Handbook of Research on the Global Impacts and Roles of Immersive Media

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Chapter 17
The Promises and Challenges of Immersive Education

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ABSTRACT

This chapter covers immersive media as an educational tool, from its origins as a simulation training device for military applications to more recent examples of how it is being used in education and training today. Educational immersive media provides firsthand experiential learning opportunities. Educational theorists have supported the use of experiential learning as an effective approach even before the current development of digital applications, and these ideas are mentioned briefly. A continuum of immersion is discussed to include several approaches from low cost to high-end simulation. The chapter provides several examples of the ways today's immersive education is being utilized. Benefits as well as challenges and issues of this approach are outlined. A call for future research concludes the chapter.

INTRODUCTION

"Education is our passport to the future, for tomorrow belongs to the people who prepare for it today."
-Malcolm X

In the beginning—millennia ago—learning was a done by one of two methods: self-exploration in the physical world, or by being guided by someone who knew something you didn't and wanted to share this information. Learning was embodied and immersive, relying on the direct experience of our human being within the world and with others around us. In the intervening millennia that brought us to today, we developed ways to encapsulate knowledge and wisdom, going beyond the embodied mechanisms, abstracting information to something "out there"—something external—that could be accessed indirectly. We invented writing, and books, and were able to encapsulate knowledge as a separate thing unto its own.

More recently we have devised electronic methods to capture, analyze and make knowledge and data accessible to the connected. And through our technological tools we can now bring people together in ways once unimaginable. However, these tools tend to circumvent the original immersive nature of

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learning and understanding in many ways. They oblige us to read, look and be alone in our quest for knowledge—interacting with a screen or book in an abstracted way.

Moving forward, we are now in an age when the very tools that connect us are becoming themselves immersive. This situation provides a unique opportunity to be able to revisit the forms of learning that supported our species in its formative years. Immersive technologies, such as the ones described in this book, are on the cusp of impacting the very way we consume and share our ever-widening forms of knowledge and understanding. In the very near future, education is poised to undergo transformation for how it is created, delivered and absorbed. Imagine a class where students across the globe can gather together without having to leave their home base and where they learn by being immersed within the lesson itself. In immersive learning scenarios, learners of all ages have the key learning objects, functions and people in the same virtual space, and experience them as embodied, spatial constructs. This is much more aligned with how humanity learned in its genesis years.

Education experts have explored the benefits of "Experiential Learning" for decades. John Dewey's early theories introduced the idea of experiential education as opposed to learning pre-digested material or rote facts, and claimed that the quality of that experience was critical, and that in part was due to the way individuals can create meaning from their interactions with the content of the experience (Dewey, 1938).

In the 1980s Seymour Papert took this idea even further by discussing how a learner can become the very thing about which they are learning.

The gear can be used to illustrate many powerful 'advanced' mathematical ideas, such as groups or relative motion. But it does more than this. As well as connecting with the formal knowledge of mathematics, it also connects with the "body knowledge," the sensorimotor schemata of a child. You can be the gear, you can understand how it turns by projecting yourself into its place and turning with it. It is this double relationship—both abstract and sensory—that gives the gear the power to carry powerful mathematics into the mind. (Papert, 1980, p. 2).

Virtual reality and immersive scenarios can facilitate a learner becoming that gear. One of the most engaging, informative and memorable virtual experiences I have encountered was being a particle in a particle accelerator (though extremely slowed down to meet my mere human perceptual constraints). "I" (my point of view) was whizzed through the accelerator and I came away with a new understanding of the twists and turns of the journey. This was on a Department of Energy (DOE) island in the virtual world Second Life (Bojanova and Pang, 2011, p. 223), itself a hotbed of instructional experimentation from about 2006 through roughly 2014.[1] It was this first-person viewpoint transporting me into the mode of *being* that particle that enabled a deeper understanding of the concepts involved.

According to Christian Itin, Experiential Learning consists of: "1) action that creates an experience, 2) reflection on the action and experience, 3) abstractions drawn from the reflection, and 4) application of the abstraction to a new experience or action" (Itin, 1999; p. 91).

Beyond the mental imagining that Papert envisioned, Virtual Reality can actually provide us a cognitively real, embodied mode of becoming the object of a lesson. From gears to particles, to foraging as a dinosaur in some Jurassic landscape, VR can engage our sensory mechanisms in visceral ways that impresses our mind into believing the experience is on a par with that which we experience in our physical reality.

Not only is Virtual Reality able to present realities—past, present and future—and the lessons we can glean from those, but also topics that are theoretical—such as mathematics or music—which can be presented and perceived in tangible ways. VR experiences can allow learners to interact with these constructs, learning more by direct manipulation, which brings into play a kinesthetic learning process known as embodied cognition that suits our physical nature. Immersive multi-sensory, embodied interactions have been shown to support stronger neural pathways in our brains beyond what simply reading about abstract concepts might do (Fisher & Coello, 2016). Immersive methods of distributing knowledge also can allow for failure in safe ways. Just as for the past several decades, aircraft pilots have trained in simulators that allow mistakes to be non-fatal (and less expensive than crashing a multi-million-dollar plane), many more types of training and learning can also benefit from more intensive lessons learned by safe failures.

And VR can even take us into realms of pure imagination. Early VR pioneer Jaron Lanier often opined about using VR to become creatures like lobsters that require a different body configuration to expand our modes of thinking (Lanier, 2010). Different types of navigation allow people to experience flying, changes in scale from macro to micro, time that goes super-fast or slow, and physics that challenge our understanding of our normal waking life, like trying the gravity on Mars. This ability to present different realties allows for participants to gain new understandings and points of view.

The promise of immersive education, of course, has challenges. The gear required to provide immersion into a spatial, embodied learning environment is only just emerging from companies, and there are no standards as yet. Head-mounted displays are bulky and one size does not fit all. Tracking, an essential core technology that supports embodiment and immersion, has made great strides in the past few years, especially with inside-out solutions, but still needs refinement. Input devices are still at the game controller stage and could be much more intuitive and closer to our normal ways of interfacing with the world. User interface design demands new techniques for immersion, but still has no agreed-upon best practices that designers can access. And incorporating additional senses such as haptics (touch) and smell, is still on a distant horizon for consumer use. We will certainly see improvements in all these areas, as buyers decide which devices best suit them and vote with their dollars. Other challenges include utilizing techniques to avoid the nausea that plagues a certain percentage of users, bringing costs down, and maintaining and upgrading rapidly developing technologies.

None of this should stop us. In fact, these emerging promises and challenges should spark ever more concerted efforts to bring the immersive educational future to everyone. This chapter will outline several efforts underway to deploy education topics in an immersive setting. Some are collaborative; some are not. Some do better with delivering a high level of embodied interaction. Some are unique one-off solutions. A very few are part of studies to see what works effectively and what doesn't in this new means of delivering education. We certainly need more formal studies, but we can learn from each and every experience being created. Each one tells us something—about what connects, what inspires, what is remembered. Some day we will look back at these efforts and see in them the seeds of the immersive transformation of education and learning that is our birthright and our future. First, however, we will explore some of the history of immersive learning.

BACKGROUND

Virtual Reality Origins (as Immersive Media)

To the current public, VR as the exemplar of immersive technology appears to have emerged fully blown with the announcement of Facebook buying a small company called Oculus that was experimenting with a low-cost headset for gamers to jump inside their 3D games (Harris, 2019). Arguably, this was less of a start and more a culmination of sorts, as VR in some form had been around since the mid 1960s as a research vector for the US military (Aitoro, 2016) and in its first commercials forays that happened (and eventually stalled) from the mid-1980s to about 2000 (Kawalsky, 1993). This second burst of VR activity saw a number of notable pioneers who worked diligently in the "second wave" of VR, but in the end, the technology was simply not cost effective enough for consumer prime time. And yet, alongside VR endeavors in entertainment, games, and health purposes during those years, some education applications were also developed.

The VR pioneers of the second wave were very aware of how immersive VR could be used for learning. Early VR expert Meredith Bricken stated in her 1991 article:

Virtual Reality as a Learning Environment

Using a head-mounted audio-visual display, 6-D position sensors, and tactile interface devices, we can inhabit computer-generated environments. We can see, hear and touch virtual objects. We can create, modify and manipulate them in much the same way we do physical objects, but without those pesky real-world limitations. VR is not only virtual: we can meet real people in virtual worlds, we can tele-exist in real places all over the world and beyond, and we can superimpose virtual displays onto the physical world (Bricken, 1991).

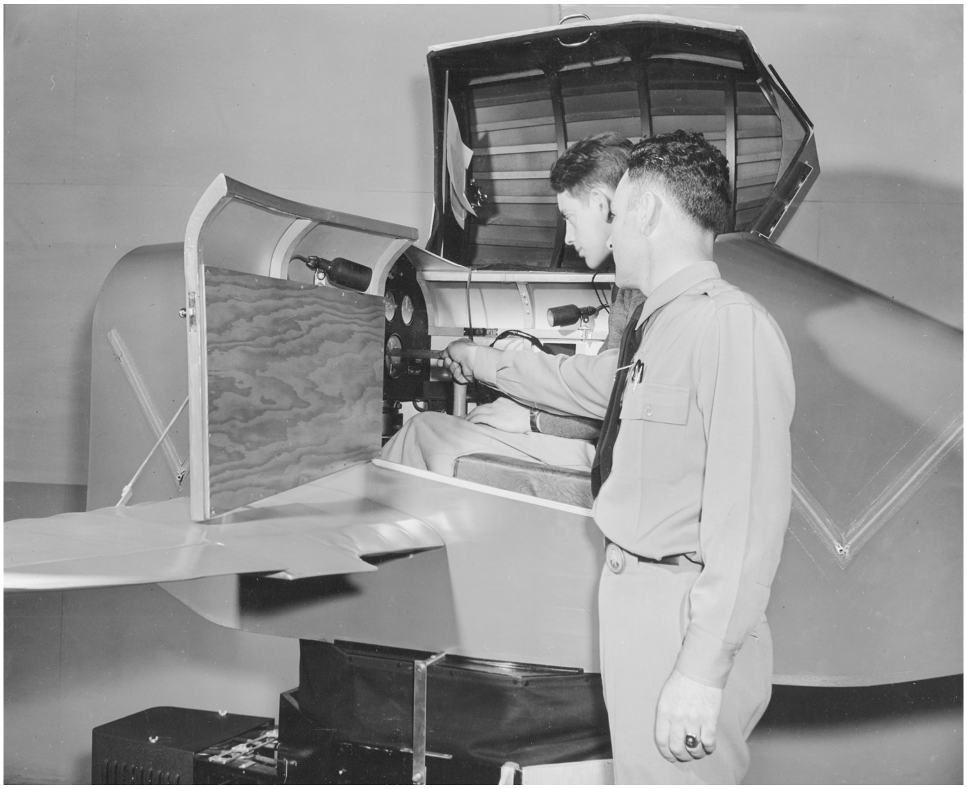
Training Simulation and VR

Even from the earliest days, virtual reality was considered an aid to training. Its history can be traced back several decades to pre-digital times. In 1929 Edwin Link created a training simulator called the "Blue Box" (Figure 1) for pilots to learn to fly when visuals were compromised, such as at night or in bad weather, a process now known as instrument flying. As such, his simulator had no display to speak of, but it did have pneumatic motion platform so the trainees felt some of the physical sensations of the flying experience (Courtney, 2017).

Ultimately this device was to find use as an entertainment device, much like mechanical horses and other coin operated "kiddie rides." Link himself patented the device for entertainment use in 1930.[2]

Years later the United States military, still interested in simulator training, paid for the earliest research into both Augmented and Virtual Realities with the ultimate goal of making better simulation devices. Connected Abrams tank simulator systems, collectively called SIMNET, allowed a crew to operate the various components of the tank such as driving, observation and handling ordinance. Visual were not worn but were digital displays that replicated the type of windows the tank would have. However, their primarily educational advantage was on how to communicate via the radio comms made necessary by the noisy environment (Miller, 2015).

Figure 1. Aircrew training during the 1940s with a link trainer
Source: The National Archives



The Advanced Research Projects Administration (ARPA, later known as DARPA) funded the building of early immersive headsets that could project a computer display in front of a person's eyes. The 1960s version, created by Ivan Sutherland, a researcher, and Bob Sproull, then head of ARPA, consisted of two cathode ray tubes affixed to the sides of a user's head that projected a stereo wireframe display to a virtual space that appeared to be in front of the wearer's eyes. This computer-generated scene was actually overlaid onto the view of the room in which the person was standing and therefore was more like Augmented Reality rather than fully immersive VR that shuts out the physical world.

This system, which included mechanical parts to keep track of where the user was looking, was so heavy that it required a counterweight to keep the user's head from being too impacted. As such, it became known as "The Sword of Damocles" after the old Greek tale about a courtier who was jealous of a king until forced to sit under a heavy sword suspended by a single hair to illustrate how those is power are also always in danger. [Roman philosopher Cicero in his 45 B.C. book *Tusculan Disputations*.]

Sutherland's original definition of what has become to be known as a Head-mounted display (HMD) is this, from his 1968 paper in the Fall Joint Computer Conference, 1968: "The fundamental idea behind the three-dimensional display is to present the user with a perspective image which changes as he moves" (Sutherland, 1968). The fact that a user's actions can affect the presentation of images in a logical, spatial and embodied way is a key tenant of VR.

Sutherland had broader futuristic visions for such devices and how they would be used. In 1965 he published a short paper called *The Ultimate Display*. In this he envisioned:

The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked (Sutherland, 1965).

As the goal for this research was better training devices, Sutherland continued to work in this area, both in creating the fledgling field of computer graphics and the hardware to run and display these digital images. By 1968 he had partnered with David C. Evans to form a company called Evans and Sutherland, which commercialize computerized immersive training. During the 1970s, 1980s, and into the 1990s, it was one of the most popular flight simulators in use by the US military. These systems had the best real time graphics and audio coupled with a six degree of freedom motion platform to realistically convey believable motion of an aircraft to a participant or trainee.

A CONTINUUM OF IMMERSION

With this background firmly placed in the reader's mind, the boundaries of immersive education as discussed in this chapter can be presented. Immersion is one of the key tenants of Virtual Reality systems, as is physical tracking of a person's body. Immersion is typically achieved via a visual system that shuts out the surrounding physical world from a user's perceptions, replacing it instead with the object of the immersive experience. This method allows a participant to focus fully on the immersive, actively generated space with fewer distractions from external world inputs.

Secondly, physical tracking allows the immersive system to include participant actions such as head orientation, body position, gaze direction, gestures and navigation (and sometimes facial expressions) as input into the system in real time, with those actions directly affecting the Virtual Reality environment itself. This aspect brings an embodied sensibility to the resulting experience as the visuals, audio and other sensory presentations are computed directly from changes resulting from a participant's actions; the resulting space of the VR environment changes with whatever the participant does. These techniques support what is known as embodiment in the virtual space.

Embodiment is a powerful construct that affects us much like physical reality because our brains are evolutionarily wired to believe the inputs of our sensory mechanisms, even when those have been "hijacked" or replaced by other forms.

Now there are many other types of digital or computational media placed around the periphery of this definition that are also valuable approaches to more engaging educational roads. These include Augmented Reality, where the physical world is still in view, collaborative spaces where one learner has control and agency and others are passive observers, and 360 video-based experiences where a user's only activity is the turning of their head, though these will be covered only briefly in this chapter.

In fact, immersivity can be considered a continuum, from a passive viewing of a two-dimensional screen (which can often engage and feel cognitively immersive) to more active viewing of a 360 "surround" video (most likely not stereo), to stereo viewing in passive mode of an experience where one participant is the active "driver," to AR that overlays the physical world and, if done well, can integrate the virtual and the physical in a tightly coupled way. Closely related to full immersion is the fulldome venue, first utilized as a means for scientific education about the nighttime skies. At the extreme end of the continuum is fully immersive virtual reality, where a person's body, eye gaze and head orientation are tracked in real time, allowing for full interaction with elements of the VR environment. This final mode of full embodiment is the ultimate realization of interaction and immersion. Add to that multiple senses, and the experience comes as close to simulating a physical world experience as our technology currently allows.

IMMERSION IN EDUCATION AND TRAINING: SOME RECENT EXAMPLES

It is critical to remember that immersion forms of education are not a pedagogical approach in and of themselves, but rather modules that support curricular objectives and goals. Immersive educational modules need to be matched to the intent of the lesson as well as the subject matter. They should provide an enhancement to traditional learning methods that immersion best fulfills.

For example, it makes sense to use immersion if the lesson has an interactive or kinesthetic component such as learning how to handle hazardous equipment, or how to perform a specific surgery. These lessons are difficult to teach via basic book learning or other symbolic methods. Being within the environment—what Meredith Bricken describes as the 'inclusive interface' (Bricken, 1994) is a much more intuitive human situation.

You don't see text much in nature, so you cannot rely on it necessarily in critical learning situations. …. As instructors, if we imagine how we place the learner in the middle of a natural, unfolding story, in which their behavior determines the next outcome, we create a learning environment in 3D (Wankel & Heinrich, 2011. p. xiv).

The field of immersive education is growing, and more and more offerings are being added as developers realize that educational experiences can provide new and powerful ways of understanding for learners. Some notable examples are provided here to show the scope of what may be coming in the future. This is not meant to be a comprehensive listing, merely ideas of what can be done. The larger questions of how such examples might be deployed and what the assumed benefits could be will be addressed in the section outlining issues.

Example 1: Domes as an Educational Vehicle

Starting in the 1920s, projections of the night sky onto hemispherical domes heralded the start of the modern planetarium as a venue for scientific education about our nighttime skies. The Zeiss optical company came up with the concept of projecting patterns of light via a multi-lens projector onto the inner surface of such a dome measuring 16 meters (Zeiss, n.d.). The first such facility was installed in Munich, Germany and was called the *Sternentheater*, or star theatre (Firebrace, 2017; Kukula, 2017).

These planetariums surged in popularity during the Sputnik era, when attention to space became a critical aspect of new space exploration efforts, primarily by Russia and the United States of America. (In fact, Russia for many years boasted the largest planetarium at 37 meters wide.). Multitudes of school children visited planetariums in the 1950s and 60s to better understand the skies, stars and planets above them (Nadworny & Anderson, 2017).

By the 1980s the projections systems for planetariums were transitioning from optical to a digital format, with Evans and Sutherland, a simulation training company in Salt Lake City, Utah launching their Digistar systems that were installed in many global educational and entertainment venues (Faidit, 2009).

These were the predecessors to what we now call fulldome venues. Today we are seeing an explosion of dome installations, many for entertainment but often now with an educational component. These range from pop-up installations and festivals to more permanent structures that are open to use for multiple purposes.

At least one company—Spitz[3]—today offers an easy to use educational planetarium system called SciDome specifically designed for teachers. It includes the project system and a full curriculum covering topics from astronomy, to weather patterns and the composition of earth's core, to basic physics concepts where variables can be changed interactively in real time.

While not fully immersive as VR (participants have no body, face or gaze tracking so these systems fall in the 360/180 degree video category where your only agency is to turn your head to change your view as if you are inside a spherical screen) they still provide a large feeling of immersion with imagery filling your full field of view. This and the interactivity provided make them a great use case for future immersive learning.

Example 2: Google Expeditions

Perhaps one of the best-known recent deployments of a type of VR technology in the classroom is Google's Expedition (GE) Project, wherein Google provided a selection of classrooms with their low-cost cardboard viewers into which a smartphone could be placed running the Google Expeditions app. This app allows students to take virtual field trips to hundreds of locations that have been captured with a 360-degree camera. The teacher leads the students through the field trip via the guide mode on a tablet, and students, using the cardboard viewer, follow along in 'student' mode.

The Open University recently conducted a large-scale study of the affordances and efficacy of this low cost VR approach (Minocha et al., 2017). Participants in the study included not only the students (grades 4-11), but also educators, curriculum experts and fieldworkers. The study aimed to answer the following questions: 1) how effective were the GE VR simulations in representing the concepts and processes, 2) can such virtual field trips support physical fieldwork, and 3) can these modules support inquiry-based learning.

Even though the GE setup did not permit direct manipulation of any objects within the 360 recording, it still provided a unique and authentic viewpoint to a world that students would otherwise be unable to experience. Other aspects particular to standard field trips were also woven into the GE experience (e.g. preparing for data collection, understanding the purpose of the trip, assessing the impact of the trip after the fact). In this way the virtual field trips proved to be quite effective. In using the GE resources in conjunction with an actual physical visit to a location, an added benefit was perceived in that additional or hard-to-see details could be showcased and emphasized. And finally, the study concluded that inquiry-based learning was supported by the geography and science modules provided and tested.

In addition to these findings, the thrill of discovery from a class of excited students underscores the ability of such technology to capture the attention of today's youth (Brown & Green, 2016).

Example 3: NASA Astronaut Candidate Training

NASA has been a prime user of VR for Training, and in fact accelerated the development of the gear necessary to support their training efforts. The NASA Ames Research Center developed a full 120° FOV HMD (monochrome) in 1984 followed by a Virtual Environment Interface Workstation (VIEW) with stereo visuals, a full spatialized auditory system powered by a DSP Board called the Convolvotron (Crystal River Engineering), head and hand tracking via a Polhemus magnetic tracker, and gesture input that used a prototype glove (Kalawsky, p. 27). Scott Fisher led the VIEW Project, which pushed the development of the technology under NASA's sponsorship far more than hopeful commercial prototypes of those early days.

NASA's interest was specific: astronauts' teleoperation of equipment such as robotic arms that would be attached to the space station. These would have to be operated remotely, but in a way that gave the user a feeling of actually being in proximity to the objects being manipulated. Not only would the system provide functionality on the station at some point, they could be used to practice the actions needed to successfully maneuver the equipment. This became a critical training component when the Hubble Telescope, launched in 1993, required repair that could only be done remotely.

To support training needs for these very complex operations, NASA has taken the immersive training of astronauts to ever more sophisticated levels. At the VR Training Center at the Johnson Space Center, advances are researched and implemented by a team led by Dr. Evelyn Morales. There are four main areas of focus: training for EVA walks, rehearsing how to get back to the ship if separated using a backpack rocket, telerobotic activities, and practicing in low levels of gravity, this latter use facilitated by a pool which more closely resembles zero gravity (Carson, 2015). In addition, networked VR training situations also help hone communication skills.

Example 4: On the Job Training

On the job training is widely considered the best way to train in industry, but it is a time and cost consuming method that can tie up both people (as trainers) and facilities. This is an area where immersive systems are proving invaluable and are starting to be extensively deployed. Immersive learning promotes what Chris Dede calls effective transfer by simulating the real world effectively.

Transfer is defined as the application of knowledge learned in one situation to another situation and is demonstrated if instruction on a learning task leads to improved performance on a transfer task, ideally a skilled performance in a realworld setting (Dede, 2009. p. 67).

A new employee can take the immersive training module not only for initial learning, but also for refresher and certification classes. Walmart uses VR to prepare its employees to deal with the conditions they will encounter in Black Friday sales days (Thompson, 2019). Several energy companies are testing out immersive scenarios for operating complex and dangerous equipment, some of which have embedded assessment tools as part of the learning experience (Joshi, 2019). Especially in this latter category, the ability to gain experience with dangerous equipment in a safe manner is invaluable.

Figure 2. An immersive science lesson with Michael Faraday and James Clerk Maxwell
Source: Image courtesy of ScienceVR and Jackie Chia-Hsun Lee

Example 5: Social Training

In addition to on the job training, many companies are investing in using VR for more socially-oriented skills. These include training for diversity, inclusion and harassment mitigation, interviewing skills for professionals such as HR personnel and doctors, cultural training with language and social skills, and safe role playing for various types of social encounters. The benefits are that the VR experience can be done multiple times, with the learners gaining valuable knowledge from each encounter (Gillies, 2018). This leaves them better prepared to deal with a variety of circumstances, without worrying about the effect a naïve decision may have on another human being.

Example 6: Learning Science from the Scientists in VR

Imagine learning scientific principles from the people who invented or discovered them: magnetism from Michael Faraday, the theory of electromagnetic radiation from James Clerk Maxwell, and the secrets of radioactive elements from Marie Skłodowska Curie (Figure 2). This is the approach of Jackie Chia-Hsun Lee's company ScienceVR, which has a created number of these engaging, interactive experiences. From Archimedes' "Eureka" moment to Volta's development of batteries, science gets personable and real, and therefore quite memorable!

Example 7: Learning Complex Concepts in VR

Dede et al. (1997) were among the first to see the potential in virtual reality for a new form of interaction with the material to be understood. This team explored the very nature of learning as it was supported by specific affordances of VR. In the mid-1990s they built three ScienceSpace worlds to "enable unique, extraordinary educational experiences that help learners challenge their intuitions and construct new understandings of science" (p. 2). This work included evaluations of the VR environments from a "learner-centric strategy." Their description of one of their Scienceworlds, NewtonWorld, is particularly intriguing:

In NewtonWorld, users experience laws of motion from multiple points of view. In this world with neither gravity nor friction, balls hover above the ground. Users can become a ball; see, hear, and feel its collisions; and experience the ensuing motion (Dede, 1997. p. 3).

But what of complex and or abstract concepts? Can immersion provide an advantageous edge for these sometimes difficult to grasp topics? Many can be aligned with the 3D, agency-oriented features of VR.

For example—one can learn the Pythagorean Theorem via direct algebraic formula, but often a better and more complete understanding is achieved through geometric derivations or what is called rearrangement. Being able to take the geometry into visuals that can be manipulated in three dimensions can lead to an "a hah" moment for some learners.

Indeed, this was observed during one of the class sessions in a 2018 ten-week curriculum for Building VR Experiences of which the author was a part. Students were struggling with the concepts of adding vectors and understanding their impact on objects in VR.[4] By allowing students to actually manipulate those vectors while inside VR with controllers and an immersive HMD led to revelations for many students that allowed them to more fully comprehend the core ideas.

Scott Greenwald, who is pioneering the use of VR within MIT's curriculum, recently completed a study comparing complex concepts as presented via VR and traditional means (Greenwald et al., 2018). He states: "VR was perceived by learners to have advantages. We did find significant quantitative differences in learners' completion times. We share findings, based on the quantitative and qualitative feedback received, about what makes VR environments beneficial for learning about complex spatial topics, and propose corresponding design guidelines."

ADDITIONAL VR LEARNING APPROACHES

Learning to Create VR Experiences: Robert Eagle Staff Middle School

Creating a virtual reality experience involves a number of disciplines working in concert, such as computer science, computer graphics, design, user interfaces, physics, modeling, code writing, and iterative assessment. Using VR production as a multidisciplinary learning process can teach not only these skills but also collaboration, communication and more.

A recent example of this was the efforts of Tom Furness and several Virtual World Society (VWS) members to teach 28 middle schoolers at Robert Eagle Staff Middle School in Seattle how to create their own VR experiences (Figure 3).

The worlds the students created illustrated several STEM concepts such as gravity and light. With equipment provided by HTC Vive, each student worked with mentors from the VWS to learn how to setup and use the VR systems, critically analyze the concepts they wanted to create, and form teams to tackle the production process. Having a project that came from their own ideas empowered these students to create exciting experiences.

Figure 3. Students at the Robert Eagle Staff Middle School creating their own VR experiences
Source: Image courtesy of the Virtual World Society

This class was successful because of the dedication of the VWS volunteers, who had the technical expertise. Most teachers would need this type of support to enable such a class, but the rewards would be invaluable.

Using VR as a Creation Tool

Simple to learn and use VR apps that do not require programming have just started to arrive. Many of these fall into a creative arts categories such as dimensional painting and sculpting or animation. Examples include Google's TiltBrush, Oculus Medium, Quill, AnimVR and more. These programs allow someone to learn a relatively simple interface quickly and create in full 3D while being immersed in the creation space.

A number of college levels course are being designed around these programs, including one the author teaches at Otis College of Art and Design in Los Angeles. Not only are the students being very original with their artistic output, they are learning a great deal by being immersed in this creation space (Figure 4). Many of the students have stated that they never fully understood 3D modeling and animation programs they were using in their Digital Media classes until they were able to be inside the 3D space. One student used the VR programs to build and measure a sword he was taking from a 2D sketch to a physically built object to ensure that his hand would fit into the hilt properly. Such creation is, as one said, designing from "a more spatially informed point of view." Another described it as "a limitless me-

Figure 4. Students creating with VR art programs at Otis College of Art and Design
Source: Photo by the author

dium" and many remarked on it being an integral part of the future of art, and that VR art could be the "barely explored immersive three-dimensional experience medium that the art world has been missing."

BENEFITS OF VR FOR LEARNING

These examples begin to illustrate some of the many positive ways in which immersive, experiential learning can supercharge the educational process. Studies have been done in which VR has been shown to improve a wide range of cognitive aspects as diverse as *response times* (Sankaranarayananet al., 2018), *procedural knowledge retention* (Zhang, 2019; Babu, et al., 2018), *second language vocabulary learning* (Legault, et al., 2019; Cho et al., 2018), *attitudes and empathy* (Formosa, et al., 2018), *manual skill acquisition* (Pulijala, et al., 2018), and *spatial understanding of complex objects*, (Parkhomenko et al., 2018; Stepan, et al., 2017). Some of these show significant improvements in short and long-term retention of information after an active immersive learning session.

Chris Dede notes:

Studies have shown that immersion in a digital environment can enhance education in at least three ways: by allowing multiple perspectives, situated learning, and transfer (Dede, 2009. p. 66).

The presentation of multiple perspectives VR can provide reinforces the understanding of the lessons to be learned. And by accurately simulating the physical world, learners can transfer the skills used from the virtual to the actual world. This more direct transfer of skills allows for the application of that knowledge to other similar situations.

Other benefits include:

- Motivation

The novelty and wow factor in immersive experiences can provide enhanced motivation and willingness to explore.

- Focused attention

Immersive experiences separate us from the ordinary world, whether through a head-mounted display or being in a separate dome space. This situation leads to fewer distractions and more concentration on the material being presented.

- Exploration in a natural way

The three-dimension and tracking affordances of VR allow us to navigate, look around and even pick up objects in an intuitive manner. Its spatialized audio means that we understand where a sound is coming from and can turn, or look up or down, to find that source. The benefit of this immersion is that it mimics many of the ways we interact naturally with the world.

- Safe exploration of dangerous environments or situations

Many experiences are inherently dangerous in the physical world. And yet people may need training to interact with such spaces. A spatial virtual environment allows safe exploration of dangerous machines or distant places, while still providing many of the benefits of being in the actual place.

- Kinesthetic learning “hands-on” experiential

Because we are moving (and being tracked) in the virtual space, we use many of the same physical actions there that we use in the physical world. Even if the controllers and navigation devices are not mapped congruently, they still tend to activate the same motor areas in our brains and thus give us the feeling that we are acting with our body kinesthetically.

- Ability to transcend physical reality

The only limitation of what can be presented in an immersive lesson is one’s imagination. From micro to macroscopic, from ancient history to predications of the future, from this planet to the stars—all forms of experiences can be presented.

- Opportunities for shared or social experiences

VR is rapidly advancing to allow for shared experiences whereby participants can log into a common VR space from anywhere in the world. Learners can access the best teachers anywhere, as well as their peers in other countries. This presents many new opportunities for learning, and most especially for cultural understanding.

- New forms of creative expression

Recent VR offerings allow participants to actually create *within* an immersive environment, as illustrated in the VR art class example described earlier in this chapter. This is a new method of creation fundamentally different from traditional forms of artistic expression. As such, VR can be utilized in diverse forms of creative expression, including dance, music, theater, plastic and fine arts and narrative storytelling. It may open up a new age of innovation and imagination in these areas.

- Opportunities for tailored learning

VR learning environments are flexible and can be tailored to individuals both in the physical aspects as well as to address varied cognitive learning styles. Especially with the inclusion of rapidly evolving artificial intelligence (AI) technologies, unique and customized variations of a lesson can be presented that matches the learner's particular needs.

ADVANCED CONSIDERATIONS

Two modalities that are just starting to be implemented within immersive learning environments are the use of personal avatars and the briefly mentioned inclusion of AI techniques to customize the educational module. These are powerful aspects that deserve a much fuller consideration, as they may stimulate news concepts in how we use these technologies for all forms of instruction. Two questions that these techniques raise are discussed next.

Does the Use of an Avatar Enhance the Learning Potential of Virtual Experiences?

The idea that avatars could become the ultimate somatic learning objects came to Jaron Lanier during the-early mapping of his body onto a that of a lobster avatar mentioned in the beginning of this chapter. He noted is was not difficult to map a very differently formed creation into something our human body could control, which he states is based on the concept of homuncular flexibility, or the ability of parts of our motor cortex to be repurposed rather rapidly when needed. Channeling Papert's becoming gear idea, Lanier states:

My favorite experiment so far involved turning elementary-school kids into the things they were studying. Some were turned into molecules, dancing and squirming to dock with other molecules. In this case the molecule serves the role of the piano, and instead of harmony puzzles, you are learning chemistry.

Somatic cognition offers an overwhelming emotional appeal for education, because it leverages vanity. You become the thing you are studying. Your sensory motor loop is modified to incorporate the logic of a science, and you develop body intuition about that logic (Lanier, 2010).

By the mid-2000s virtual worlds that people entered via an avatar (a personal digital representation) were gaining popularity.[5] KZero, a research firm that tracked their usage from age groups starting as early as five years old through mature adults, showed that in 2014 there were almost 100 million registered user avatars (though not unique) from age 25 up, 250 million in the 15-25 age range, almost a billion in the 10-15 segment, and approximately 400 million in the youngest range from 5 to 10 years old (Mitham, 2014). These are astonishing numbers! The important idea here is that the young generations that six years ago were using avatars in online flat screen virtual worlds are well-primed to jump into fully immersive spaces with avatars. What has been overlooked are the benefits that understanding avatar use can have for VR education. Online avatars were often designed or customized by their users, often involving an emotional attachment to these surrogates. While today's VR worlds often provide avatars for participants, they have a long way to go before they are customizable in the way the online avatars were. However, having an avatar that means something to its owner may enhance the educational experience in constructive ways. More research is needed to fully understand the educational potential for avatar engagement.

How Can AI Fit into Making the Educational Experience Better?

The move from instructor-led education to the more self-directed approach that VR provides presents some additional challenges. How does the student navigate the experience to maximum effectiveness?

Best practices need to be developed and evaluated as to their effectiveness, both in steering the student through the experience as well as in assessing learning outcomes and material retention. This is where AI technologies can play a role. From AI assistants who can recognize when a student is stuck and offer just-in-time help, to fully developed systems that ascertain a student's optimal learning approach and deliver that in VR in real time, the potential enhancements are unbounded.

ISSUES, CONTROVERSIES, PROBLEMS

Because immersive technology is evolving at a rapid rate, it is not surprising that there are several challenges associated with using it for education and training. Of course, any new technology will raise concerns that need to be addressed. A short list of these include:

1. Initial cost
2. Upkeep and staying up on the rapid technology advancements
3. Space for trackers and other equipment
4. Security for equipment and users
5. Hygiene for shared systems
6. Simulator sickness (simsickness)
7. Training the educators
8. Age controversies

9. Uncomfortable or ill-fitting gear
10. Bullying in shared environments
11. Incomplete understanding of long-term effects
12. Lack of definitive studies

The initial cost as well as funds targeted at upkeep is a given, even with VR systems being the most affordable they have ever been. The ongoing advances in the gear alone demands a change out approximately every three years. An organization's IT department also has to keep up with the frequent software and computer updates (Steam, the VR portal for many applications, seems to require an update every time it is launched!), and often a dedicated employee is needed to know about keeping things both secure and updated. Space for the VR gear and security issues will also be considerations for the foreseeable future. There is overhead in the setup and tear down if there is not a dedicated space for the equipment. This is especially true in the classroom, which tends to be scheduled by different kinds of classes sharing the same space.

Classroom use currently seems to be an afterthought to the main VR companies. Educational institutions expect such support as site licenses for software so all students can access what they need. Currently this is not possible with VR content, so often each student must purchase their own copy of something like TiltBrush or Medium. And the constant software and firmware upgrades require administrator access, which is not often provided to students.

For shared systems, there are other issues that are small but might make the difference between people disliking the VR training and not—such as promoting hygiene (e.g. wearing masks or cleaning an HMD between users). There is also the issue of simsickness, which can cause some people to become nauseous when using VR. This is often caused by badly designed content, or by tracking and display issues such as low frame rates on older equipment, but some people are simply prone to it no matter how good the VR program.

Educators might ask: "Where does this VR module really fit in my curriculum?" and there may well be a mismatch between the available created experiences and what actually needs to be taught to students. There is also the need to train the trainers, who may be initially unfamiliar with VR systems.

A current controversy revolves around the best age to allow young people into immersive media. Most of the VR hardware manufactures state their product is for ages 12 or 13 and up. Many say that young children should not use their products at all (probably to limit liability and out of an abundance of caution). Supposed negative ramifications include physical concerns like kids developing near sightedness over time (Hill, 2016), as well as psychological ones due to children not being able to discern whether something is actually virtual or real. Segovia and Bailenson (2009) suggest that children may be unable to remember whether an experience initiated from a real world or virtual world space, due to the richness of the immersive media. This could result in the introduction of what are sometimes called "false memories."

As well, there are problems related to the form factors of the equipment itself, which is not adaptable to the range of potential users. Very young or small people have difficulty using the current HMDs, as do those with certain types of hair or head-worn religious garb. Even displays that allow for adjustable interpupilary distance may not cover the full extent of what some people need. Users with glasses are also left out, though some manufacturers are starting to address this with better spacing or additional lenses.

In social VR platforms there is the threat of bullying or other unwanted interactions. These challenges have garnered the attention of the software companies and there are several solutions that help a bit in this area, but certainly more can be done beyond safety bubbles, making one's avatar invisible, and better reporting methods.

Unfortunately, many of the educational examples provided in this chapter are prototypes, and few have been deployed to any scale within modern educational systems. And very little has been done to study them widely. It's somewhat a chicken and egg problem. Do we study the effectiveness in a small population and then deploy more broadly, or deploy broadly, then gather data on the effectiveness? Immersive education won't replace existing teaching methodologies any time soon, but may be used as supplemental modules within existing curricula. We really don't yet know the best ways to incorporate technology-based immersive modules in a classroom. For the foreseeable future, we will be most likely be gathering anecdotal and small study data to determine these best practices. This leads into a call for more research to underscore the beneficial uses of VR as an experiential educational tool.

FUTURE RESEARCH DIRECTIONS: A CALL FOR MORE RESEARCH

In a recent Venture Beat article by Amir Bozorgzadeh (2019), he states: "AR and VR have delivered on the promise to supercharge the enterprise's education and training industry." However, that article differentiates the successes that are primarily happening in enterprise training, as contrasted to public education, which the author characterizes as "a bureaucratic jungle of red tape."

While we may be beginning to understand what works for industry training, we are still far from knowing what the best instructional design approaches for immersive learning are. School-aged children span a wide range of ages and learning styles. A recent report from The Joan Ganz Cooney Center at Sesame Workshop outlines a possible research agenda to address the needs of young children using immersive media (Sobel, 2019). Such testing is needed to see how different learners adjust to and get the most out of a VR immersive experience. Currently we are at the early testbed phases of using VR for education. Meredith Bricken again, wisely states:

By making VR tools and environments available to educators, we may discover more about the very process of learning. By participating in the development of VR, educators can guide the growth of the technology, and perhaps influence the course of educational change. As we test and refine this unique learning environment together, we might even hope that VR really will help us to teach more effectively, and that we will see more often that bright light of understanding in our students' eyes. (Bricken, 1991)

This is how we should look at VR for learning—as a radical change and improvement for how we deliver and consume information in a learning context. Its promise is to change education for the better—back to how we originally learned in the beginnings of time—by direct exploration of our world (which now can be virtual or real), and by knowledge being shared with others who are in that environment with us. In addition, the use of AI and avatars within immersive education is barely starting and there is an abundance of understanding we need to research to effectively incorporate these technologies into immersive learning. For every dollar spent on developing new experiences, investment in the research to see what we can learn must be considered as equally important.

CONCLUSION

J.R. Pierce, the chairman of the President's Science Advisory Committee (PSAC) wrote a report in 1963 that included this quote: "After two decades of unprecedented development, the computer is approaching its infancy" (in Sproull, 2006). We are now approaching the "infancy" of VR within educational contexts, and this inception is both remarkable and exciting as we contemplate the impacts it may have going forward!

There are many benefits we already know immersive education provides, and more we will learn over time. We already know this approach:

VR will add a layer of detail and realism to a student's experience of the curriculum, but it should not be seen as an end in and of itself. It seems to work best as a complementary tool to previously taught information, or as a fun and engaging introduction to a topic. (Black p. 57)

What we continue to discover while VR and its kin carry on their meteoric rise may change the very fabric of learning. VR is showing promise at changing the way we actually think (Bailenson et al., 2008). And in many ways, this is a paradigm shift. I often note, "We have underestimated the plasticity of the brain, and VR is a way to unlock it." With such unlocking comes marvelous new opportunities for learning.

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ENDNOTES

1 In other words, up until the third wave of VR started to gather steam. For more information see Wankel and Heinrich's edited volume: *Transforming Virtual World Learning* (2011).

2 https://patents.google.com/patent/US1825462 "Combination training device for student aviators and entertainment apparatus." *Google Patents*. Retrieved 24 September 2017.

3 https://www.spitzinc.com/planetarium/educate/

4 A Euclidean vector is a mathematical construct comprising a geometric object that has magnitude and direction. Vector algebra allows for vectors to be added or subtracted to other vectors within the rules of Vector Algebra. Because it is Euclidean, the direction of a vector can point anywhere in 3 dimensional space.

5 Virtual worlds can be considered a predecessor to today's fully immersive VR environments. The KZERO numbers come from the more easily accessed online virtual worlds, used typically with a mouse and a flat screen, including multiplayer games such as Everquest, as well as offerings like Linden Lab's Second Life (for adults) and Disney's Club Penguin for young children.