Chapter 6
Developing an Immersive Virtual Classroom:
TeachLivE – A Case Study

Kathleen M. Ingraham
University of Central Florida, USA

Annette Romualdo
University of Central Florida, USA

Angelica Fulchini Scruggs
University of Central Florida, USA

Eric Imperiale
University of Central Florida, USA

Lisa Dieker
https://orcid.org/0000-0002-0789-580X
University of Central Florida, USA

Charles E. Hughes
https://orcid.org/0000-0002-2528-3380
University of Central Florida, USA

ABSTRACT

As virtual reality (VR) technologies continue to improve and become more accessible, educators are increasingly incorporating VR learning experiences in teacher education contexts. This chapter is a case study of TeachLivE™, a virtual classroom platform designed for practicing teaching in a safe virtual space. This chapter describes the system, development, and challenges faced when incorporating immersive VR technologies. Recommendations are provided for future research, development, use, and facilitation of immersive VR learning experiences.

DOI: 10.4018/978-1-7998-4960-5.ch006

INTRODUCTION

As virtual reality (VR) technologies continue to advance, opportunities emerge for simulation training to take advantage of new affordances to improve the effectiveness and efficiency of virtual learning experiences. This chapter will examine the development cycle and challenges of incorporating newer immersive VR technologies into existing VR platforms using the TeachLivE™ simulation platform as a case example. The objective of this chapter is to describe how new immersive VR technologies have been introduced to the platform and how these technologies have affected development, system use, and teacher learning. The authors also describe some of the challenges encountered in using an immersive VR system as well as recommendations for future research, use, and development.

BACKGROUND

The immersive VR classroom can provide a dynamic medium to promote meaningful learning. Since the early 1990s, VR has been promoted as a vehicle to facilitate learning across subject domains (Helsel, 1992; Psotka, 1995). The blank canvas nature of the virtual classroom enables developers and users to adapt the classroom, with "active participation, high interactivity and individualization" (Mikropoulous & Natsis, 2011, p. 770) as integral components of the dynamic space.

One such use of the virtual environment has been to prepare preservice teachers for the 21st century, accountability-driven classroom. As background, teacher preparation programs (TPP) ready novice educators for placement; well-prepared beginning educators enter the classroom with a strong background in evidence-based instructional practices and classroom management techniques (Brownell et al., 2010; Every Student Succeeds Act, 2015; Scheeler et al., 2016).

However, high rates of teacher turnover and burnout indicate novice teachers often are under-prepared for the challenge (Carver-Thomas & Darling-Hammond, 2019). First-year teachers may struggle to implement best-practice in both instructional methods and behavior management (Ingersoll, 2001; Cochran-Smith, et al., 2012; Hong, 2010; Lankford et al., 2002). To mitigate this gap, researchers at the University of Central Florida (UCF) implemented an innovative means to prepare beginning teachers (Dieker et al., 2008). Within a VR simulator (TeachLivE™), participants are immersed into a classroom of virtual students. The abstract spaces of the physical room fade (Mikropoulous & Natsis, 2011), and beginning educators use the classroom and its avatar residents to rehearse and hone research-based strategies of teaching practice (Dieker et al., 2007; Dieker et al., 2008; Dieker et al., 2014; Dieker et al., 2017).

This section discusses the evolution of VR, components and characteristics of current VR systems, and VR use in education. VR is described as an interactive virtual environment simulating real-life experiences accomplished in one of two ways: non-immersive and immersive. Non-immersive VR is displayed through traditional media or technologies, such as computer, keyboard, mouse, and/or screen. Users in the non-immersive environment are not required to wear any special equipment (Freina & Ott, 2015; Suh & Prophet, 2018).

Whereas, an immersive VR experience requires the user to wear specialized equipment to experience the simulation. As researchers began to promote VR for the education space, Psotka (1995) promoted the fully-immersive experience for its unique characteristics, including participants' feelings of control and immediacy with its use. Once immersed, the virtual world becomes real-life as participants experience "the feeling of 'being there' or presence" (p. 405). A fading of the external environment promotes feelings of control over one's surroundings (Mikropoulous & Natsis, 2011). User's perception of presence is central to immersion through head and eye movements within a head-mounted display within the VR environment (Hayes et al., 2013; Jung et al., 2018; Winn, 1993).

The Evolution of Virtual Reality

Attempts to immerse audiences have taken on many forms throughout history, each rising in complexity along with emerging technology. In the nineteenth century, panoramic paintings attempted to immerse the viewer by dominating their field of vision with the massive width of their canvasses. Later, stereoscopes like the ViewMaster represented early prototypes for head-mounted displays intended to command the audience's sense of sight (Whiteman, 2009). In the 1950s, a cinematographer named Morton Heilig developed what he called the Sensorama. It was a stationary booth for one person that featured stereo speakers, a stereographic 3D display, fans, odor generators, and a vibrating chair (Heilig, 1962). Though the Sensorama was still unable to adapt to the viewer's movement, Heilig made a revolutionary attempt to create a completely immersive sensory experience granting him the unofficial title of the "Father of Virtual Reality". By the 1960s, head-mounted displays became more capable of representing a viewer's natural vision by correlating the visual input to their head movements via a motion tracking system (Sutherland, 1968). At this time in history, the equipment and the computations necessary to simulate a three-dimensional, virtual world were cumbersome, uncomfortable, and slow: all hindrances to immersion.

While Mr. Heilig's invention may have later dubbed him "Father of Virtual Reality," not until the late 1980s did the term "Virtual Reality" enter the popular lexicon to describe this research field. Jaron Lanier, the founder of the Visual Programming Lab (VPL), popularized the term "Virtual Reality" as his company went on to develop innovations in VR gear. His company was the first to sell VR goggles, which they called the "EyePhone Head Mounted Display" (Pantelidis, 1993). Not only were these goggles lighter than previous iterations of head tracking visual displays, but they also included headphone speakers that could emit 3D directed audio. Lanier's company also developed the "Dataglove," a wearable glove that introduced *haptics* to the VR experience by simulating the user's sense of touch (Pantelidis, 1993). With these devices, three out of five reality-defining senses could be engaged within a wholly artificial environment. By the 1990s, VR devices were appearing in public arcades, represented in mainstream movies, and as consumer-level devices such as Nintendo's Virtual Boy (Zachara & Zagal, 2009). After a lull in development and public interest, VR reemerged in the 21st century, bolstered by advancements in high-density displays, smaller and more powerful 3D computing devices, a drastic reduction in cost, and an enthusiastic and innovative video game industry. Today, products like the Oculus Rift S, PSVR, and the HTC Vive are common, more affordable, and provide a viable platform for expanding immersion in all forms of entertainment, communication, and education. With these newer platforms in mind, the authors provide a description of some of the major components and characteristics of these systems.

Components and Characteristics of Current VR Systems

Headsets

Most interactions with an immersive VR environment involve the use of a VR headset. Virtual reality equipment manufacturers are constantly innovating in order to compete in a quickly evolving marketplace, balancing technological advancements with affordability. As a result, the headsets currently available vary greatly in performance, price, and quality of the user experience. There are three common forms: Mobile, Tethered, or Standalone.

Mobile

With mobile setups, a peripheral device, such as a smartphone or mobile game system, makes the VR calculations. They usually include only one motion controller and are restricted to three degrees of freedom (DOF) for both the headset and motion controller. They have insufficient active sensors to track 3D positioning in space and have a lower threshold for VR computations, but they are also cheap, lightweight, and unencumbered with heavy cables. One such example of a mobile setup is the Samsung Gear VR (Powered by Oculus, requires a smartphone for operation, preferably Samsung devices) (Samsung, 2019). Google Daydream View is similar but more versatile regarding smartphone compatibility (Daydream, 2019). Other examples embody a do-it-yourself perspective and are folded out of cardboard, thus making them the cheapest possible option (Olson et al., 2011). Google Cardboard and Nintendo Labo VR Kit fit this description, the former requiring a smartphone for use (Google Cardboard, 2019) with the latter requiring a Nintendo Switch (Nintendo Labo, 2019).

Tethered

These headsets are physically connected via cables to a dedicated PC or (in the case of PSVR) a PlayStation. The cables can make them awkward to operate but having the processing power offloaded to a separate device not strapped to the head makes for a VR experience that can be complex and responsive. The dedicated displays are superior to smartphone enabled displays in image fidelity and external sensors or outward-facing cameras allow for 6DOF motion tracking. Some common examples include the Oculus Rift S, which was purchased by Facebook in 2014, making it a well-funded producer of consumer-level VR (Oculus, 2019). Another example that is popular with gamers, is the PlayStation VR; the proliferation of PlayStation game systems already in use and affordable pricing make the barrier for entry extremely low (Playstation VR, 2019).

Standalone

Standalone systems require no peripheral devices such as a smartphone, game system, or even a computer, making them truly standalone. Most are considered entry level VR for newcomers and are limited to 3DOF, such as the Oculus Go (Oculus Go, 2019). New advancements have brought forth a new breed of standalone setups, like the Oculus Quest and the HTC Vive Focus Plus. These new devices outperform their standalone peers by being capable of 6DOF without the need for external sensors or connection cables (Oculus Quest, 2019; VIVE Focus Plus, 2019).

VR Treadmills and Gloves

360-degree Treadmills

Incorporating VR treadmills and gloves to the VR system allows for motion in a confined space. With tethered or even wireless headsets, physical limits to the virtual space can be imposed within the limits of the sensor space or the length of the connecting cord. Using a 360-degree treadmill, a participant can essentially run in place while registering as free movement within the virtual space. Various models include foot-tracking sneakers to determine movement direction and speed and/or waist height sensors to determine crouch or jump height. One example is the Virtuix Omni Treadmill (Virtuix Omni, 2019).

VR Gloves

The market has seen an upsurge in several types of VR gloves designed for specific uses. Some gloves simply track finger movement for the purposes of handling 3D manipulatables or driving robotic machinery. Other gloves track finger movement for recording finger animation in conjunction with motion capture or performance capture software. Haptic VR gloves apply vibrations, motions, or other forces to simulate the sensation of touch. Some examples include the Manus VR family of Manus Prime VR, Performance/Motion Capture, or Haptic gloves (HaptX, 2019; Manus VR, 2019).

As we consider these components of VR systems, defining these experiences in higher education provides a context for use in this space. Far from being a homogeneous technology, VR experiences can be structured in many ways.

Structures of VR Systems

Window on World

This system maintains a distance between the user and the virtual world by existing through a window of access such as a television, desktop monitor, laptop computer, tablet, or other mobile devices. This type of system is commonly used as an interactive portal for simulation training scenarios.

Telepresence

With less of an emphasis on virtual constructs, this system's focus is on presence at a distance. Using VR equipment or more conventional audio/visual interfaces, the user remotely operates sensors and/or equipment such as drones, bomb disposal robots, or deep-water exploration vehicles.

Immersive System

This system is the one most often associated with VR. In this system, the user wears a VR headset that translates the virtual 3D perspective according to the user's head movement and usually includes one or two hand-held motion controllers for interacting with the environment. With this system, a user's sense of sight and sound are completely informed by the VR headset, resulting in a greater detachment from the outside world and resulting in an enhanced sense of immersion.

Mixed Reality (MR) and Augmented Reality (AR)

With MR/AR, the virtual is intertwined with the user's existing reality. Computer generated inputs are brought into the user's view of the real world via peripheral glasses, or through the viewport of a hand-held camera such as a smartphone. Devices like the Magic Leap One incorporate sensors that detect real world objects to intersect with the virtual objects in space and occludes the virtual objects accordingly (Magic Leap 1, 2019). Another type of application resembles a heads-up display such as a fighter pilot's helmet visor, where the computer-generated content is displayed over the user's field of vision.

With these technologies becoming increasingly available and accessible, the question becomes how are educators using these technologies?

VR Use in Education

Helsel, in 1992, began discussing VR with educators, in an effort to include the school community in planning for VR's future use in education settings. She felt educators were "responding powerfully to the notion of virtual reality curriculum" (p. 38), and claimed educators expressed an "almost visceral" understanding of the potential for VR in the classroom. Helsel argued VR would facilitate a revolutionary change in instructional practice and student learning; textbooks would be relic, and text-based learning would transition to symbol and imagery-based curriculum. Moreover, she predicted the visual-processing center of the brain would surpass text decoding as the means to information processing.

Helsel concluded her manuscript by urging educators not to leave VR to the computer science field, and to instead involve themselves in the VR development process. Yet, two decades later, VR remains a largely unused means to increase student engagement and learning, within the K-12 education system. To Helsel's point regarding computer science, Freina and Ott (2015) found over 60% of immersive VR education literature, within a two-year time frame (2013-2014), centered around the university-level computer science domain. Further, Freina and Ott found educational VR largely unused for commonplace learning, and instead primarily utilized for scenarios not easily accessed - such as dangerous situations, historical events, physically inaccessible environments, and ethically problematic events (i.e. surgery, fire-fighting, and time travel).

Recently, Kaminska and colleagues (2019) provide an overview of applications of VR in education. Within this overview, they propose three types of VR use in educational environments: (1) VR to present knowledge within a subject domain - often presented on a static display, (2) VR presented through Kinect (Zhang et al., 2018) or MYO Gesture-type platform (Pilatásig et al., 2018); used to impart skill-based knowledge, such as work-safety training, and (3) immersive VR environment, with wearable devices, as a means to overcome challenging tasks, such as medically-based scenarios. According to their survey of literature, the majority of educational VR software centers around health-related or STEM fields; educational domains included are engineering, medical, space technology, mathematics, and general education (the authors used virtual field trips as an example of general education). Within the review, the authors promote VR as a powerful tool to support learning, including in support of diverse learning needs. Much like Helsel (1992), Kaminska and colleagues (2019) conclude by encouraging educators to "embrace" and "prepare for" the immersive VR revolution, particularly when educating digital natives: Generation Z.

Also, of note when considering the current state of VR in education, Suh and Prophet (2018) conducted a systematic review of immersive VR technology research. Like Kaminska and colleagues (2019), Suh and Prophet (2018) report immersive VR is primarily used across science, engineering, and medical domains - with most studies conducted within higher education levels. Their summary of the research concludes: immersive VR enhances motivation and conceptual blending in the education setting.

TEACHLIVE™

A recent and expanding use of VR in the educational domain of teacher education occurred with the creation of a simulation system at UCF. This section provides background on the TeachLivE™ virtual simulation system along with past and current uses of TeachLivE™ in a non-immersive VR environment. The authors provide an overview of future expansion of TeachLivE™, including insight into an immersive version of the simulation, built in the HTC Vive HMD.

As overview, educators in TeachLivE™ practice teaching a diverse group of digital student avatars in a virtual classroom environment. This environment can be accessed through an immersive head-mounted display (HMD), on a large screen or projector, or on any personal computing device equipped with a microphone and camera.

Stepping into the TeachLivE™ virtual classroom, a facilitator assists teachers in putting on and adjusting the HMD or in setting up materials in front of a projector or large screen. In cases where teachers are connecting remotely on a personal computing device or smartphone, facilitators assist teachers in connecting to a device view of the virtual classroom. Teachers can look around the classroom and speak to a group of five to six students either within the HMD or on the screen. The students are controlled remotely by an interactor who provides vocal responses and controls the physical movement of the students. Having a human actively controlling the virtual students allows the students to respond to any lesson or choice the teacher makes during the rehearsal session. Using a webcam, the interactor can hear and see the teacher and react to verbal and non-verbal teaching choices.

To further improve practice, an expert coach can pause the simulation at any point to give feedback to the teacher. The teacher can choose to either replay a moment without the virtual students remembering their previous actions, or they can continue with their lesson. In this way teachers can practice skills that range from identifying and addressing content misconceptions, to practicing classroom management strategies, to differentiating instruction for individual student needs. Coaches also can pre-plan specific content or behavioral challenges for teachers to practice.

Historically, the majority of TeachLivE™ simulations have been provided through a virtual environment in which teachers interact with the virtual classroom on a screen - such as a projector, a laptop computer, desktop computer, smartphone, or large screen display. This VR experience facilitates meeting the "needs of teachers in high-end university laboratories, at regional centers, at their schools and in their homes" (Dieker et al., 2007, p.7). Within this platform, participants and researchers are not required to have special equipment, beyond what is typical within these settings (computer and internet access). Within the simulation, users, coaches, and researchers can collect simple multi-modal data, as well as record and catalog performance. For teachers and other professionals who seek to change behavior within the simulation, the user-friendly, transportable experience facilitates ease of documentation, after action review, and (ultimately) improves development within the profession.

With purposeful design, developers created an experience that affords an open canvas of scenarios. The platform of TeachLivE™ has been host to a myriad of scenarios, ranging across age, experience, and background; including coaching and feedback, professional development, instructional development, and practicing real-life scenarios. Specific examples of usage include:

- Provide in-action coaching and self-reflection for pre-service special education teacher practices
- Address bullying behaviors
- Simulate lock-down scenarios (active assailant drills)

- Increase parent advocacy of parents of children with disabilities; particularly in IEP process
- Increase student exposure to virtual environments, and thereby spark interest in STEM fields
- Practice teaching inquiry-based science
- Increase praise and response rate
- Utilize assessment data to drive instruction
- Illustrate evidence-based English Learner (EL) instruction
- Increase novice teacher problem-solving skills
- Manage classroom dynamics and behaviors
- Practice parent-teacher conference scenarios
- Navigate first day of school management tasks
- Demonstrate evidence-based literacy practices

A benefit of the non-immersive environment is the transportable ease-of-use, and the ability to rehearse real-life scenarios. Ease of use is critical in reaching in-service teachers who may have limited time and willingness to engage with activities difficult to access or use. Thus, a simulation experience designed to help address some root causes of teacher attrition should avoid adding to teacher stress. Within the education field, teacher attrition (teachers leaving the profession) is an urgent crisis, which requires immediate response (Barnes et al., 2007; Ryan et al., 2017). Development of the TeachLivE™ simulation platform was in direct response to waning teacher preparation enrollment and rising teacher attrition. TeachLivE™ was launched to provide an environment in which preservice teachers could safely and effectively develop evidence-based practices of the profession, before stepping into the K-12 classroom. The original and continued vision of TeachLivE™ researchers is to facilitate virtual rehearsal, involving high stakes situations, without risking the loss of valuable resources, such as money, time, and people (Dieker et al., 2013). The team continues to develop the simulated experience with an array of scenarios where mistakes are welcome and discrete skills are coached in real-time.

An additional benefit of the TeachLivE™ VR environment is its capacity to provide access to scenarios uncommon or difficult to practice in a real classroom. Within simulation, traditional obstacles to quality teacher preparation may be overcome. One such obstacle is limited preservice educator classroom experience within diverse classroom environments. The brick-and-mortar nature of TPP may limit experiences to school systems immediately surrounding the providing university. For the novice educator, juggling the myriad of classroom needs while trying to facilitate student learning can be overwhelming. The TeachLivE™ environment can be delivered remotely to rural or distant areas so preservice teachers can practice situations that uncommon in their geographic location. Within TeachLivE™, teacher educators can uncouple pieces of classroom challenges into achievable exercises. Novice teachers can individually rehearse each challenge, before attempting to meet the needs of an entire classroom. This adaptive nature of simulation enables university teacher preparation programs to expand preservice teachers' experiences, allowing for scenario rehearsal, and ultimate educator excellence in practice - even before placement into the brick-and-mortar classroom.

Another obstacle to quality teacher preparation is finding effective in-service educators who can model and mentor evidence-based teaching (Hobson et al., 2009; Jones, 2009). Adding an inexperienced student-teacher to an already busy classroom is a big ask. Complicating the mentoring process in a live classroom, supervisory teachers cannot pause student learning to coach each poor interaction or inadequate presentation of content. As a result, novice teachers may move into the profession while struggling to manage their classrooms, leading to burnout and career abandonment. By coupling the simulation with live coaching, preservice teachers are mentored through the basics of classroom management and pedagogical practice. This coaching feature allows teacher educators to mentor preservice teachers in instructional practice. Simulations can be guided, rehearsed, paused, and reflected upon - all within a supervised, safe learning environment. The novice educator is afforded the opportunity for apprenticeship, even before stepping foot into an internship (real-life classroom). For example, the teacher educator or coach can prepare a simulation involving a student with a disability who may need additional instructional interventions. Through the simulation, a novice teacher can navigate implementing evidence-based practices of intervention to meet the diverse needs of the avatar student. Concurrent with the simulation, the instructional coach can facilitate participant learning through ongoing and reflective feedback on practice.

This coaching process is validated within simulation, as demonstrated through After Action Review (AAR); the preservice teachers can experience valuable returns on improving teaching practice [Hanoun & Nahavandi, 2018, provide a review of the After-Action Review process]. As mentioned, within the simulated environment, teacher educators have used TeachLivE™ to prepare preservice teachers to improve instructional and pedagogical practice. The VR setting has been shown to improve practice; the efficiency of behavior modification within the simulator is supported: Empirical evidence indicates five minutes in a simulator can provide the emotional equivalent of a 30-minute in-person interaction, in terms of emotional taxation on a participant (Alexander et al., 2005; Dieker et al., 2008). Also, four 10-minute simulator sessions on a specific effective teaching practice can change at least one critical teaching behavior (Dieker et al., 2014). In sum, the use of TeachLivE simulation allows experiential learning to take place via realistic, specific scenarios that give learners an opportunity to practice alternative skills and learn from mistakes in a safe environment (Chini et al., 2014).

TEACHLIVE™: IMMERSIVE VR

As improving professional identity and craft becomes increasingly relevant for educators throughout their careers, the adaptive data-gathering components (such as capacity to record eye tracking, facial expressions, and body positioning) within simulation prove critical to improving evidence-based practices in the classroom. Researchers now have the capacity to gather both automated and manual data of participant performance within the simulator; these data may be analyzed to pinpoint pedagogical and instructional areas of need. This capacity may be greater realized within the immersive simulated environment, as full immersion can provide preservice teachers an even greater feeling of presence in the scenario.

The immersive virtual environment provides an experience in which the user can find "specific sense of self-location within it, can move her or his head and eyes to explore it, feels that the space surrounds her or him, and can interact with the objects in it" (Psotka,1995, p. 406). Kaminska et al. (2019) promote a definition of VR found in technology literature:

"interaction + immersion + imagination" (p. 2). Although not widely used in education environments, research has demonstrated the immersive VR experience "can enhance education in at least three ways: by enabling multiple perspectives, situated learning, and transfer" (Dede, 2009, p. 66). Suh and Prophet (2018) agree: Within the field of education, "researchers found that the use of immersive technologies enhanced learning processes, student engagement, and outcomes" (p. 85).

The TeachLivE™ fully immersive experience is designed to implement three critical components of a strong simulated environment: (a) personalized learning, (b) suspension of disbelief, and (c) cyclical procedures (Dieker et al., 2013). Within seconds of entering the simulator, participants experience a "suspension of disbelief," defined as "forgetting…the environment is not natural, but constructed and contrived, to enhance engagement, presence, and belief of the experience" (Dede, 2009; Hayes et al., 2013, p. 144). In this simulated virtual environment, educators can focus on achieving specific, desired outcomes to improve confidence and ultimate success in the field.

To achieve the high level of engagement needed to fully immerse the user (Dede, 2009), the TeachLivE™ simulation blends virtual components with live performance (i.e. Human in the Loop) throughout the simulation. For the TeachLivE™ participant, this blending is fundamental to the dynamic and responsive nature of the experience. In addition to providing human characteristics to the avatars, the combination of the Human in the Loop (HIL), semi-automated, and automated behaviors create a real-life experience which facilitates meaningful dialogue. As the interactor and coach respond to the learning needs of each participant, behavior is modified, and efficient achievement of learning goals is realized; the coaching capacity will be discussed in depth, in later sections.

In the kindergarten classroom, preservice teachers can don the head-mounted display, and step into circle time with five child avatars. Navigating the realistic, evolving nature of an active group of five-year old students can be realized without stepping outside of the university campus. Novice educators can facilitate a simulated story-time or numeracy lesson, often with an instructional mentor or coach facilitating the interaction. Features unique to the fully immersive environment include: automated eye gaze, gestures, and body positioning data (all of which have potential to impact classroom management). Stereo sound within the fully immersive environment also enhances the user experience. "Unlike research in actual classrooms, where controlled data collection is difficult to ascertain, this virtual environment enables consistency in preparation, immediate feedback, and ongoing data collection, as well as refinement of the environment to ensure the maximum impact on teacher performance and student learning" (Dieker et al., 2008, p. 5). These data can be analyzed and reflected upon, by both coach and participant.

Educators use the kindergarten, immersive virtual environment in develop their pedagogical practice in a safe environment. Educators have the opportunity to practice their teaching while research is conducted using student reflections, surveys, interviews, or other forms of data collection. A specific example of use within the immersive classroom is behavior management strategy rehearsal within kindergarten circle-time. Educators may prioritize an explicit teaching practice, such as using *four positive praises to every one criticism*. The educator uses the 4:1 positive praise technique to decrease off-task behavior displayed by the student while providing encouragement and building trust. This behavior management technique can be as simple as a verbal compliment to the student which educators can practice in the virtual environment before working with real students in a classroom. The facilitator or coach can manually tally participant success of the technique. Within the immersive experience, automatic data on eye gaze and physical proximity can be gathered, analyzed, and reflected upon - as means to measure mastery of evidence-based teaching practice.

Researchers can also use the virtual environment to examine pre-service teachers' feelings of self-efficacy, in both instructional practice and behavior management. When four pre-service teachers were asked about their experiences in the immersive kindergarten classroom, three of them shared the following:

- "As a classroom teacher for five years, I stepped into the classroom expecting awkwardness and a distinct awareness of this being a virtual reality. At first, I was taken back by the environment, but within minutes of interacting, everything faded, and it felt like being back in the classroom again. Students were engaging and I was able to teach like I would in my classroom" (User 1).

- "I think that the VR headset really encourages you to be present and that is what is necessary in this classroom setting. You are applying the skills that were learned about being in the classroom and then you are actually sitting with the students and engaging and seeing how you can put skills into practice" (User 3).
- "Circle time is also critical in kindergarten; this is how most kindergarten teachers start their day with students. For preservice teachers (or anyone needed to practice this skill), the Vive would give them a great sense of how this moment will occur in the classroom including, sitting on the floor crisscross, in a circle with students. The Vive allowed me to feel as though I was included in circle time with a group of Kindergarten students in the classroom" (User 4).

Development

A live virtual simulation like TeachLivE™ requires many stages of development including development of the virtual setting and development of the student avatars. In both stages, the unique affordances and challenges of moving toward an immersive VR structure had to be considered.

Virtual Environment

Prior to the construction of the TeachLivE™ kindergarten classroom environment, the production team received input from educators in written and photographic form. Some of the input came from teachers who were already familiar with TeachLivE™'s other incarnations and methods of operation, while others were not. Requests began with open possibilities before being whittled down to what would make a reasonable mix of function, realism, and affordability. The production team studied several variations of kindergarten classes and began finding common elements among them to merge. A series of concept drawings were submitted for review until a few approved finalists informed the resulting design. With a general form in mind of the shape and function the classroom would take; the production team artist began designing an idealized version of a kindergarten classroom. Many of the reference images submitted by teachers portrayed windowless, crowded, disheveled rooms, which may have represented a more realistic depiction of today's kindergarten classrooms. However, these were prohibitively expensive to construct in 3D as well as being resource-heavy for some of the older computers the software is intended to run on. With the critical elements in mind, such as floor circle time or semi-circle table time, the artist sought to create a roomy, well-lit, modern-looking environment while incorporating the common elements noted during the study of photo submissions.

Since many of the educator's computers using the TeachLivE™ software may be older generation machines with comparatively limited processing power and memory, an effort was made to construct the classroom using as few resources as possible. This meant low polygon construction, frugal texture dimensions, and minimal dynamic lighting. To conserve resources, items not expected to be in the line of sight of a camera are usually either not constructed, or not made with detail. However, as seen in figure 1, in a free roaming 3D virtual environment, anywhere could potentially be scrutinized by the camera, so every detail is considered. The immersed VR user gets a real sense of the real-world scale and presence of the kindergarten avatars when exploring the environment, leading many to get down on the floor to interact with them, which is not usually seen in cases where the user is connecting via a "window on world" setup. The TeachLivE™ production team artist, after seeing the environment virtually, remarked how much more real the classroom looked to him compared to through his desktop workstation; suggesting that even to digital creators who see the same classroom for weeks during its creation, immersive VR can result in fundamentally more engaging experiences.

Figure 1. Kindergarten classroom virtual environments
Source: E. Imperiale, (2019)

Avatars

To begin development of our kindergarten avatars, researchers started by listening to the elementary teachers who worked with our existing classroom of middle school avatars. They noted how teachers described the middle school avatars as different from the kids that they were teaching. Next, researchers conducted interviews with teachers asking them to describe their teaching experiences, their students, elements of teaching that they found the most challenging, and areas that they wish they had had more practice with before stepping into a classroom. From these conversations, and field observations of real kindergarten classrooms researchers realized that the kindergarten avatars would need to be significantly more dynamic and wigglier than the existing virtual students.

Thus, a team of five master elementary teachers worked with interactors to build behavior palettes and academic profiles for our virtual kindergarten classroom. This team videotaped behavioral references that were then shared with an animator who used a combination of motion capture and hand animation to translate these references into controllable animation sequences that can be used in live rehearsal.

One challenge that emerged in developing the characteristics of these kindergartners was how to include the range of possible behaviors for students with Autism. In order to create an authentic virtual student profile, researchers invited an adult individual with Autism and his family to partner with the team in creating a virtual avatar that would authentically represent his kindergarten self. Real home videos and academic documents were used to create the academic profiles and behavior palettes. Additionally, researchers went through an iterative feedback process where his mother directed performance choices until she felt that they authentically represented her son's behavior in a kindergarten classroom. Thus, while most of the virtual avatars are amalgamated behavior and academic profiles from many sources, Martin, a virtual avatar with Autism, is directly modeled after one individual with Autism.

Additionally, revisions and improvements in the performance profiles and behavior palettes are ongoing. The current available avatars are pictured in figure 2. Researchers actively collect feedback from teachers and expert coaches who use the system in order to improve the authenticity of the virtual students.

Figure 2. Kindergarten avatars
Source: E. Imperiale, (2019)

CHALLENGES

As with any new technology, comes challenges that need to be addressed. These challenges include using the technology, designing and implementing effective scenarios in the virtual space, and challenges encountered by facilitators. In order to describe some of the challenges of using an immersive virtual environment, challenges experienced in the current TeachLivE™ kindergarten classroom are being used as a test case.

Use of Technology

First, most kindergarten classroom teachers want to incorporate objects into the lesson such as manipulatives for math, demonstration materials for science, or books for read-aloud activities. In an HMD that is fully immersive and not mixed with a camera feed of the real physical environment, teachers cannot see real-world objects that they hold in their hands. This makes activities such as writing on a smart board, reading a book out loud, or demonstrating a concept with objects very difficult. In order to use any of these objects in the virtual environment, they would need to be modeled and added in a way in which teachers could use the objects with handheld controllers or haptic gloves. It is an open research question whether the adjustments needed to use objects in the virtual environment may help or hinder teaching practice. Thus, while further development to model and control common classroom objects, like math manipulative, is ongoing, further research is needed to determine if practice with virtual objects influences real world classroom practice. Exploring a more mixed-reality approach integrating elements of a virtual environment with a live camera feed of real-world objects teachers can see and manipulate more naturally may prove to be a better approach. The limitations for object manipulation also may explain why many teachers choose to practice with the virtual kindergarten classroom on a projected screen rather than in an immersive virtual environment even when the more immersive virtual environment is available.

In addition to physical interaction with objects, teaching in an immersive virtual environment seems to affect physical movement during the session. Some teachers seem hesitant when first entering the simulation, perhaps fearing collision with a real-world object they cannot see. Some participants also noted the immersive virtual environment encourages them to get down on the floor to interact with the virtual avatars as they would kids in a real classroom: "The best part of interacting with the kindergarten classroom is the fact that it feels so real. I start talking to the avatars as if they are real students in my classroom and immediately sit on the ground to join them during circle time" (User 2, Nov. 20). Additional research is needed to explore how physical movement during teaching differs between an immersive virtual environment, a projected virtual environment, and a real classroom.

So far, we have primarily described challenges for teachers using the system, however, there are additional challenges for the interactors operating the avatar in an immersive virtual environment. In a projected simulation environment, the interactor can see a teacher's face and body through a webcam video feed so that the interactor can respond to a teacher's facial expressions, body postures, and other non-verbal communication. But when the teacher is wearing an HMD their facial expression is obscured. Additionally, it can be difficult to determine where teachers are looking. Although HMDs are advancing and some offer eye tracking features, these data points have yet to be integrated into a view for the interactor. Preliminary experimentation with giving interactors a screen to show the participant's view through the HMD resulted in significantly negative feedback from the interactors. The constant motion of the view through the HMD made it difficult for the interactors to monitor system puppetry and thus interactors requested a stable view of the virtual students that does not respond to teachers' changes in viewing the environment. Thus, additional development is needed to communicate teachers' gaze data to interactors, so they can respond more accurately to teachers' actions in the virtual system.

Faculty Scenario Design and Implementation

As we have discussed some of the opportunities and challenges regarding the technology components of an immersive virtual environment, it is also worth noting some of the advantages and challenges of using a human-in-the-loop simulation design within the virtual environment. Having an interactor control and perform the avatars in real time allows for great flexibility and responsiveness to teachers. This flexibility of the system allows teachers to teach any lesson in any manner that they choose without needing to reprogram the software. However, this same flexibility can sometimes tempt faculty using the simulation to underplan simulated activities. Teachers need clear, measurable objectives as well as feedback on those objectives for teaching skills to improve in a simulated environment. Past research has shown when performance feedback is not included, teachers do not improve on targeted teaching skills (Straub et al., 2014). Similarly, if objectives are not communicated clearly between teachers, facilitators, and interactors, opportunities to practice targeted skills may be missed.

Facilitation of an Immersive VR Experience

With greater technological advances in VR, unique challenges follow. These challenges can include participant individual differences in reception to the immersive experience, including adverse reactions to the experience. Regarding individual differences, the facilitator may need to navigate gender differences (women are at greater risk of adverse reaction to the simulation), age-related response or reception to the environment, and individual feelings of presence (Suh & Prophet, 2018). Further complicating the immersive VR experience is the (often) bulky, wearable technology; physical discomfort from the headset may inhibit the user from achieving a field of presence. Notably, regarding a coaching model, the wearable headset limits interaction to the immediate virtual environment. This physical, visual, and audio barrier limits the way coaches can provide feedback - modeling behavior can only occur if the coach usurps the simulation; whereas, in non-immersive VR, the coach can saddle alongside the participant to model evidence-based practices.

Facilitators also need to be aware of potential, well-known adverse reactions to immersive VR, which can include physical reactions to the simulation, which are related to balance and eye movement; "although using modern technology in education environment is clearly beneficial, it is not without risks and dangers" (Kaminska et al., 2019, p. 13). User adverse-response to immersive technology may take the form of motion sickness, cognitive overload related to visual input, and distracted attention with limited suspension of disbelief (Suh & Prophet, 2018). When facilitating an immersive experience, researchers should ensure participants are given proper attention, if adverse reactions to the environment materialize.

Relatedly, Freina and Ott (2015) discuss the limited recommendations for use of immersive VR among children, which may be related to "health and safety" warnings associated with immersive technology. These limitations include the Oculus Rift, which limits its recommendations-for-use to participants over age 13. The authors cite ongoing eye development in young children as a limiting factor; use of the headset may impact balance and coordination needed within the immersive setting.

RECOMMENDATIONS TO ADDRESS CHALLENGES

Continuing development, research, and refinement of implementation procedures are needed to address the challenges of using VR in educational contexts, including how participants can naturally interact with objects in an immersive virtual environment. As technology develops new tools, methods of interaction should evolve that can be adapted to virtual classroom contexts. Following are recommendations that address the aforementioned challenges.

Use of Technology

One of the challenges of using an immersive VR headset is an inability to see the outside world. If a user becomes preoccupied with navigating the obscured real world in lieu of interacting with the virtual avatars and objects of the simulation, the goal of immersion is hindered, negating the simulation's benefit. To combat this, the dedicated simulation space should be completely cleared of obstacles except where such obstacles are aligned with objects in the virtual space, boundaries for movement within the virtual space should be obvious, and all required manipulatives would need to be built for use with the handset controller or haptic gloves. However, this solution may not be practical for all cases. An alternate solution could be to utilize mixed/augmented reality glasses to bring the student avatars into an existing real world classroom. Advanced MR glasses like Microsoft's HoloLens 2 could potentially scan the real world environment, project the student avatars in a predetermined configuration in the room, and even project over real world objects with virtual objects, such as making a pencil look and function like a magic wand (Microsoft HoloLens, 2019). The glasses would allow the user to feel comfortable seeing themselves in a natural environment while engaging with the virtual avatars and manipulatives.

Another issue discussed above affects the abilities of an interactor to read the facial expressions of a teacher or determine where their attention is focused. Eye tracking improvements and the implementation of emotion-detecting AI could potentially address these problems but additional features would need to be developed for the TeachLivE™ system, such as a virtual representation of a teacher's facial expressions within the interactor's viewport and a dynamic marker representing the teacher's focal point. A balance is required between the useful features of the software and the cognitive load an interactor must manage while retaining focus on their performance. Similarly, teachers' engagement with the simulation should be intuitive enough for them to remain focused on their lessons rather than fighting the equipment and/or simulation. Improvements to environment scanning, FOV enhancements, eye tracking, and object replacement are new, ongoing, and discussed further in the Future Trends section.

Faculty Design and Implementation

While technology advancements and further development may address some challenges, human-in-the-loop structures are likely to persist, at least until artificial intelligence algorithms improve (Ablanedo et al., 2018). Thus, guidelines for communicating with interactors in the system may be helpful. Provided are four basic recommendations for working with interactors to design high quality virtual simulation sessions:

1. Share lesson materials with the interactor in advance of the session.
2. Make sure that session objectives are clear, specific, observable, and possible in the simulated environment.
3. Discuss a framework for decision making.
4. Give feedback to the interactor on their performance.

First, though it may seem obvious, interactors need lesson materials well in advance of the session, so they can plan responses from different students' perspectives, create differentiated work samples, and seed research-based academic misconceptions if applicable. Even though interactors often are hired for their expertise in improvisational performance and may be very accomplished as improvising authentic student responses, all interactors provide better responses with preparation. Preparing these materials in advance also increases consistency across teachers teaching the same lesson and helps avoid interactor mistakes or misconceptions that are unintentional.

Second, session objectives must be clear not only to teachers participating as the learner, but also to the interactor, so they can plan specific opportunities to practice the targeted skill. For example, if a targeted skill is to practice positive specific praise to students, interactors will plan a session where students respond especially well to praise, and classroom disruptions decrease in response to praise. An interactor would likely also seed several instances of undesirable classroom behaviors the teacher could correct or would pause during the session, offering the teacher an opportunity to praise compliance with classroom expectations. In order to respond positively or negatively to teacher actions, the interactor would need to understand when they are observing effective praise and when praise efforts are missing or inadequate. Finally, if a specific component or skill would be difficult to achieve in the virtual environment the interactor needs to address this issue. For instance, if teachers want to include a token reward system as a part of their praise strategy, faculty would need to determine how that would work in a virtual environment. Handing physical objects to the avatars is not possible, so an alternative solution such as marking points on a board, or verbally telling students to record a point may be alternatives that could be implemented virtually.

Third, a framework for decision making is necessary for the interactor. Every session requires the interactor to make hundreds of decisions including: how to respond to teacher statements or actions, what interactions to instigate, how and when to escalate or deescalate disruptive behavior, how deeply to question content material, which misconceptions to present from student perspectives, and which interpersonal challenges to include. Some decisions will be guided by the session objectives or characteristics of students themselves, but some decisions need to be based on the teacher. Teacher experience level is one factor. The challenge level of the simulation should differ from beginning pre-service teachers who are practicing basic skills to master in-service teachers who are polishing new activities before presenting them to their class. Faculty must also decide if the level of challenge needs to be consistent across participants for purposes of research or evaluation or if the level of challenge should respond to the skill level of individual teachers in the system. This principle of changing the level of challenge based on the individual's actions is called dynamic difficulty scaling (DDS) in game design theory (Arzate Cruz & Ramirez Uresti, 2017). If decision making frameworks are not explicit prior to the session, then interactors will be employing internal decision-making frameworks that may or may not align with faculty goals for the session.

Finally, just as teachers need feedback on their performance in order to improve on targeted skills (Straub et al., 2014), interactors also need feedback from faculty members to improve their performance of the virtual students. Data should be collected not only on teacher actions, but on interactor performance choices so that the interactor can receive targeted feedback regarding the authenticity of their performance, the appropriateness of student responses, and the adherence to session goals and decision-making frameworks. Depending on the complexity of the session, it may be too difficult for one faculty member to attend to both teacher and interactor actions during a session. Video recording and review of sessions can be a very helpful tool to address this issue. Providing video recordings of sessions to teams of interactors also offers an opportunity for interactors to peer review performance techniques.

Facilitation of an Immersive Experience

Utilization of VR in education is in its nascent stages, leaving the field wide-open for facilitators to expand learning opportunities for participants. There are a number of challenges to overcome before the use of VR is ubiquitous in the K-12 setting, including prohibitive cost of materials, age restrictions on recommended use, and adverse reactions to the immersive environment. Yet, research indicates use of VR within education yields positive outcomes for participants, including increased motivation, engagement, and interest in the content (Suh & Prophet, 2018). It is our belief the primary goal of the facilitator is to maximize these positive outcomes to increase student learning and growth within the immersive VR setting.

To enhance immersive VR learning experiences, we offer the following recommendations for facilitators:

1. Develop validated standards for immersive VR learning experiences
2. Maximize data collection opportunities within the enclosed environment
3. Simulate experiences which closely mirror real-life scenarios
4. Decrease adverse effects on users, resulting from immersive technology

As immersive VR technology becomes increasingly ubiquitous within the education setting, development of validated standards should follow. Researchers and facilitators should weigh benefits and risks of sensory and perceptual stimulus levels, with particular care given to users under age 18. Stimulus input should be balanced with learning gains, differentiated according to user stages-of-development, content, and setting. For example, standards-of-use within immersive military education settings may be different from those within a K-12 setting.

This leads to a second recommendation: Maximize data collection opportunities within the enclosed environment, to enhance student learning. Collection of data is essential when developing standards-of-use, particularly when measuring user response to sensory input. The enclosed nature of the immersive experience allows facilitators to quickly and dynamically respond to individual student learning needs; and allows for control of extraneous variables. "Unlike research in actual classrooms, where controlled data collection is difficult to ascertain, this virtual environment enables consistency in preparation, immediate feedback, and ongoing data collection, as well as refinement of the environment to ensure the maximum impact on teacher performance and student learning" (Dieker et al., 2008, p. 5). For instance, researchers in teacher preparation may wish to measure preservice teacher eye-gaze or body proximity within the classroom – this can be easily achieved within an enclosed immersive VR setting.

Aligned, Hanoun and Nahavandi (2018) recommend a number of next steps for facilitators within the VR setting. One recommendation is to ensure collected data is diverse in nature; the VR setting affords measurement of multiple perspectives of the performance or task. Perhaps this translates to including multiple means to track biophysical interaction with the simulated environment. Measures could include movement tracking, voice intonation, verbal response, and interaction with the setting. These data can be measured and compared between participants to determine a standard of performance or as measures of learning.

A third recommendation is to simulate experiences closely mirroring real-life scenarios. Again within teacher preparation, a simulated kindergarten classroom may include circle time or table groupings, while a high school immersive experience may include a science lab. By developing skills, within a simulated kindergarten classroom, preservice teachers are able to immediately apply developed skills directly in the real-life classroom; these skills can include behavior management skills, content delivery, positive praise, and small group or center activities.

As educators and coaches continue to explore student growth within the immersive VR setting, the fourth recommendation is to consider the safety and comfort of participants. To achieve the high level of presence needed to achieve a suspension of disbelief, the user must achieve a level of comfort to ensure psychological ownership of the immersive setting (Suh & Prophet, 2018). Practicing in a safe learning environment allows users to make mistakes, without risk to themselves or others. Users should be encouraged to pause the simulation if they are overwhelmed or uncomfortable. Further, as some immersive technologies are not recommended for users under age 13, facilitators must weigh risks when including VR technology in K-12 settings.

FUTURE TRENDS

With VR development advancing so fast, many of the ideas sounding like science fiction actually come from the present or even the recent past. VR social networking platforms, teleconferencing, and all manner of educational, theatrical, and medical applications have been around for years. Mainstream adoption has been slow to manifest in part due to the prohibitively expensive cost of access for most people, and a level of real-time visual fidelity that has only recently been made more available. Technological advances such as seamless integrated eye tracking, which makes dynamic foveated rendering possible, exist today. Foveated rendering is the technique of reducing the rendering workload by reducing the image quality of objects viewed outside the zone of the eye's fovea (which constitutes the peripheral vision) (Parrish, 2016). More than just being resource efficient, this is also more akin to the natural way humans focus on visual stimuli. Precise eye tracking is also useful for the recording of eye movement for insightful analytics of a user's experience. Microsoft's HoloLens 2 MR glasses use eye tracking to identify users and can customize lens widths to provide a more comfortable, personalized experience. They have also implemented laser technology to create a microelectromechanical systems (MEMS) display. With it, the HoloLens 2 can position waveguides in front of a user's eyes, directed by mirrors. Subsequently enlarging images can be accomplished by shifting the angles of the mirrors, effectively doubling the active FOV (Microsoft HoloLens, 2019). The previously mentioned real-time environment scanning capabilities of devices like the Magic Leap One AR device will continue to improve so that virtual characters will not only convincingly exist in the real world, as seen in Pokemon Go, but real-world objects could be made to appear as virtual objects. For example, your countertop could become a touchscreen.

Emotion-detecting AI software now exists, which coupled with VR devices, could convey the subtler aspects of communication such as eye movement and micro-expressions (Affectiva, 2019). Other advanced developments include the previously mentioned standalone VR 6DOF devices like Oculus Quest and the HTC Vive Focus Plus. These devices connect via Wi-Fi connectivity today, with 5G connectivity waiting tomorrow. 5G networks could potentially reduce latency between connected users to imperceptible levels, making telecommunications feel more natural. These things are here now, are not prolific yet, but are likely to become more common in the future as the cost for these technologies decrease. Once these technologies become affordable to incorporate in classrooms and in professional development contexts for teachers, new and innovative use strategies are likely to emerge.

VR Use in Education

From VR's inception, researchers have predicted VR technology would revolutionize learning within the K-12 education setting (Helsel, 1992; Psotka, 1995). Thirty years post, Kaminska and colleagues (2019) contend this next decade will provide the moment for which VR researchers have been waiting; they argue, "the digital world is as important and immersive as the real one" for Generation Z (Kaminska et al., 2019, p. 13). As Generation Z ages, the challenge remains with the educator to present content in digital format - which includes the use of VR in the classroom (Kaminska et al., 2019). The authors submit numerous advantages associated with VR in education settings. They posit, VR is superior in visual presentation, transportable and inclusive in nature, information-rich in framework, promotes increased engagement of learners, and allows for ease of self-directed learning.

Educators can continue to expand use of immersive VR in ways proven effective within teacher preparation. Ideas for future use within the K-12 system include using the virtual environment to:

- Reduce bullying by altering perceptions of biased participants; reach rural education settings with expert delivery of content (i.e. delivery of Advanced Placement courses);
- Rehearse classroom discussion to reduce student anxiety; reduce negative behaviors using avatars as peer supports;
- Use automated systems of feedback to track participation; incorporate haptic gloves and other additional VR technologies to fully immerse the participant into the environment;
- Include greater use of biofeedback analysis to manage stressful classroom situations, and increase use of a bug-in-ear technology to provide coaching feedback to the participant.

With increasing interest and access to VR, the education community is provided an opportunity to diversify student opportunities for learning. Gutierrez and colleagues (2017) cite an expected $120 billion in VR industry profits in 2020 - the authors anticipate investment will focus on content and wearable creation. They forecast the education community will see residual benefits of increasing accessibility and affordability, as wearable technology (HDM) evolves. The authors further contend, as increases are seen in "power and capabilities of newer mobile devices, increased investment to the development of virtual technologies, and access to user-generated virtual contents through social networks" (p.482) are realized, it will be increasingly possible for VR technology to be present across the education spectrum. As wearables become ubiquitous, students and educators will have a blank canvas with which to shape learner experiences; that is, as access to technology increases, creative response will increase, in turn (Gutierrez et al., 2017). The next decade will reveal the full extent of realized learning benefits; Generation Z, a generation of true digital natives, will advance immersive possibilities beyond the lab-nature of today's VR experience.

Human Performance and Increased Use of Interactors

As we consider future trends in the technology and the use of virtual environments in educational settings, use of human performance, interactors, is likely to become a trend. Although advancing developments in artificial intelligence (AI) may eventually replace human interactors in virtual simulation systems, a gap currently exists as to what those AI algorithms can understand about complex human behavior such as teaching. Digital puppetry is likely to remain a technique used to fill that gap until AI systems catch up (Ablanedo et al., 2018). Thus, it is worth considering the implication of potential future wide-scale use of interactors in virtual simulation.

Performance through technology presents unique opportunities and challenges. Through technology, an actor is freed from the casting confines of their physical appearance. An interactor could potentially play virtual characters different from themselves in age, gender, or cultural background. One interactor can play multiple characters, such as multiple students in a classroom, which provides significant cost savings compared to hiring multiple actors in a live training scenario. In one sense, this freedom has the potential to create more equitable casting opportunities for actors ideally based on skill rather than appearance. However, with this freedom comes increased risk of non-transparent, biased performance that may reinforce negative cultural or gender stereotypes (Reed & Phillips, 2013).

This risk is of concern for educational training applications which are especially vulnerable to negative training reinforcing student deficit biases (Matias et al., 2016). At its worst, poor interactor performance could become a form of digital blackface that reproduces negative racial or gender stereotypes while presenting them as authentic student behavior (Reed & Phillips, 2013). Biased performance of student avatars could influence negative teacher biases and expectations for their real classrooms causing potential harm to real students. Research suggests that virtual representations such as video game avatars may already influence perceptions of race and gender in negative ways (Behm-Morawitz & Ta, 2014; Burgess et al., 2011). Vigilance and sensitivity to performance of gender and culture of virtual avatars is essential to avoid unconscious racism or gender bias in performance.

This risk increases as one imagines future applications scaling into larger widespread use. Computer systems used to control virtual avatars are small and affordable enough that interactors can work from home, remote from potential clients. With a small-scale operation like TeachLivE™ where there are generally eight to twelve interactors on staff, some of these risks can be mitigated by having a diverse team that monitors each other's performance with extra sensitivity to performances outside of an individual's personal background. Expert outside feedback on performance authenticity also is a regular part of performance rehearsal. But, maintaining rigorous performance monitoring becomes more difficult as teams expand and spread geographically.

Additionally, as the availability of customizable scenario design increases, and higher education faculty and interactors use systems without institutional oversight, a risk exists of a normalization of white cultural views could be propagated unconsciously in the simulation system through the feedback cycles meant to monitor performance authenticity (Matias et al., 2016; Nishi et al., 2015). Thus, additional research and exploration of scalable performance monitoring systems is essential for ethical use of human-in-the-loop simulation systems.

CONCLUSION

As discussed throughout the chapter, VR technologies represent an evolution in immersive storytelling and provide innovative approaches to teaching and learning. VR use in education is an open, largely underutilized means to increase teacher effectiveness and student learning. The simulated experience, TeachLivE™, is in direct response to a need for more effective teacher preparation. Providing simulated experiences with avatar students whose movements and voices directly interact, through the use of interactors, is a promising use of technology to increase teacher preparation prior to having one's own classroom of students. Given the use of technologies which is expected to become more widespread in the future, more empirical studies are needed to theorize VR use on experiences and performance. We hope this chapter assists and supports educators in understanding the current state of VR, immersive and non-immersive technology, and develop research agendas for future investigation.

ACKNOWLEDGMENT

The authors would like to thank all the Center for Research in Simulation Education Technology (CREST) partners who have worked with us and informed our practice over the years.

We would also like to thank the CREST team members whose contribution make this research possible including Michael Hynes, Donna Martin, and the CREST interactor team.

REFERENCES

Ablanedo, J., Fairchild, E., Griffith, T., & Rodeheffer, C. (2018). Is this person real? Avatar stylization and its influence on human perception in a counseling training environment. Virtual, Augmented and Mixed Reality: Interaction, Navigation, Visualization, Embodiment, and Simulation, 10909, 279–289. doi:10.1007/978-3-319-91581-4_20

Affectiva | Home. (n.d.). Retrieved December 18, 2019, from https://www.affectiva.com/

Alexander, A. L., Brunyé, T., Sidman, J., & Weil, S. A. (2005). From gaming to training: A review of studies on fidelity, immersion, presence, and buy-in and their effects on transfer in pc-based simulations and games. *DARWARS Training Impact Group*, *5*, 1–14.

Arzate Cruz, C., & Ramirez Uresti, J. A. (2017). Player-centered game AI from a flow perspective: Towards a better understanding of past trends and future directions. *Entertainment Computing*, *20*, 11–24. doi:10.1016/j.entcom.2017.02.003

Barnes, G., Crowe, B., & Schaefer, E. (2007). *The cost of teacher turnover in five school districts: A pilot study*. National Commission on Teaching and America's Future.

Behm-Morawitz, E., & Ta, D. (2014). Cultivating virtual stereotypes?: The impact of video game play on racial/ethnic stereotypes. *The Howard Journal of Communications*, *25*(1), 1–15. doi:10.1080/10646175.2013.835600

Brownell, M. T., Sindelar, P. T., Kiely, M. T., & Danielson, L. C. (2010). Special education teacher quality and preparation: Exposing foundations, constructing a new model. *Exceptional Children*, *76*(3), 357–377. doi:10.1177/001440291007600307

Burgess, M. C. R., Dill, K. E., Stermer, S. P., Burgess, S. R., & Brown, B. P. (2011). Playing with prejudice: The prevalence and consequences of racial stereotypes in video games. *Media Psychology*, *14*(3), 289–311. doi:10.1080/15213269.2011.596467

Carver-Thomas, D., & Darling-Hammond, L. (2019). The trouble with teacher turnover: How teacher attrition affects students and schools. *Education Policy Analysis Archives*, *27*(36), 1–32. doi:10.14507/epaa.27.3699

Chini, J., Straub, C. L., & Thomas, K. H. (2014). Learning from avatars: Learning assistants practice physics pedagogy in a classroom simulator. *Physical Review Physics Education Research, 12*(1), 010117-1- 010117-15.

Cochran-Smith, M., McQuillan, P., Mitchell, K., Terrell, D. G., Barnatt, J., D'Souza, L., Jong, C., Shakman, K., Lam, K., & Gleeson, A. M. (2012). A longitudinal study of teaching practice and early career decisions: A cautionary tale. *American Educational Research Journal*, *49*(5), 844–880. doi:10.3102/0002831211431006

Daydream – Daydream View. (n.d.). Retrieved December 18, 2019, from https://arvr.google.com/daydream/smartphonevr/

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science*, *323*(5910), 66–69. doi:10.1126cience.1167311 PMID:19119219

Dieker, L., Hughes, C., Hynes, M., & Straub, C. (2017). Using simulated virtual environments to improve teacher performance. *School-University Partnerships*, *10*(3), 62–81.

Dieker, L., Hynes, M., Hughes, C., & Smith, E. (2008). Implications of mixed reality and simulation technologies on special education and teacher preparation. *Focus on Exceptional Children*, *40*(6), 1–19. doi:10.17161/foec.v40i6.6877

Dieker, L., Hynes, M., Stapleton, C., & Hughes, C. (2007). Virtual classrooms: STAR simulator. *New Learning Technology SALT*, *4*, 1–22.

Dieker, L., & Rodriguez, J., Lignugaris/Kraft, B., Hynes, M., & Hughes, C. E. (2013). The potential of simulated environments in teacher education: Current and future possibilities. *Teacher Education and Special Education: The Journal of the Teacher Education Division of the Council for Exceptional Children*, *37*(1), 21–33. doi:10.1177/0888406413512683

Dieker, L., Straub, C., Hughes, C., Hynes, M., & Hardin, S. (2014). Learning from virtual students. *Educational Leadership*, *71*(8), 54–58.

Every Student Succeeds Act., Pub. L. No. 114–95, 1177 (2015).

Freina, L., & Ott, M. (2015). A Literature review on immersive virtual reality in education: State of the art and perspectives. *ELearning & Software for Education*, *1*, 133–141. doi:10.12753/2066-026X-15-020

Google Cardboard. (n.d.). Retrieved December 18, 2019, from https://arvr.google.com/cardboard/

Gutierrez, J., Mora, C., Anorbe-Diaz, B., & Gonzalez-Marrero, A. (2017). Virtual technologies trends in education. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(2), 469–486.

Hanoun, S., & Nahavandi, S. (2018). Current and future methodologies of after action review in simulation-based training. *2018 Annual IEEE International Systems Conference (SysCon), Systems Conference (SysCon), 2018 Annual IEEE International*, 1–6. 10.1109/SYSCON.2018.8369516

Hapt, X. (n.d.). *Haptic gloves for VR training, simulation, and design*. Retrieved December *24*, 2019, from https://haptx.com

Hayes, A., Hardin, S., & Hughes, C. (2013). Perceived presence's role on learning outcomes in a mixed reality classroom of simulated students. *Virtual, Augmented & Mixed Reality. Systems & Applications, 8022*, 142–151. . doi:10.1007/978-3-642-39420-1-16

Heilig, M. L. (1962). *U.S. Patent No. 3,050,870*. Washington, DC: U.S. Patent and Trademark Office.

Helsel, S. (1992). Virtual reality and education. *Educational Technology*, *32*(5), 38–42.

Hobson, A. J., Ashby, P., Malderez, A., & Tomlinson, P. D. (2009). Mentoring beginning teachers: What we know and what we don't. *Teaching and Teacher Education*, *25*(1), 207–216. doi:10.1016/j.tate.2008.09.001

Hong, J. Y. (2010). Pre-service and beginning teachers' professional identity and its relation to dropping out of the profession. *Teaching and Teacher Education*, *26*(8), 1530–1543. doi:10.1016/j.tate.2010.06.003

Ingersoll, R. M. (2001). Teacher turnover and teacher shortages: An organizational analysis. *American Educational Research Journal*, *38*(3), 499–534. doi:10.3102/00028312038003499

Jones, M. L. (2009). A study of novice special educators' views of evidence-based practices. *Teacher Education and Special Education*, *32*(2), 101–120. doi:10.1177/0888406409333777

Jung, S., Wisniewski, P., & Hughes, C. (2018). In Limbo: The Effect of Gradual Visual Transition Between Real and Virtual on Virtual Body Ownership Illusion and Presence. *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), Virtual Reality and 3D User Interfaces (VR), 2018 IEEE Conference*, 267–272. 10.1109/VR.2018.8447562

Kamińska, D., Sapiński, T., Wiak, S., Tikk, T., Haamer, R., Avots, E., Helmi, A., Ozcinar, C., & Anbarjafari, G. (2019). Virtual Reality and Its Applications in Education: Survey. *MDPI: Information*, *10*(318), 318. Advance online publication. doi:10.3390/info10100318

Lankford, H., Loeb, S., & Wyckoff, J. (2002). Teacher sorting and the plight of urban schools: A descriptive analysis. *Educational Evaluation and Policy Analysis*, *24*(1), 37–62. doi:10.3102/01623737024001037

Magic Leap 1. (n.d.). Retrieved from https://www.magicleap.com/magic-leap-1

Manus, V. R. (n.d.). *World's leading VR Gloves for training*. Retrieved December 18, 2019, from https://manus-vr.com/

Matias, C. E., Montoya, R., & Nishi, N. W. M. (2016). Blocking CRT: How the emotionality of Whiteness blocks CRT in urban teacher education. *Educational Studies*, *52*(1), 1–19. doi:10.1080/00131946.2015.1120205

Microsoft HoloLens. (n.d.). *Mixed reality technology for business*. Retrieved December 18, 2019, from https://www.microsoft.com/en-us/hololens/

Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education*, *56*(3), 769–780. doi:10.1016/j.compedu.2010.10.020

Nintendo Labo™ for the NINTENDO Switch™ home gaming system - official site. (n.d.). Retrieved December 18, 2019, from https://labo.nintendo.com/

Nishi, N. W., Matias, C. E., & Montoya, R. (2015). Exposing the white avatar: Projections, justifications, and the ever-evolving American racism. *Social Identities*, *21*(5), 459–473. doi:10.1080/13504630.2015.1093470

Oculus, Go. Standalone VR Headset. (n.d.). Retrieved December 18, 2019, from https://www.oculus.com/go/

Oculus | VR Headsets & Equipment. (n.d.). Retrieved December 18, 2019, from https://www.oculus.com/

Oculus Quest. All-in-One VR Headset. (n.d.). Retrieved December 18, 2019, from https://www.oculus.com/quest/

Olson, J. L., Krum, D. M., Suma, E. A., & Bolas, M. (2011). A Design for a Smartphone-Based Head Mounted Display. *Proceedings of the 2011 IEEE Virtual Reality*, 233-234. 10.1109/VR.2011.5759484

Pantelidis, V. (1993). Virtual reality in the classroom. *Educational Technology*, *33*(4), 23–27.

Parrish, K. (2016). Nvidia plans to prove that new method improves image quality in virtual reality. *Digital Trends.* Retrieved December 18, 2019, from https://www.digitaltrends.com/virtual-reality/nvidia-research-foveated-rendering-vr-smi/

Pilatásig, M., Tobar, E., Paredes, L., Silva, F. M., Acurio, A., & Pruna, E. … Sánchez, Z. (2018). Virtual system for teaching-learning of initial education using a haptic device. In L. T. De Paolis & P. Bourdot (Eds.), Augmented Reality, Virtual Reality, and Computer Graphics (pp. 118–132). Cham: Springer International Publishing.

PlayStation®VR - over 500 games and Experiences. feel them all. (n.d.). Retrieved December 18, 2019, from https://www.playstation.com/en-us/explore/playstation-vr/

Psotka, J. (1995). Immersive training systems: Virtual reality and education and training. *Instructional Science*, *23*(5–6), 405–431. doi:10.1007/BF00896880

Reed, A., & Phillips, A. (2013). Additive race: Colorblind discourses of realism in performance capture technologies. *Digital Creativity*, *24*(2), 130–144. doi:10.1080/14626268.2013.808965

Ryan, S. V., Nathaniel, P., Pendergast, L. L., Saeki, E., Segool, N., & Schwing, S. (2017). Leaving the teaching profession: The role of teacher stress and educational accountability policies on turnover intent. *Teaching and Teacher Education*, *66*(1), 1–11. doi:10.1016/j.tate.2017.03.016

Samsung Gear VR with Controller. (n.d.). Retrieved December 18, 2019, from https://www.samsung.com/global/galaxy/gear-vr/

Scheeler, M. C., Budin, S., & Markelz, A. (2016). The role of teacher preparation in promoting evidence-based practice in schools. *Learning Disabilities (Weston, Mass.)*, *14*(2), 171–187.

Straub, C., Dieker, L., Hynes, M., & Hughes, C. (2014). *Year 1 findings using virtual rehearsal in TLE TeachLivE™ mixed reality classroom simulator to determine the effects on the performance of mathematics teachers.* Retrieved from http://teachlive.org/wp-content/uploads/2014/10/2014_GR_Technical_Report_10_20_FINAL.pdf

Suh, A., & Prophet, J. (2018). The state of immersive technology research: A literature analysis. *Computers in Human Behavior*, *86*, 77–90. doi:10.1016/j.chb.2018.04.019

Sutherland, I. E. (1968). A head-mounted three-dimensional display. *Proceedings of AFIPS*, *68*, 757–764.

Virtuix Omni™. (n.d.). Retrieved December 18, 2019, from https://www.virtuix.com/product/virtuix-omni/

VIVE™ | VIVE Virtual Reality System. (n.d.). Retrieved from https://www.vive.com/us/product/vive-virtual-reality-system/

VIVE Cosmos - a new way of Pc VR: VIVE™. (n.d.). Retrieved December 18, 2019, from https://www.vive.com/us/product/vive-cosmos/features/

VIVE Focus Plus. (n.d.). Retrieved December 18, 2019, from https://enterprise.vive.com/us/product/focus-plus/

Whiteman, D. (2009). View-Master, an icon of souvenirs since 1939, enters nonscenic era. *The New York Times*. Retrieved from https://www.nytimes.com/2009/03/04/business/worldbusiness/04iht-view.4.20593331.html

Winn, W. (1993). *A conceptual basis for educational applications of virtual reality* (Report No. TR-93-9). Human Interface Technology Laboratory, Washington Technology Center.

Zachara, M., & Zagal, J. P. (2009). Challenges for success in stereo gaming: A virtual boy case study. *ACM International Conference Proceeding Series*, 99–106. 10.1145/1690388.1690406

Zhang, M., Zhang, Z., Chang, Y., Aziz, E. S., Esche, S., & Chassapis, C. (2018). Recent developments in game-based virtual reality educational laboratories using the microsoft kinect. *International Journal of Emerging Technologies in Learning*, *13*(1), 138–159. doi:10.3991/ijet.v13i01.7773

KEY TERMS AND DEFINITIONS

Artificial Intelligence (AI): The theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.

Augmented Reality: Technology that enables users to engage with virtual information superimposed on the physical world. This mediated immersion places digital resources throughout the real world, augmenting users' experiences, and interactions.

Dynamic Difficulty Scaling (DDS): Adjusting the level of challenge in a game or simulation based on the skill level of the player or learner.

FOV (Field of View): The open observable area a person can see through their eyes or via an optical device.

Foveated Rendering: The technique of reducing the rendering workload by reducing the image quality of objects viewed outside the zone of the eye's fovea (which makes up the peripheral vision).

HMD: Head-mounted display. This is a display device worn on the head that regulates the user's vision to one (monocular) or two (binocular) digital displays, allowing only computer-generated imagery (CGI) or video input to be seen rather than the physical world.

Human in the Loop: A type of simulation where a human operator plays a role in controlling the events of the simulated scenario.

Immersive Virtual Reality (VR): Users are required to wear a head-mounted display and are completely encompassed by the virtual environment. In an immersive VR environment, user responses can be observed and recorded in a controlled situation.

Interactor: A human operator who controls virtual avatars in a virtual environment using digital puppetry and voice performance.

Kinect: A Microsoft motion-sensing device equipped with cameras, projectors, microphones and sensors in order to function as a natural user interface peripheral. Some capabilities include real-time gesture recognition, speech recognition and body skeletal detection for up to four people at a time.

Mixed Reality: The space where the physical and virtual worlds co-exist. Within the reality virtuality framework, a generic MR environment is a space in which real and virtual objects are presented together within a single display.

MYO Gesture-Type Platform: A platform that utilizes input from a MYO gesture control armband. A MYO gesture control armband is a wireless device worn around a user's forearm that detects muscle activity in the forearm to provide touch-free control of technology via hand gestures and motion. The term MYO is derived from the Greek "mŷs", meaning mouse or muscle.

Non-Immersive Virtual Reality (VR): The VR content is displayed via a computer screen. Traditional media, such as keyboards and mice, are used for the interaction. Non-immersive VR does not require users to wear any equipment.

Sensorama: One of the earliest prototypes of immersive, multimodal technology. Introduced in 1962 by inventor Morton Heilig, it is considered one of the first virtual reality (VR) systems.