Digi-Capital, 2017). Many are optimistic that VR/AR can transform several industries, including education, entertainment, healthcare and corporate training.

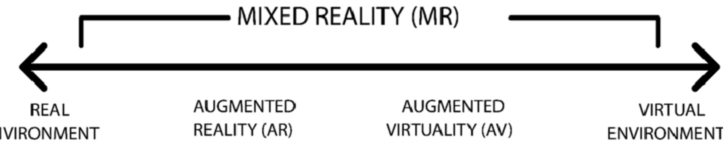
Figure 1 Microsoft HoloTours, a virtual field trip experience (see online version for colours)

Source: Used with permission from Microsoft

3 Definitions

VR is a part of a larger family of technology-mediated experiences involving a varying degree of blends of reality with virtual components. Related areas along this continuum of reality and virtuality are *augmented reality* and *mixed reality* (Figure 2).

Figure 2 Milgram's reality–virtuality continuum



Source: Milgram et al. (1995)

Augmented reality (AR) can be described as an integration of digital information onto a view of the real-world environment, such as using a smartphone camera to view a live translation of characters into a foreign language or scanning a QR code on a card to see a 3D image of an animal. *Mixed reality*, in between a real and virtual environment, is an overlay of synthetic content onto the real world that is anchored to – and interacts with – the real world, such as interactive holograms. In this paper, we are primarily concerned with the affordances of VR, any form of digital media that creates a 3D visually-immersive experience simulating a different reality.

In the following sections, we describe how past research in VR supports new affordances that can address major educational challenges. We also highlight current examples of how VR can create new learning opportunities.

4 Problems in education and opportunities in VR

4.1 Problem: traditional methods of teaching lead to a lack of student engagement

A widespread problem in education is that traditional methods of lecture-based education lead to disengaged students (Delialioglu, 2012). This lack of engagement is considered a major reason for many unfavourable behaviours hindering student success, including dissatisfaction, negative experience, and dropping out of school (Delialioglu, 2012). If students' engagement with academic activities is increased, so does the students' learning and personal development (Delialioglu, 2012; Winn et al., 1997). In this section, we describe two learning opportunities provided by VR that can complement traditional forms of teaching.

4.1.1 Opportunity: virtual reality leads to increased student engagement

Several characteristics of VR provide an opportunity to boost student engagement. As a hands-on, interactive, immersive experience, it provides a novel way of learning for students, delivering powerful new experiences they may not have encountered before (Bricken, 1991; Crosier et al., 2000; Eschenbrenner et al., 2008; Winn et al., 1997; Johnson and Levine, 2008; Lau and Lee, 2015). For example, *Google Expeditions* allows teachers to transport students to virtual field trips to Mars, the bottom of the ocean, and many other settings, which can spark new interest in subject matter, provide a shared experience for better classroom discussion, and improve overall engagement (Ferriter, 2016). Experiences like these provide unique and fresh learning moments that draw in students and pique their interest as they actively explore and exercise their curiosity. This increased engagement can be an opportunity for addressing typically boring or low appeal subject areas. For example, Costa and Melotti (2012) found that VR exhibits increased interest in archaeology, especially where interest was low in the past. The novelty and entertainment value of VR can be used strategically to draw in the attention of lost and disinterested students, including in subjects that some students may usually find boring or irrelevant. From there, VR-specific pedagogy, which will be discussed later, can maximise the learning potential of these experiences.

VR also boosts engagement by providing students with a strong sense of presence and immersion compared to traditional learning environments (Bailenson et al., 2008; Dalgarno and Lee, 2010). Different kinds of classroom experiences have varying levels of presence: reading literature in a classroom; passively watching videos; watching performance theatre; and the most interactive, actually embodying actors and objects in VR. (Aylett and Louchart, 2003). By enveloping a student in an authentic, multi-sensory experience, VR makes a subject area come alive. For instance, students have the opportunity to navigate inside the human body's bloodstream as a red blood cell in *The Body VR* (The Body VR, n.d.). The ability to simulate an environment and increasing a student's sense of presence is one of the most important opportunities of VR to create more engaging educational experiences.

4.1.2 Opportunity: virtual reality allows for constructivist learning

VR also provides an opportunity for constructivist learning, i.e., allowing students to construct their own knowledge from meaningful experiences. In these types of experiences, students engage in authentic problems, exploring solutions and perhaps collaborating with others. In research on virtual world-building simulations, low-performing students improved academically more than those learning through traditional methods, even more so than their high-achieving counterparts (Winn et al., 1997). Furthermore, in introductory astronomy courses, VR activities where students built 3D Solar Systems supported greater understanding of astronomical concepts (Barnett et al., 2005). This affordance of VR gives students the ability to construct visual and manipulable objects to represent knowledge, an affordance that traditional learning methods lack. *Fantastic Contraption* is another example that uses constructivist theory to reinforce principles of physics, where the player builds a machine and if it does not work properly, he or she uses problem-solving skills until it functions correctly (Porter, 2015). These types of experiences hold great potential for utilising the constructivist principles of authentic activity and knowledge-creation environments (Dalgarno and Lee, 2010; Driscoll, 2012; Bailenson et al., 2008). Thus, VR has great potential to enhance the educational landscape by making immersive learning environments customisable, actively engaging, and self-paced for student success (Smith et al., 2014).

VR also provides an opportunity for training, therapy, or simulation in situations where repeated practice and a safe space to fail are present. This can be useful as spaces for therapy for students with disabilities, post-traumatic stress disorder, or social anxiety. The virtual environment allows students control over their learning in a consequence-free, explorative manner, through which they become empowered and more engaged (Crosier et al., 2000; Standen and Brown, 2006). VR applications such as *VR Language Learning* and *Public Speaking VR,* give students a way to practice public speaking without fear of serious consequences from their mistakes (Virtual Speech, 2016). In essence, VR allows for practice in environments that are highly immersive and closely parallel real-world situations.

4.2 Problem: it is difficult to deliver authentic, highly relevant contexts for learning

Students often find classroom-based learning to be irrelevant; there is a disconnect between content learned in textbooks and authentic practice in the 'real-world'. Gee (2004) describes this as education lacking 'situated' learning (p.38). Correctly implemented, situated learning in the example of biology allows students to learn terms while seeing the broader applicability, instead of simply memorising biological facts isolated from context. Virtual reality can provide an environment for situated learning that is relatively easy to access. Through the increased relevance and situated nature of virtual worlds, students can learn academic content in contexts that increase the potential for learning (Gee, 2004).

4.2.1 Opportunity: virtual reality provides authentic experiences to impact student identity

VR makes it possible to visit any location, time, or person in a relatively inexpensive way via virtual field trips. This creates powerful learning opportunities for experiencing historical contexts, scientific environments, and personally meaningful moments. Already the immersive nature of VR is allowing assisted-living elders to visit their childhood homes (Conti, 2016), the human body to be explored through the blood vessels (The Body VR, n.d.), and battles from the 1500s to be reenacted in great detail (Bienz, 2016). In classroom settings, the immersive nature of virtual field trips has enabled students to have 'authentic and powerful' experiences in Colonial Williamsburg (Stoddard, 2009, p.431) and increased attention and retention of information on Mexican immigration (Lacina, 2004).

Perhaps equally important is the opportunity to impact student identity – for example, can students be given experiences to inspire them to enter STEM careers? Virtual field trips already exist that permit students to experience life in a professional's workplace or to learn from a mentor. *Google Expeditions*, for example, contains 'career expeditions' experiences where students can 'shadow' a scientist or professional in their laboratory or office (O'Brien, 2016). This can be encouraging for students, especially minority students, to pursue academic interests or occupations in fields in which they are historically underrepresented (Butler, 2003). In addition, the existence of social VR applications such as *Rec Room* and *Facebook Spaces* also provide channels for more intimate and immersive communication. Already, scientists like Bill Nye have entered into these virtual spaces to interact with the public. Opportunities like this, in schools where low resources or time constraints limit going out into the field, are excellent examples of VR's potential benefits (Lacina, 2004; Placing and Fernandez, 2001; Tuthill and Klemm, 2002). By delivering these first-hand experiences, VR increases the possibility that students can adopt new identities that can impact their career trajectories.

4.3 Problem: teaching 21st century skills in a traditional classroom setting is difficult

A third problem in education is that today's workforce increasingly demands 21st century skills such as creativity, empathy, critical thinking, and technological literacy (P.21, 2015) but these kinds of skills are difficult to teach and are not emphasised. This is because of several reasons, most notably that technology is frequently used to simply increase the effectiveness of traditional teaching methods (Dede, 2010). In this section, we describe below two opportunities provided by VR that provide 21st century skill development.

4.3.1 Opportunity: virtual reality affords new perspective taking and empathy

VR excels at providing opportunities for new perspective taking, empathy, and the ability to visualise difficult models**.** For example, when students were given a VR experience of being an elderly person their empathy towards older generations significantly increased (Bailenson et al., 2008). Chris Milk (2016), one of the foremost 360° film directors, argues that VR makes anyone and anywhere feel local. In his VR film, *Clouds Over Sidra*, Milk creates a compelling experience where the viewer is transported to a refugee camp in Jordan. He uses this medium, where empathy with the subject is engendered by immersing the viewer in a realistic experience of becoming a refugee. Another powerful VR experience of this nature is the simulation *Outcasted*. In *Outcasted*, the player gets to experience true stories of how people become homeless. VR builds empathy as the player begins to experience the social rejection that many homeless people face (Priestman, 2015). One of the strongest arguments for VR as a learning tool is this ability to create empathy in students and to change perspectives (Bailenson et al., 2008); this opportunity is especially important in a divisive age in which understanding another's point of view can be essential to find solutions and ways to compromise.

4.3.2 Opportunity: virtual reality affords creativity and the ability to visualise difficult models

VR also enables students to create anything from their imagination and to easily visualise and manipulate objects to make difficult concepts easier to grasp. Inside creation-oriented or world-building virtual environments (e.g., a tool such as *CoSpaces (Figure 3) that permits coding and easy VR creation*), students can easily reify abstract ideas and demonstrate their mental models (Winn et al., 1997). This ability to physically gesture to create and its link to increasing cognitive learning is supported by the theory of embodied cognition. This advantage of embodied learning through VR carries great potential in expensive, dangerous, or spatially creative tasks (Dalgarno and Lee, 2010). For example, *Tiltbrush* by Google is a VR application that encourages creativity and artistic expression. Using *Tiltbrush* (Figure 4), students can paint, sculpt, and design life-sized three-dimensional objects and landscapes using imaginative – and impossible materials such as fire, snow and stars – and share them with others.

VR's affordance of transferring perspective is not just limited to social or artistic contexts. Winn et al. (1997) have also seen the advantages of VR in making abstract concepts into concrete objects in science curricula. They posit that virtual environments 'can represent in directly visible and manipulable forms concepts and procedures that are intangible and invisible in the real world' (p.2). In the realm of mathematics, VR offers great possibilities in using technology to help students represent hard-to-visualise and complex concepts. Students using a virtual environment to learn about surface area and composite solids were seen to exhibit better performance on immediate and maintained learning tests (Sung et al., 2015). This use of VR had an especially large impact on the attitudes of low- and moderate-math level students, where 'the concrete, individualised, and feedback-available environments mentioned above may have compensated for the limited learning abilities' (Sung et al., 2015, p.133). Thus, VR shows promise that it can improve general learning contexts as well as bring important new strategies to reach students who need the most support.

Figure 3 CoSpaces, a world-building tool for 3D and VR environments (see online version for colours)

Source: Used with permission from Delightex GmbH

Figure 4 Tiltbrush, a VR app for drawing in 3-dimensions (see online version for colours)

Source: Used with permission from Google

5 Conclusion

As educators who teach in the experience age, we must embrace and leverage better methods to deliver the most effective learning experiences. Educators have begun to embrace VR and its wide possibilities for learning as the technology rapidly moves to the mainstream. As discussed above, VR is especially useful for providing several opportunities: increasing student engagement; providing constructivist, authentic experiences to impact student identity; allowing for new perspective taking and empathy; and supporting creativity and the ability to visualise difficult models.

A strong reason for utilising VR as a learning tool is that it meets young students experientially, a way that they prefer (Wadhera, 2016). Our current education system needs engaging, authentic experiences that will drive successful learning. VR can provide this and offers potential to expose students to worlds and people that are normally inaccessible (Dalgarno and Lee, 2010). For example, a deliberate use of the social affordances of VR could connect students with role models, thus encouraging greater participation by students who typically shy away from certain fields, i.e., STEM fields and minority and female students.

It should be pointed out that VR is no silver bullet; we must be wary of the tempting novelty of technology and its initial hype – which is often followed by disillusionment. Thorough research and practice are necessary to explore the full potential of using VR in educational settings. As Lau and Lee (2015) warn against replacing real-world educational experiences with virtual reality, they also emphasise that "the best way to use virtual reality in learning is to create experiences that help students to understand the learning context better" (p.15). A pedagogy based on the unique affordances of VR is what is needed. A wrong way of implementing VR in education would be simply to replicate face-to-face, didactic experiences of learning.

Instead, we should design creatively while building on how we know students learn. Since VR is an excellent medium for constructivist learning experiences (Dalgarno and Lee, 2010), pedagogy targeting its use should be founded on constructivist learning models. Problem-based learning, anchored instruction, cognitive apprenticeship, and intentional learning environments are all effective models founded on constructivism (Wilson, 2012). VR has the potential to enrich these methods with interactive simulations and stunning visuals that immerse students in authentic learning experiences. It can push the boundaries of the traditional classroom to be engaging, creative, and responsive to the needs of the student. As such, overlap with game design principles is likely and ideal. VR is a medium where limits are still being explored, so likewise, why limit the possibilities of how education can be delivered? With sound pedagogy and innovative experiences, virtual reality is a gateway for educators to enter the Experience Age.

References

Aarseth, E. (2001) 'Virtual worlds, real knowledge: towards a hermeneutics of virtuality', *European Review*, Vol. 9, No. 2, pp.227–232.

Aylett, R. and Louchart, S. (2003) 'Towards a narrative theory of virtual reality', *Virtual Reality*, Vol. 7, No. 1, pp.2–9.

Bailenson, J., Yee, N., Blascovich, J., Beall, A., Lundblad, N. and Jin, M. (2008) 'The use of immersive virtual reality in the learning sciences: digital transformations of teachers, students and social context', *The Journal of the Learning Sciences*, Vol. 17, pp.102–141.

Barnett, M., Yamagata-Lynch, L., Keating, T., Barab, S.A. and Hay, K.E. (2005) 'Using virtual reality computer models to support student understanding of astronomical concepts', *The Journal of Computers in Mathematics and Science Teaching*, Vol. 24, No. 4, pp.333–356.

Bienz, J. (2016) *Microsoft Quietly Releases Three new HoloApps, One is More VR Than MR*, Road to Holo, 27 April, Retrieved from http.//www.roadtoholo.com/2016/04/27/1342/microsoft-quietly-releases-three-new-holoapps-one-is-more-vr-than-mr/

Boyle, K. (2016) *Citi GPS: Virtual and Augmented Reality*, Citi: Private Bank, 19 October, Retrieved from https.//www.privatebank.citibank.com/home/fresh-insight/citi-gps-virtual-and-augmented-reality.html

Bricken, M. (1991) 'Virtual reality learning environments: potentials and challenges', *Computer Graphics*, Vol. 25, No. 3, pp.178–184.

Butler, S.K. (2003) 'Helping urban African American high school students to excel academically: the roles of school counselors', *The High School Journal*, Vol. 87, No. 1, pp.51–57.

Capps, D.K. and Crawford, B.A. (2013) 'Inquiry-based instruction and teaching about nature of science: are they happening?', *Journal of Science Teacher Education*, Vol. 24, No. 3, pp.497–526.

Conti, K. (2016) *MIT Startup Lets Seniors Enter the World of Virtual Reality*, The Boston Globe, 12 May, Retrieved from https.//www.bostonglobe.com/business/2016/05/12/mit-startup-lets-seniors-enter-world-virtual-reality/XbaWge6EseufMYu2tZ87TN/story.html

Costa, N. and Melotti, M. (2012) 'Digital media in archaeological areas, virtual reality, authenticity and hyper-tourist gaze', *Sociology Mind*, Vol. 2, No. 1, pp.53–60.

Crosier, J.K., Cobb, S.V. and Wilson, J.R. (2000) 'Experimental comparison of virtual reality with traditional teaching methods for teaching radioactivity', *Education and Information Technologies*, Vol. 5, No. 4, pp.329–343.

Cruz-Niera, C. (2016) 'Beyond fun and games: VR as a tool of the trade', Session Presented at the *Virtual Reality Summit*, 12 April, New York, NY.

Dalgarno, B. and Lee, M.J. W. (2010) 'What are the learning affordances of 3-D virtual environments?', *British Journal of Educational Technology*, Vol. 41, No. 1, pp.10–32.

Dede, C. (2010) 'Comparing frameworks for 21st century skills ', in Bellance, J. and Brandt, R. (Eds.): *21st Century Skills: Rethinking How Students Learn*, Solution Tree Press, Bloomington, IN, pp.51–76.

Delialioglu, O. (2012) 'Student engagement in blended learning environments with lecture-based and problem-based instructional approaches', *Journal of Educational Technology and Society*, Vol. 15, No. 3, pp.310–n/a, Retrieved from http.//eduproxy.tc-library.org/?url=/docview/1287025353?accountid=14258

Digi-Capital (2017) *Record $2.3 billion VR/AR investment in, 2016*, February, Retrieved from http.//www.digi-capital.com/news/2017/02/record-2–3-billion-vrar-investment-in-2016/#.WWZmP.4jyuUn

Driscoll, M.P. (2012) 'Psychological Foundations of Instructional Design', in Reiser, R.A. and Dempsey, J.V. (Eds.): *Trends and Issues in Instructional Design and Technology*, 3rd ed., Boston: Pearson, pp.35–44.

Eschenbrenner, B., Nah, F.F. and Siau, K. (2008) '3-D virtual worlds in education: applications, benefits, issues and opportunities', *Journal of Database Management*, Vol. 19, No. 4, pp.91–110.

Ferriter, B. (2016) *Tool Review: #GoogleExped.s. Virtual Reality App*, The Tempered Radical, 9 March, Retrieved from http.//blog.williamferriter.com/2016/03/09/tool-review-googleexped.s-virtual-reality-app/

Gee, J.P. (2004) '*Situated Language and Learning: A Critique of Traditional Schooling*, Routledge, London.

Gee, J.P. (2009) 'Deep learning properties of good digital games: how far can they go?', in Rittenfeld, U., Cody, M. and Vorderer, P. (Eds.): *Serious Games: Mechanisms and Effects*, Routledge, New York, pp.67–82.

Hamilton, I. (2016) *Exclusive: Titans of space 2' Arrives in Early Access Next Week for Vive and Rift*, Upload, V.R., 20 May, Retrieved from http.//uploadvr.com/titans-space-2-arrives-early-access-next-week-rift-vive/

Hayden, S. (2015) *Review: Incell'is A VR Racer that Puts You Inside the Microscopic World of a Cell*, Road To, V.R., 4 September, Retrieved from http.//www.roadtovr.com/review-incell-vr-racer-puts-inside-microscopic-world-cell/

Hill, A.M. and Smith, H.A. (2005) 'Research in purpose and value for the study of technology in secondary schools: a theory of authentic learning', *International Journal of Technology and Design Education*, Vol. 15, No. 1, pp.19–32, Retrieved from http.//eduproxy. tc-library. org/?url=/docview/870284311?accountid=14258

Johnson, L.F. and Levine, A.H. (2008) 'Virtual worlds: inherently immersive, highly social learning spaces', *Theory Into Practice*, Vol. 47, No. 2, pp.161–170.

Lacina, J.G. (2004) 'Designing a virtual field trip', *Childhood Education*, Vol. 80, No. 4, pp.221–222.

Lau, K. and Lee, P. (2015) 'The use of virtual reality for creating unusual environmental stimulation to motivate students to explore creative ideas', *Interactive Learning Environments*, Vol. 23, No. 1, pp.3–18.

Mason, W. (2016) *8 of the Top.10 Tech Companies in the World are Invested in VR/AR*, Upload, V.R., 8 March, Retrieved from http.//uploadvr.com/8-of-the-top-10-tech-companies-invested-in-vr-ar/

Milgram, P., Takemura, H., Utsumi, A. and Kishino, F. (1995) 'Augmented reality: a class of displays on the reality-virtuality continuum', *Proceedings of Society of Photo-Optical Instrumentation Engineers: Telemanipulator and Telepresence Technologies* (*2351*), Boston, MA, http.//dx.doi.org/10.1117/12.197321

Milk, C. (2016) *How Virtual Reality can Create the Ultimate Empathy Machine [Video file]*, February, Retrieved from https.//www.ted.com/talks/chris_milk_how_virtual_reality_can_create_the_ultimate_empathy_machine

O'Brien, S. (2016) *Exped.s. Career Tours can take Kids to Work, Virtually. [Web log comment]*, 28 April, Retrieved from https.//www.blog.google/topics/education/exped.s-career-tours-can-take-kids/

P.21 (2015) '*Framework for 21st Century Learning. P.21 Partnership for 21st Century Learning*, Washington DC, https.//doi.org/http.//www.21stcenturyskills.org/documents/framework_flyer_updated_jan_09_final-1.pdf

Placing, K. and Fernandez, A. (2001) 'Virtual experiences for secondary science teaching', *Australian Science Teachers Journal*, Vol. 48, No. 1, pp.40–42.Retrieved from ProQuest.

Pollack, A. (1989) 'For artificial reality, wear a computer', *New York Times*, 10 April, Retrieved from http.//www.nytimes.com/1989/04/10/business/for-artificial-reality-wear-a-computer. html?pagewanted=all.

Porter, C.G. (2015) *Hands-on: Creating Magical Machines with 'Fantastic Contraption' on HTC Vive*, Road to VR, 21 August, Retrieved from http.//www.roadtovr.com/fantastic-contraption-htc-vive-hands-on-pax-prime-2015/

Priestman, C. (2015) 'The video game trying to change how we teach the homeless', *Kill Screen*, 26 March, Retrieved from https.//killscreen.com/articles/outcasted/

Psotka, J. (2013) 'Educational games and virtual reality as disruptive technologies', *Educational Technology and Society*, Vol. 16, No. 2, pp.69–80.

Smith, J. and Hu, R. (2013) 'Rethinking teacher education: synchronizing eastern and western views of teaching and learning to promote 21st century skills and global perspectives', *Education Research and Perspectives (Online)*, Vol. 40, pp.86–108, Retrieved from http.//ezproxy.cul.columbia.edu/login?url=http.//search.proquest.com.ezproxy.cul.columbia.edu/docview/1462385468?accountid=10226

Smith, M.J., Ginger, E.J., Wright, K., Wright, M.A., Taylor, J.L., Humm, L.B. and Fleming, M.F. (2014) 'Virtual reality job interview training in adults with autism spectrum disorder', *Journal of Autism and Developmental Disorders*, Vol. 44, No. 10, p.2450–2463.

Standen, P.J. and Brown, D.J. (2006) 'Virtual reality and its role in removing the barriers that turn cognitive impairments into intellectual disability', *Virtual Reality*, Vol. 10, Nos. 3–4, pp.241–252.

Statista (2017) *Number of Smartphone Users in the United States from 2010–2021*, Retrieved from https.//www.statista.com/statistics/201182/forecast-of-smartphone-users-in-the-us/

Steinicke, F. (2016) *Being Really Virtual: Immersive Natives and the Future of Virtual Reality,* Springer, Switzerland.

Stoddard, J. (2009) 'Toward a virtual field trip model for the social studies', *Contemporary Issues in Technology and Teacher Education*, Vol. 9, No. 4, pp.412–438.

Sung, Y., Shih, P. and Chang, K. (2015) 'The effects of 3D-representation instruction on composite-solid surface-area learning for elementary school students', *Instructional Science*, Vol. 43, No. 1, pp.115–145.

The Body VR (n.d.) Retrieved from http.//thebodyvr.com/

Tuthill, G. and Klemm, E.B. (2002) 'Virtual field trips: alternatives to actual field trips', *International Journal of Instructional Media*, Vol. 29, No. 4, pp.453–468.

Virtual Speech (2016) Virtual Speech Ltd., Retrieved from http.//virtualspeech.com/

Wadhera, M. (2016) 'The information age is over; welcome to the experience age', *Tech Crunch*, May, Vol. 9, Retrieved from https.//techcrunch.com/2016/05/09/the-information-age-is-over-welcome-to-the-experience-age/

Wilson, B.G. (2012) 'Constructivism in practical and historical context', in Reiser, R.A. and Dempsey, J.V. (Ed.): *Trends and Issues in Instructional Design and Technology*, 3rd ed., Pearson, Boston, pp.45–52.

Winn, W., Hoffman, H., Hollander, A., Osberg, K., Rose, H. and Char, P. (1997) 'The effect of student construction of virtual environments on the performance of high-and low-ability students', *Presented at the Annual Meeting of the American Educational Research Association* ResearchGate, Chicago, IL.