Immersive virtual reality, children and school education:

A literature review for teachers.

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ACRONYMS AND ABBREVIATIONS

3D VLE	Three dimensional virtual learning environment
AR	Augmented reality
HMD	Head mounted display
IVR	Immersive virtual reality
MR	Mixed reality
VR	Virtual reality

GLOSSARY

Augmented reality	Augmented reality (AR) overlays virtual objects on the real world environment.
Affordance	The properties or features of a technology which suggest possibilities for action. *Learning affordance* refers to the properties of virtual reality which suggest ways in which learning can be designed and facilitated e.g. an affordance of VR is the ability to manipulate the size of a virtual object and this can allow for an examination of the microscopic (cell, atom).
Biometrics	Automated recognition and collection of measureable data on biological and behavioural characteristics of individuals. Biological data includes facial recognition, fingerprints and iris patterns. Behavioural data includes vocal patterns, eye tracking/gaze attention, gait tracking or typing recognition.
Cybersickness	Motion sickness caused by movement on any display device e.g. monitors, TVs, smartphones, tablets or head mounted displays (VR headsets).
Desktop virtual reality	Virtual reality environments that are delivered via a computer monitor and mobile device screen (tablet or smart phone). Interaction in the virtual environment is by using a keyboard, mouse, touch screen, joystick or other gaming device.
Immersive virtual reality	Virtual reality delivered via a head mounted display (HMD) - a virtual reality headset. These virtual environments give the user the impression that they are in the environment. Immersive virtual reality can range from a passive experience (looking around) to more interactive experiences where the user can navigate around the environment and manipulate virtual objects.
Head mounted display	A head mounted display (HMD) is a device (goggles or a headset) worn over the eyes that displays virtual objects and environments (e.g. Google Cardboard, VR Gear, Oculus Rift). Virtual reality HMD completely block out the real world replacing it with a virtual world. Mixed reality HMDs allow the user to see the real world and augment or anchor virtual objects in it so that the user can interact with these objects (e.g. Microsoft HoloLens or Magic Leap).
Highly immersive virtual reality	Virtual reality delivered via a head mounted display (HMD) in which the user has a high degree of agency (ability to act) by manipulating virtual objects, interacting with other users and computer generated non-player characters, and having the ability to create within the virtual environment.
Immersion	Where the properties of a technology (visual and auditory stimuli) are designed to allow the user to feel a sense of presence ('being there') in a virtual environment.
Mixed reality	Mixed reality (MR) overlays and anchors virtual objects on to the real world and often allows users to interact with these objects. Sometimes the term is used to refer to the inclusion of physical objects that can interacted with as part of a virtual environment. The term 'mixed reality' is relatively new and still being defined.
Presence	The feeling of 'being there' in the virtual environment. Co-presence is the feeling of 'being there with others' in the virtual environment.
Virtual reality	A 3D computer-generated world which can be a highly imaginative or realistic simulation. Depending on the VR environment, a user can experience the world in the first person (through their eyes or the eyes of a character/avatar) or in a third person (disembodied) perspective or switch between the two.
Virtual reality simulation	3D objects and environment developed for training and learning purposes.

INTRODUCTION

Immersive virtual reality (IVR) has arrived for mass consumption. It is estimated that more than two million school children have tried Google Expeditions (Charara, 2017, May 16), and that PlayStation VR has sold in excess of two million gaming units (Webster, 2017, December 7). Social media corporations have invested heavily in IVR: Facebook's CEO predicts one billion people will be living in IVR in the future (ABC news, 2017, October 12).

While computer desktop VR has been around for decades, publicly available IVR is a relatively recent phenomenon: Entry-level Google Cardboard was released in mid-2014, and highly immersive (and more expensive) VR such as the Oculus Rift and HTC Vive only became commercially available in 2016. Given the considerable dialogue on the potential educational application of immersive technologies, it is timely to ask questions about the learning properties (or affordances) of IVR technology, and importantly, what we currently know about its effects on children and young people (hereafter child refers to 0-18 years of age).

This literature review is written for teachers with the aim of providing a snapshot of the most current research on IVR, children and school education. The methodology for the review can be found as an appendix to this document. In general, this review does not cover the extensive and interesting literature on desktop virtual reality and education or virtual worlds for learning (for a systematic review and a meta-analysis of this literature see Mikropoulos and Natsis, 2011, and Merchant et al., 2014, respectively). The main exception to this is the section on the learning affordances of virtual reality which draws on desktop VR literature.

This review is structured according to the following topics: defining IVR; the learning affordances of virtual reality; IVR and school education; and the ethical and safe use of IVR and children.

WHAT IS IMMERSIVE VIRTUAL REALITY?

The commercial advent of immersive technologies has launched the terms virtual reality (VR), augmented reality (AR) and mixed reality (MR) into mainstream discourse. Briefly, virtual reality immerses users in a fully simulated digital environment; augmented reality (AR) overlays virtual objects on the real-world environment; and, mixed reality (MR) overlays and anchors virtual objects on to the real world and often allows users to interact with these objects (Tokareva, 2018, February 2).

Virtual reality has been around for a number of decades [1] and includes diverse applications from realistic training simulations used by NASA to multi-player 3D virtual worlds such as Second Life. There is no accepted definition of immersive virtual reality; however, it is usually classified as a type of VR mediated through a head mounted display (HMD). A HMD is a headset that presents visuals directly to the eyes so that wherever a user looks the display is in front of the eyes and which tracks [2] (in various ways and degrees) the user's position in space. This technology creates a feeling of presence or 'being there' in the virtual world, or in the case of a networked computer environment, co-presence or 'a sense of being there with others' (Slater and Sanchez-Vives, 2016). For feelings of presence to occur two factors are vital. These are place illusion, which is a strong feeling that you are actually in the virtual place, and plausibility illusion, which is a powerful feeling that what is happening in the virtual place is occurring (Slater, 2009).

IVR is different to desktop VR (or that displayed on a tablet or smart phone) because there is no intermediary 'reality check'. In other words, you are not looking at a screen or interacting with what is on a screen; rather, you feel you are actually in the virtual environment and wherever you look it is surrounding you. IVR is a deeply experiential technology and can elicit distinct affective (emotional) and embodied (physiological) responses especially when place and plausibility illusion are heightened. From life-like simulations to fantasy worlds, IVR 'dramatically extends the range of human experiences way beyond anything that is likely to be encountered in physical reality' (Slater and Sanchez-Vives, 2016, p.6). However, not all IVR experiences are the same. IVR allows for different degrees of user agency or the ability to act freely in the virtual world. IVR experiences range from those that allow the user limited interaction (the person can look around in a 360° manner) to others in which a person can navigate or tour an environment in a more mobile way with limited interaction. There is also highly IVR which involves sophisticated body tracking systems and controller devices which allow for a natural gestural interface within the virtual environment (for instance you can pick up or throw a virtual object). This type of IVR allow a person to exercise a significant degree of agency (the ability to act freely) in the virtual environment through: navigation opportunities; interaction with virtual agents and

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[1] For a brief history of virtual reality see https://www.vrs.org.uk/virtual-reality/history.html

[2] For more on the technical aspects of IVR see http://www.realitytechnologies.com/virtual-reality and for tracking systems see https://www.wareable.com/vr/inside-out-vs-outside-in-vr-tracking-343

other players in the environment; manipulation and creation of virtual objects; and free and bounded play (Southgate, Smith and Cheers, 2016). In highly IVR, you are not just looking at and navigating through a virtual environment, you are a creator in and of the environment. Recent developments include the release of 'stand alone' VR HMD (e.g. Oculus Go) that need limited (and soon probably no) interaction with a smart phone and do not need a computer to operate the software (the HMD has the computing power built into it). These 'stand alone' VR systems use a hand controller which allows for navigation and manipulation but physical movement and gestural interface is currently much more limited than in the type of high end IVR that plugs into a computer. Distinguishing between different types of IVR is important because of their potential effects on children in different developmental stages and their pedagogical potential.

Highlights

- Immersive virtual reality (IVR) using a head mounted display (HMD) has only been widely available since 2014.
- Immersive virtual reality replaces the world with an artificial or simulated reality. The head mounted display blocks out the world so that the user can be immersed in the artificial world.
- Different IVR technology create different levels of immersion and feelings of 'being there' in the artificial/simulated environment. Experiences range from looking around, to those where the user has limited navigation and interaction, to highly immersive environments where a user can freely manipulate, navigate, interact and create a customised experience.

THE LEARNING AFFORDANCES OF VIRTUAL REALITY

For several decades, VR learning affordances (properties that can allow for learning) have been documented (Winn, 1993; Youngblut, 1998; Pellas et al., 2017) with some suggesting that the technology has the potential to radically transform education (Blascovich & Bailenson, 2011). Dalgarno & Lee (2010) argue that 3D virtual learning environments (3D VLEs) can: enhance spatial knowledge; facilitate experiential learning that would otherwise be impossible or impractical in the real world; can improve transfer of knowledge and skills learned in virtual environments to real situations; and can increase motivation and engagement in learning and lead to richer collaborations. De Freitas & Veletsianos (2010) extend on this by suggesting that 3D VLEs can: present new opportunities for creativity in learning through role play and mentoring, open up learning spaces for rehearsal and exploration, experimentation and user-generated content; and broaden capabilities for learner-led problem and inquiry-based learning.

Mikropoulos & Natsis (2011) highlight the following learning affordances (properties or features) of VR which can contribute to learning:

1. First order (person) experiences that support social constructivist conceptions of learning.
2. Natural semantics or understanding the basis of something before learning about its symbols and abstractions. For example, manipulating angles before learning about why angles are important in mathematics.
3. Size and scale manipulation where users can change the size of themselves, objects or environments to interact with micro/macro worlds. For example, going into an atom.
4. Reification or transforming fairly abstract ideas into perceptible representations. For example, travelling with a virus as it mutates and spreads within a population.
5. Transduction or extending user capability to feel 'data' that would normally be beyond the range of their senses or experiences. For example, a simulation of the migration paths of whales that allows the learner to follow the paths of different species.

Recent research has highlighted the potential for IVR to act as an 'empathy machine'. This research suggests that swapping perspectives in an embodied way (a key affordance of IVR) can challenge stereotypes and bias. Highly IVR experience can induce an illusion of ownership in someone else's body, and that person might be of a different age, gender or from a different ethnic, cultural or religious group. In one experiment, Maister and colleagues (2015) had light-skinned Caucasian participants occupy either a white or black avatar body in a virtual environment where they could see their body from a first-person perspective when they looked down, as well as in a virtual mirror. A control group of similar participants had either no virtual body, or the body that was purple in colour in the virtual environment. The researchers measured the implicit racial biases of all participants, before and after the experiment. They found that participants 'who embodied a black avatar showed a decrease in their implicit biases against black individuals, which was significantly greater than for those who embodied a white avatar' (Maister et al., 2015, p. 9).

Winn's (1993) early work on the educational potential of VR captures the different mindset educators must adopt when deploying the technology beyond realistic simulation for procedural training:

> *'(I)t is often the case that the power of VR is wasted when it is used for simulation. For example, if you enter a virtual world in which there is a virtual microscope through which you can look at a virtual drop of water, you gain nothing. Learning about the microscopic life-forms that live in the droplet is accomplished far more effectively by using a real microscope in the biology laboratory. The microscope in the virtual world is a transducer (revealing to the eyes what would not otherwise be revealed), and the participant is on the wrong side of it! VR comes into its own when, through a massive change of size, the participant jumps through the virtual microscope's eyepiece and into the drop of water, attaining the same relative size as the microorganisms that live there. At this scale, the experience is first-person. But then you do not need the microscope at all.' (p.11).*

When Winn wrote this, the possibility of feeling like you were actually 'swimming' with micro-organisms and even behaving as one through interfaces that allowed for navigation and manipulation, were some decades away. This is no longer the case. The arrival of highly immersive virtual reality heralds an exciting era for learning; however, the psychological, affective and embodied intensity of the experience, especially for children, have prompted many to argue that a caution approach is required.

Highlights

- Several decades of literature on desktop VR has identified the potential learning affordances (properties that can allow for learning) of the technology. These learning affordance (and perhaps others that are yet to be discovered) require robust investigation, evaluation and pedagogical consideration within the context of IVR.

IMMERSIVE VIRTUAL REALITY AND SCHOOL EDUCATION

Given the recent commercial availability of IVR, it is unsurprising that there is limited research on using IVR in school classrooms (Freina & Ott, 2015). There is a growing literature on IVR for learning in higher education, especially in engineering, science and medicine and some of this may have implications for using IVR in schools. For example, Potkonjak et al's [2016] reviews the benefits of virtual laboratories in science, technology and engineering higher education, highlighting the potential cost-effectiveness of high quality virtual laboratories and the way in which multiple students can access virtual equipment which is, unlike physical equipment resistant to damage. They also suggest that virtual laboratories can make the 'unseen' as the cover of equipment can be easily removed or made transparent to how the workings of the inner structure (in a robot, for example, it is possible to easily to reveal all its working parts). Potkonjoak et al. (2016) do warn however that virtual laboratories are often time consuming to develop, that students may not take simulated experiences as seriously as real ones, and that in the final or advances stages of training and learning, there is no substitute for actual hands-on experience with real equipment. The results from a recent science laboratory experiment with university students, which compared learning in desktop VR with immersive (HMD) VR, suggested that while students felt a greater sense of presence in IVR they may have experienced cognitive overload resulting in poorer test performance (Makransky et al., 2017).

Interestingly, the issue of cognitive load and highly realistic simulation experiences has been explored in an experiment with 14-15 year olds, some of whom were given desktop computer space flight simulator experiences in classrooms (lower immersion) while others were allowed access to a large scale realistic space flight simulation in a customised truck (higher immersion) (Ke and Carafano, 2016). The study found that immersion levels did not affect learning outcomes but that a higher level of sensory immersion may impeded conceptual processing. While relatively small in number, methodologically rigorous studies using desktop VR in school STEM classrooms have shown that the technology can assist in developing higher order thinking skills in students (Pellas et al., 2017).

Most literature on immersive virtual reality in schools is primarily descriptive in nature; for instance, Minocha, Tudor, and Tillings (2017) exploration of how Google Expeditions might be used in the classroom. There are some small scale experimental studies with an educational focus; for example, where certain conditions such as emotional induction (mood manipulation) and level of immersion are altered in order to measure short-term knowledge retention (Olmos-Raya et al., 2018).

An international survey of educators on the learning affordances of wearable technologies, such HMDs, identified a range of issues. These included: privacy; the potential for learner distraction; cost of equipment; a concern that the novelty of using a new 'gadget' would displace the necessary focus on pedagogy and learning design; and a lack of off-the-shelf software suitable for educational purposes (Bower and Sturman, 2015).

Studies on highly IVR and school children include research which examined the use of dance software to teach middle school (predominantly) girls computational thinking and programming in an after-school program (n=8) (Daily, 2014) and a summer camp (n=16) (Parmar et al., 2016). The same research team also conducted an experiment with 36 middle school students (4M, 32F) to investigate how the presence or absence of character customization influenced learning outcomes (Lin et al, 2017). The study was offered as an opt-in activity for the school's graphics communication class but was mandatory for students in the dance/aerobics class. The research found that participants with customizable characters displayed deeper learning. Other school-based research, while not using a HMD but polarised glasses and haptic devices, found that augmented simulation was associated with deep learning of abstract scientific concepts with a significant effect on achievement (Civelek et al., 2014).

Early findings from the Australian VR School Study[3], which involved embedding highly IVR (networked Oculus Rifts) in STEM high school classrooms, highlighted a number of practical, ethical, safety and gender concerns (Southgate et al. 2018a, Southgate 2018b). The research team, which includes teachers, developed a health and safety screening protocol for parents/carers and students and produced resources to educate students on cybersickness. To minimise the risk of cybersickness, students were limited to 15 minutes in IVR within a 3 hour time frame and IVR experiences were not scheduled during the last lesson of the day to ensure student safety after leaving school.

Observational data for the VR School Study revealed that some students became so immersed in the virtual experience that they appeared to ignore the guardian system designed to warn users that they are straying outside of the designated safety zone (with the potential to collide with objects and other students) and that constant supervision by the researcher or other students was required to ensure safety. Furthermore, the process of assisting students to put on and take off VR equipment led to the development of a child protection protocol that would also be suitable for students who are touch adverse. The research also revealed that girls were much less likely to have tried IVR before the study compared with boys and that a minority of girls exhibited initial embarrassment about putting on the HMD and being seen by peers: this was not apparent in boys. The research also revealed that students needed more time to familiarise themselves with the IVR experience and the affordances of the technology for learning through a period of play integrated into the curriculum.

Highlights

- The applications of IVR to school education are only starting to be explored and evaluated through rigorous research.
- There is some promising research that indicates IVR might be used to engage girls in computational thinking and that customisation (an affordance of IVR) can be used to enhance learning.
- Some early research on highly IVR highlights a range of ethical, safety and child protection issues related to deploying the technology in classrooms and recommends constant supervision of students in IVR.

[3] www.vrschoolresearch.com

ETHICAL AND SAFE USE OF IMMERSIVE VIRTUAL REALITY WITH CHILDREN

Researchers have raised serious ethical concerns about exposing children and young people to IVR inclusive of, but beyond, issues of the content of VR applications. Madary and Metzinger's (2016) code of ethical conduct for using VR issues a timely warning about the possible psychological risks of long term immersion for children. Indeed, there are no large scale longitudinal studies on the effects of immersion on children or adults and this represents a key challenge in assessing risk (Slater, 2014).

Some researchers have suggested that any deployment of IVR with children should be informed by a child development approach (Southgate, Smith and Scevak, 2017). Child development includes physical (motor and perceptual), cognitive, linguistic, emotional (affective), social and moral domains, and how these interact together during the broad stages of human development (Berk, 2006). Unlike previous technologies and media, some highly IVR can feel very real and, to take just one area of child development, cognition, this raises serious questions about the effects of exposing children to such virtual experiences. For example, it is important to consider the cognitive dimensions of how children discern what is real from what is not. Between the ages of 3 to 12 years, most children begin to learn the difference between reality and fantasy (Sharon and Woolley, 2004). There is ample evidence that the majority of young children accept fantastic figures and magical processes as real (Principe and Smith, 2008). Indeed, some experiments have found that when primary school children were given an IVR experience many came to believe that the virtual experience had really happened (Segovia et al., 2009; Stanford, 2015). Baumgartner et al. (2008) raised concerns about the ability of children to cognitively and affectively regulate IVR experiences. The experiment compared prefrontal brain arousal in adults and children (mean age 8.7 years) on an IVR roller coaster ride. They found that children were more susceptible to the impact of audio/visual stimuli and that the children seemed unable to evaluate and monitor the experience or inhibit a sense of presence. The authors concluded that there should be more reluctance to 'expose children to emotional virtual reality stimuli as currently practiced' (Baumgartner et al., 2008, p.11).

Such findings have led some to argue that IVR 'is likely to have powerful effects on children because it can provoke a response to virtual experiences similar to a response to actual experiences' and that when choosing VR content consideration should be given to whether it would be acceptable for the child to have that experience in the real world (Common Sense, 2018, p.2-3). At a psychological and profoundly philosophical level, exposure to IVR does raise questions about the ethics of (unintentionally) implanting false memories, especially for children who because of their developmental stage are unable to distinguish what is real from what is not.

Southgate, Smith and Scevak (2017) contend that consideration needs to extend beyond content to the types of interaction in IVR to include how children in different developmental stages might react to and understand the affordances of the technology and its modes of social interaction (Figure 1). Practically, teachers must apply their knowledge of the different domains of child development and the individual differences of their learners in order to make informed decisions about the ethics of using IVR in their classrooms.

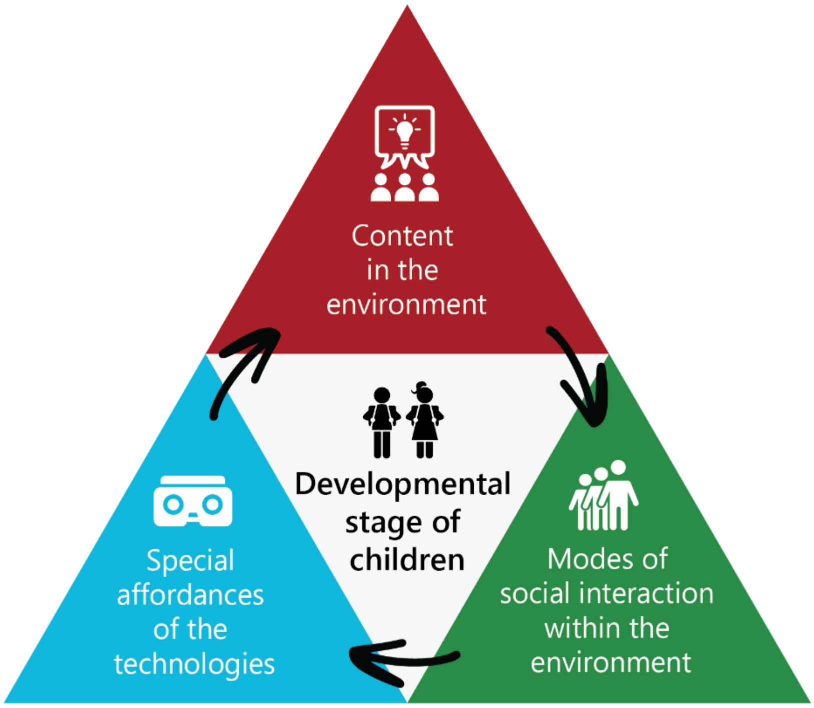

Figure 1: Conceptual framework for considering aspects of immersive environments in a developmental context (from Southgate, Scevak and Smith, 2017).

Manufacturers of HMDS have released health and safety guidelines, and most have age recommendations. For example, while Google Cardboard has no age recommendation it is suggested that the equipment should be under adult supervision. More highly IVR HMDs, including those that use mobile phones (Samsung Gear VR, Google Daydream), consoles (Sony VR) and top of-the-line versions that have sophisticated tracking systems and require expensive computers (HTC Vive, Oculus Rift), have applied age recommendations for use. These types of IVR recommend that the child be between 12-13 years of age or over. Guidelines usually stipulate adult supervision and that users taking frequent breaks. Consulting manufacturer's guidelines is vital before using IVR in the classroom.

One key risk highlighted in manufacturer's guidelines is cybersickness, a very unpleasant form of motion sickness with symptoms including nausea, disorientation, headaches, sweating and eye strain (Davis, Nesbitt and Nalivaiki, 2014). Cybersickness can be bought on even after a small amount of time in highly IVR. Surveys indicate that parents (Common Sense, 2018) and young people (Touchstone Research, 2015) are concerned about the potential health risks of IVR. For example, a recent marketing survey (Castaneda, Cechonu & Bautista, 2017) reported that a small minority of students had an IVR experience that they considered to be 'too intense' with some feeling physical discomfort. There is a considerable research effort directed at understanding cybersickness and designing environments that alleviate it. It is difficult to predict if an individual will experience cybersickness; however, children aged 2-12 years have the greatest susceptibility to cybersickness with this decreasing from the ages of 12 (Davis, Nesbitt and Nalivaiki, 2014).

Related to physical impacts, a recent experiment with twenty children (aged 8-12 years) who played a twenty minute game in IVR found that: two children exhibited disrupted stereo-acuity (the ability to detect differences in distances); one child showed worsening balance after playing the game; and no children experienced serious deterioration in eyesight (McKie, 2016).

Finally, in the age of big data where technological applications harvest information in educational and other settings (Rodríguez-Triana, Martínez-Monés, and Villagrá-Sobrino, 2016), it is worth considering the privacy implications of IVR. This includes not only collecting data about a person — for example, when accounts are set up — but information directly *of* the person, a type of data known as biometrics. Biometric data 'enables the use of unique physical characteristics — such as a person's face, voice or fingerprint — for verification or identification purposes' (Royakkers et al., 2018, p.2). It is information of biological/physical attributes which can be linked to behavioural data. In IVR biometrics can include data on head, body and arm movements when using a HMD and/or tracking system (Adams et al., 2018). In the near future this may include eye tracking (Soler et al., 2017), and (perhaps even pupil dilation) to assess the emotional state or engagement of users (Pan and Hamilton, 2018). The integration of biometrics in VR, AR and MR presents consent and privacy challenges. This is coupled with a lack of transparency regarding if and how this type of data is collected by manufacturers of IVR equipment and software developers. Biometrics is emerging as an area of paramount concern in legal, human rights, and technology circles.[4] Given the ethical and legal implications for schools and their students it is important that educators keep apprised of developments in this field.

Highlights

- There are no large scale longitudinal studies on the effects of immersive virtual reality on children or adults. We do not know what the long term effects of immersion will be.
- Manufacturers of IVR equipment have issued online health and safety guidelines with age limits on use. These should be consulted before implementing IVR in classrooms.
- Teachers should consider the physical (motor and perceptual), cognitive, linguistic, emotional (affective), social and moral developmental stage of learners before using IVR in their classroom. IVR can evoke powerful reactions in children who may not be able to cognitively regulate the experience and, for the very young, may come to believe that the virtual experience was real.
- When using IVR for learning teachers should consider how children at different developmental stages might respond to the content, modes of interaction and affordances of IVR technology.
- There is no way to predict if a child might become cybersick and so teachers should educate students on identifying symptoms for early opt-out during IVR sessions, especially when using highly IVR.
- The privacy of students should be considered not only in setting up IVR accounts but also in relation to the possibility that biometric data might be collected by manufacturers of IVR hardware and software. At present, it is difficult to ascertain if or what type of biometric data is being collected. This is becoming an area of increasing concern for consumers, law-makers and human rights advocates.

[4] For a recent expert podcast on IVR, privacy and biometrics see https://www.roadtovr.com/oculus-privacy-architects-discuss-policy-jenny-hall-max-cohen/

CONCLUSION

The age of immersive learning has arrived. However, research on the effects of IVR on children and their learning is still nascent. Large scale longitudinal studies on the effects of immersion are required and rigorous studies on the pedagogical potential of IVR are essential if the affordances of the technology are to be leveraged for creativity, collaboration and deep learning. Building this knowledge base will take time. In the interim, teachers must take a cautious approach, drawing on manufacturer health and safety guidelines and the substantial research on child development in order to make informed decisions about ethical and safe use of the technology. Importantly, school systems should be supporting teachers to understand the privacy implications of using immersive (embodied) technologies with their students.

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APPENDIX: METHODOLOGY

This is a traditional literature review which aims to synthesis the research on immersive virtual reality, school-aged children and education. A Boolean search was conducted using a combination of keywords with modifiers (AND/OR) to produce an initial set of relevant papers. Key words included Immersive virtual reality, Virtual reality, VR, Head mounted display, Headset, Google Cardboard, Google Expeditions, and Education, Learning, School, K-12, Teachers, Teaching, Pedagogy, Curriculum, Assessment, and Children, Teenagers, Adolescents and Students. Databases searched included Education Journals and ERIC Proquest, ACM Digital Library, IEEE Explore, ScienceDirect and Scopus. A search of Google Scholar was also conducted. Reference lists from relevant articles and reports were scanned for pertinent literature. Due to the timeframe for completing the review books and book chapter lay outside of the purview of this analysis. Searches restricted to papers published in English and primarily restricted to those published in the period 2014-2018; however, where relevant literature published outside this timeframe is included. This period was chosen as it marks the advent of commercially available immersive virtual reality.

To ensure quality, this review is primarily based on peer reviewed conference papers and journal articles that contain detailed methodology and findings based on empirical qualitative and quantitative research. Due to the relatively recent advent of commercially available IVR, some non-peer reviewed reports, web-based articles and technology reporting have been included as they provided the most recent technical information and perspectives of interest on the topic of IVR, children and education. Some related literature has been excluded from the review because it is tangential to the topic of IVR and school education. For example where research was conducted with children in a CAVE (CAVE Automatic Virtual Environment) or semi-CAVE immersive system, it was excluded from the review as putting CAVEs in schools would be prohibitively expensive. It is worth noting that, although not covered in this review, there are clinical experiments and therapeutic interventions related to: life education with hearing impaired children (Vogel et al., 2004); teen smoking prevention (Nemire et al., 1999); time on task for children with ADHD (Bioulac et al.,2012); social and affective recognition skills of children and youth with autism (Bellani, 2011; Didehbani et al, 2016) or cognitive disabilities (Freina et al, 2016); and road safety (Clancy et al., 2004; Plumert et al., 2004).

To conclude, while this review is not exhaustive, a concerted attempt has been made to locate and include peer reviewed and grey literature and expert reporting of research that would be of interest to teachers and school leaders on the topic.