**Learning in the Metaverse: A Constructivist Approach to Using Virtual Reality in the Classroom**

**Abstract**

All across the nation’s educational institutions, creative strategies are being developed

that focus on increasing student recruitment and retention. These initiatives seek to engage and

motivate in order to attract new students and assist existing students on progressing through their degree programs more effectively. Virtual Reality Learning Environments (VRLEs) are an innovative strategy to meet these goals. Some disciplines have been using VRLEs for student

learning for several years; however, the technology has not been used more broadly in other

disciplines. This is changing due to the lower cost and widespread availability of the software

and hardware required to use virtual reality; however, more research needs to be conducted to determine the overall barriers of VRLE implementation and the ways practical VRLEs can be linked to research and theory. A descriptive study was created to investigate, explore, and review the challenges of using VRLE. It also explains how VRLEs can be constructive in nature. Results showed that challenges center around these areas: (a) costs, (b) space, (c) accessibility, (d) usability and training, and (e) cybersickness. VRLEs in the education setting are considered constructive when they include active learning, creation of meaning, individual exploration, open-ended interactions, creative contexts, critical thinking, reflection, documentation, comparison, and contrast. A seven-step model for constructive implementation of VRLEs is proposed based on the results. This research would interest anyone who would like to know more about virtual reality and the implications it has for the classroom setting.

*Keywords*: Virtual Reality, Student Learning, Virtual Learning Environments, Learning

Theory, Constructivism

**Introduction**

Colleges, universities, and other educational institutions across the country continue to seek innovative ways to recruit and retain students. Technology can and has been used to enhance traditional educational approaches in order to engage and motivate students on an ongoing basis. For example, collaborative learning environments (CLE) incorporate the use of smart phones, tablets, and clickers to enhance the classroom experience. Learning management systems (LMS), such as *Blackboard* and *Moodle*, are used to deliver, track, and manage data for training and education (Ramirez-Arellano, Bory-Reyes, & Hernández-Simón, 2019; You, 2015). One of the latest technologies to be incorporated into education to further improve the learning experience is virtual reality (VR).

A virtual reality learning environment (VRLE) is a learning platform that allows students to interact and learn in a virtually simulated setting. Students receive instruction from a real-life, qualified teacher who is virtually present during the experience when in a VRLE. These systems use avatars, web cameras and/or headsets to represent users in the virtual environment. Advanced VRLEs incorporate other media as well. This might include video conferencing, media sharing, advanced security protocols, and recording features.

The use of VRLEs to augment traditional classroom learning has been explored in recent

years, but these efforts have been limited to just a handful of disciplines, although this is changing. This effort is expanding due to reductions in the cost associated with the software and hardware to run a simulation. While virtual reality has been around for several decades, it is only recently that the technology has become more widely available to the general population. Several disciplines, such as medicine, engineering, media, and psychology, have been actively using the technology for years. New disciplines, such as chemistry, history, and criminal justice, are recognizing the benefits of its use. A growing body of research has tested the use of VR in the classroom. Within these studies, constructivism is often cited when discussing the value of VRLEs for student learning. It is unclear how constructivist learning can help increase the usability and relevance of VR in a standardized way for students today. The idea of using VR for learning is not a new concept. Virtual Reality Learning Environments (VRLEs) have been used in several fields of study to increase educational outcomes for students of all ages. Those in the natural sciences, mathematics, and the social sciences are most noted examples in the current literature. Science, Technology, Engineering, and Mathematics (STEM) classes use VR to focus on organizing information in ways to promote knowledge acquisition, provide experiential learning opportunities, and conduct experiments (Mikropoulous & Natsis, 2011). The social sciences tend to focus on historical information and cultural references, but this is evolving. Based on the current issues within VR today, we conducted a descriptive study to determine answers to the following research questions: What are the challenges of VRLE implementation in education? How do teachers and researchers generally implement constructivist-based VRLE?

**Conceptual Framework**

Constructivism is a learning theory that explains how people learn and acquire knowledge. The accumulation of knowledge is based on direct experiences. Constructivism is actually a family of theories that encourage a student-centered approach to learning (Palmaru, 2016; Thompson, 2015). Jean Piaget, Lev Vygotsky, Humberto Maturana, Ernst von Glasersfeld, and Jerome Bruner are some of the authors associated with constructivist theory. These theories provide a foundation for understanding how virtual reality can be used to increase the effectiveness of traditional learning activities.

Piaget was well-known for cognitive constructivism, which outlines specific developmental milestones that students reach according to age (Beins, 2016; Powell & Kalina,

2009). This includes sensory motor skills from infancy to 2, preoperational skills from 2 to 7,

concrete operational skills from ages 6 to 11, and formal operational skills from ages 11 to

adulthood (Krulik et al., 2003; Powell & Kalina, 2009). Essentially, Piaget emphasized that

children learn through experience. They organize information in order to restore equilibrium to

the mind (Powell & Kalina, 2009; Slavin, 2006). Imbalance in thought occurs in situations that

create challenges for them as they learn how to make sense of what is around them. Ideas that can fit within what they already know are assimilated in the mind, but new ideas create unique

categories in the mind via accommodation. The idea of a simulated virtual world where students

are able to experience a simulation that allows them to classify various information fits within this framework (De Freitas, 2018). The interactivity provides new challenges for individuals because there is a designed world construct that requires its own system interface, management systems and guidance apart from what would be typical within strictly traditional lectures and teacher-centered discussions (i.e., passive learning).

Vygotsky expanded on constructivist-based ideas with social constructivism, which

describes the importance of history and communication in development (Powell & Kalina, 2009). He focused on how private speech, scaffolding, and cooperation can help students learn important concepts. He found that children are able to readily absorb and comprehend information when they participate in student-centered discussions and guided activities (Krulik, et al., 2003). For instance, students learn how to tackle challenges within a zone of proximal development (ZPD). This is a mental area of development for an individual that belongs to tasks that are difficult to master alone but are able to be completed with the help of others. By communicating with others and learning how to grasp concepts with the use of language, students are able to place more complicated tasks in the ZPD. Within the areas of cybernetics and education science, activities that center on the creation and translation of programming language would help students to play the role of designer within their own learning (De Freitas, 2018). Interactive conferences and virtual fairs have cooperative elements to them that would help students build on what they already know (Sweeting & Hohl, 2015).

Von Glasersfeld (1984) and Maturana (1970) focused on radical constructivism, which

gives more credence to the individual as the creator of experience and reality. Von Glasersfeld

(1984) explained within the founding tenets of radical constructivism that learning processes (a)

are limited within the mind according to natural and biological constraints, (b) help to construct

the very nature of reality itself through life experiences, and (c) are a byproduct of individuals’

active operations and classifications of their experiences. Maturana (1970) supported this view of

constructivism when he stated that the nervous system is a closed reference network, where language and thought are separate systems of development that can be tied to consciousness.

Unlike Vygotsky, Maturana described language as a byproduct of the social systems of the mind.

It cannot be linked directly to thought because it is an exclusive process. Vygotsky was of the

belief that language preceded thought, which also disagrees with Piaget’s assertion that thought

preceded language in terms of importance and development (Powell & Kalina, 2009).

Radical constructivism is a framework that encourages autonomy when learning about self and circumstances around the self (Palmaru, 2016). This means that the use of choice is especially important within learning environments due to the fact that learning already has preset constraints. Understanding the learner means that teachers have to get out of the learner’s way so that it is easier to determine the actual thoughts and social processes of said learner. This is hard to do, given that most teaching environments establish the teacher as an important authority figure for the students (Thompson, 2015). This flexible environment is possible to create when teachers give students free time or a form of exploration time where teachers play the role of observer.

Another well-known strategy is the discovery learning approach, which is also referred to

as discovery learning theory. Jerome Bruner (1961) developed this instructional approach with

constructivism in mind. It is an active, self-referential approach that uses internal motivations to

guide learning (Bruner, 2007; Cattaneo, 2017). Bruner posited that the learning process involved

three phases (Krulik, et al., 2003). Students first have to acquire new information. This usually

involves the use of concrete materials to discover new concepts. Second, students must transform

what they find. This can be done through the use of pictures or illustrations. Third, evaluation

takes place. Students can use symbols, abstractions, and other communication systems formulated in the mind to help with reviewing tasks and gauging the success of the activities performed. Inquiry-based approaches to learning that include experimentation, metacognition, and evaluation would fit within discovery learning (Asfeldt et al., 2018; Bruner, 1961; Dalgarno et al., 2014; Reynolds & Caperton, 2011). Students, when using the discovery learning approach, would avoid receiving external feedback or motivation where feasibly possible (Bruner, 2007).

Teachers who prescribe to this approach use these propositions to develop their classes.

VR could be used to augment current instruction under a constructivist theory by being student-focused and allowing students to have direct experience with the concepts. VR provides additional avenues for exploration that can increase motivation, engagement, and knowledge acquisition. Because of the decreases in cost and improvements in usability within the last five years, many educational institutions are beginning to use the technology for student learning but progress has been slow. It hasn’t been as widely distributed in educational settings due to a lack of understanding about the how the technology works and the benefits/weaknesses of use.

Understanding how to use VR under a constructivist approach requires a basic understanding of

the technology and how it is currently being used.

**Defining Virtual Reality**

VR is a computer-generated environment that uses two- or three-dimensional visualization software and transmission devices that allow a user to communicate in a virtual setting (Ticknor, 2019; Ticknor & Tillinghast, 2011). These simulations are assessed using specific hardware such as mobile phones, traditional computers, projectors, or head-mounted displays (HMDs). Participants explore an environment using input devices such as a keyboard, touch screen, or hand controllers. During the experience, the human visual and auditory systems are engaged with a focus on the level of immersion and presence that is achieved*.* Immersion represents the awareness of the participant of the real world. Presence represents “the psychological state in which a participant accepts, interacts and is physically, socially, and emotionally engaged in the virtual world” (p. 8). VR helps students contextualize a given topic or period in time.

**Levels of Immersion**

There are three main types of VR experiences. These are distinguished by the level of

immersion the participant can achieve. Participants in a non-immersive simulation have limited

interaction with objects or the environment during the simulation. These experiences are most

commonly accessed using a mobile phone, tablet, or a laptop/desktop computer. Users may

explore a limited number of areas and have pre-defined choices they can make.

Semi-immersive systems are typically assessed using computers with enhanced graphics

capabilities, gaming systems, projectors, or HMDs. Participants can manipulate objects and

interact with the environment during the simulation. Fully-immersive environments are the most

advanced of all the VR experiences. Unlike semi-immersive systems that engage one or two of

the sensory systems (i.e., visual and hearing), fully-immersive simulations can engage all of the

them (i.e., vision, hearing, smell, and touch). These simulations use either Cave Automated

Virtual Environment (CAVE) technology or HMDs with haptic feedback devices. CAVE

simulations are very expensive to build and manage, so most semi- and fully-immersive VR use

HMDs.

**Head Mounted Displays**

The first modern HMDs were introduced in the mid-1980s through a collaboration between the National Aeronautics and Space Agency (NASA) and Virtual Programming Languages (VPL) Research. By the mid-1990s, however, exploration into VR began to wane as the internet became more widely available and web development became the focus of resources for many businesses. Many people also thought VR was too expensive for wide distribution at this time resulting in abandoned research and development projects. It wasn’t until Palmer Luckey developed the *Oculus Rift* following a crowdfunding campaign in 2012 that widespread interest for VR was renewed. Luckey’s company was sold to Facebook in 2014 for an estimated $2 billion USD). Under new ownership, the *Rift* began selling in the first quarter of 2016 for $599USD. Oculus later released the first standalone, untethered HMD, the *Oculus Go*, in May of 2018. This device is an all-in-one headset, meaning it does not require a laptop/desktop to run an experience. You shop for apps on the device much like you would shop for apps on a mobile phone. In the Spring of 2019, Oculus released the *Oculus Quest*. This unit has better graphics than the *Go*, weighs less, is also untethered, and retails for $499USD. Users can also use a link cable on the *Quest* to gain access to content for the *Rift.*

The *HTC Vive,* was also unveiled in 2016. The base system costs roughly $500USD. The *Vive Pro* was released in the Fall of 2018. This system offers enhanced optics and high-resolution sound and costs approximately $800USD. This unit adds precision eye tracking, better graphics than previous versions, and more advanced modular tracking. The *Pro Eye* was released in the United States in June of 2019 at a cost of $1599USD. The *Rift* and *Vive* varieties are the most popular of the advanced VR headsets currently on the market. They currently offer the most features and have the best screen resolution and frame rates. Resolution and frame rate are important as they greatly impact how our brains perceive and interpret the virtual environment.

There are several other HMDs now available that are more economical. These devices can also be useful for educational purposes. The *Samsung Gear, Google Cardboard,* and *Google*

*Daydream* provide mobile-VR capabilities at a cost of roughly $10 to $100USD, USD plus the cost of a smart phone. Users download apps via iOS or Android to view the VR content. There is limited interaction while in these simulations, but the technology has been successfully used for digital storytelling.

These systems are now widely available and the cost has come down considerably within

the past two years. This has resulted in renewed development efforts in VR for purposes outside

of gaming, including education. While VR is still strongly associated with entertainment,

educators and researchers are finding new ways to incorporate this technology into their

curriculum, including its incorporation into mixed reality and extended reality (Dreger & Ticknor, 2022). It also becomes more viable as more degrees and courses are being offered online. The technology is being increasingly used to enhance educational outcomes in a variety of disciplines. These initial explorations provide promising insight into how to implement the technology in colleges and universities across the nation.

**Methods**

VRLEs are implemented in several ways. First, customized virtual environments can be

created using software such as *Unity* or *Unreal*. This requires VR developers but offers the most

flexibility. This can be expensive, restricting the use of VR for learning to many institutions. Predesigned virtual worlds, such as Second Life, are widely used for student learning. Dass and

colleagues (2011) analyzed 15 case studies using virtual worlds, particularly with the use of *Second Life*. They found that students generally had a positive reception when using the virtual worlds for learning purposes. The continued development and implementation of these pre-designed environments has greatly increased since the early-2000s (Dass et al., 2011; De Freitas, 2008; Pearce et al., 2015).

Mobile apps are also becoming a popular option for VRLEs. For example, *Discovery VR*

allows participants to explore various places and people. *Star Chart* enables students to learn

about constellations and space discovery. *Virtual Speech* provides opportunities for students to

practice public speaking and prepare for job interviews in a virtual simulation. There are thousands of mobile-VR apps, many available at no cost to students, making this an attractive option for educators to implement the technology in their classes.

Finally, special VR cameras are used to capture 360-videos that can be viewed in an HMD. These experiences are typically playback-only videos that offer a 360-3D view of a filmed environment. Advancements in the hardware, such as the *Vuze* and *Insta360 Pro*, offer educators the opportunity to create their own digital stories relatively inexpensively. While these simulations are not interactive, they can be used to illustrate important concepts and provide students the opportunity to learn through direct experiences in a safe, controlled environment.

While the implementation of the technology is expanding and the body of literature is

growing, using a VRLE in the classroom is supported through several existing learning theories.

Constructivism is a learning theory that researchers have used to evaluate the effectiveness of VR for student knowledge acquisition, motivation, and engagement. While many constructivist studies are exploratory in nature, they can offer insight into the benefits and weaknesses of using the technology for student learning.

**Feasibility Study**

To find out the trends, challenges, and current educational implementation of VR, a review of literature was conducted about VRLE in order to see the feasibility of it within different theoretical paradigms. This review was descriptive in nature since it helped to “determine the characteristics of a population or particular phenomenon” in order to establish how and why VRLEs should be applied in higher education through a constructivist lens (Qualtrics, 2025, p.3). The databases used for the search were EBSCOhost Academic Search Complete, ProQuest, and Google Scholar. Using multiple databases allowed for triangulation of data, which thereby increased the validity, reliability, and credibility of the review. Key theories included constructivism, situated learning, discovery learning, experiential learning, and direct instruction. Specific search term combinations related to constructivism were (a) Virtual Reality + Constructivism, (b) Higher Education + Virtual Reality + Constructivism, and (c) Mixed Reality + Constructivism. Sources relevant to the research results were journal articles, dissertations, and reports. For this article, we selected resources that discussed VR benefits, VR challenges, VRLEs, classroom applications of VRLEs in higher education, and practical examples of VRLEs within a constructivist paradigm. Out of the resources found, there were 56 that fit this criteria, which are all cited throughout this article. We looked for educational situations primarily within the United States, but information that provided global perspectives or studies from other countries that enhanced the discussion of virtual reality as a whole were also included as resources for review.

**Results**

The potential benefits for incorporating VR into education are feasible, but there are

additional considerations when implementing this type of solution. Challenges related to cost,

accessibility issues, training requirements, on-going support for the technology, and physiological responses during the simulation should be carefully considered prior to the implementation of VR in the classroom. These considerations could greatly impact the success or failure of the learning experience.

**Costs**

The first consideration for creating a VRLE for most institutions of learning will be

cost. The cost required for the hardware and software can greatly vary depending on the goal of

the simulation (Ticknor, 2018). Semi- and fully-immersive systems require more advanced hardware but are generally more expensive. The cost of software can also be a barrier. Non-immersive systems often access free content, and the hardware is less expensive but not as interactive. Decisions on how much funding to invest in VRLEs can greatly impact the learning experience.

***Hardware.*** Non-immersive VR is the most cost-efficient of the VR systems because they

use existing equipment or technology many students already have. These environments are

accessed with a desktop computer, laptop, tablet, or mobile phone. Programs that use mobile-VR

tend to be the most affordable. Participants download apps from IOS or Android. There is

considerable free downloadable content, and fees for those apps that do charge are generally less

than $10USD. The experience can be made more immersive with the purchase of a basic HMD for mobile-VR. These units can cost as little as $7USD.

Semi- or fully- immersive simulations require the use of a more advanced HMD or other

special equipment. Products such as the *Rift* and *Vive* cost hundreds of dollars and require

computers that have more power, memory, and advanced graphics cards. These machines can run up to $3000USD. Untethered models, such as the *Go* and *Quest* are becoming more popular because they don’t require the additional computer power. A CAVE is the most expensive option but provides a fully immersive experience. These units, however, can cost anywhere from $25,000 to $200,000USD.

***Software.*** Another important component is the software to run on the hardware. There are

several ways to obtain and create VR content. Downloadable applications are the most common.

VR journalism now offers additional ways to obtain content that focuses on specific events or topics. Educators can use development engines, authoring tools, or 360-VR Cameras to create

their own content. Each come with their own advantages and disadvantages.

Several companies now offer downloadable apps that focus specifically on learning. For

example, *In Cell VR* teleports students inside the human body to learn about biology. *Titan of*

*Space* allows students to tour the solar system. This app also allows instructors to customize tours to outer space. Other apps, such as *Tilt Brush*, open new opportunities for students to create virtual art. This can include printing the art using a 3D printer. Some apps work on a variety of devices while others only work on a specific HMD. Many are free with the most expensive costing roughly $30USD.

Digital storytelling is increasing and can be a useful tool for the classroom. Several news

agencies now offer VR journalism apps. These simulations are usually accessed via mobile-VR

and have limited interaction. One example was created by *The Guardian.* They created a 10-

minute simulation on the solitary confinement experience. The user can look at objects and walk

around the room. Sounds that an inmate might hear can also be heard. This app was created so

people outside the prison could gain a better understanding of the prisoner experience while in

solitary confinement. Most of the mainstream news media outlets offer some sort of VR content.

These experiences cover a broad range of topics including touring Chernobyl (CNN), exploring

conflict in the Congo (BBC), or being present during a moon landing (New York Times), to name a few.

VR films are also becoming popular means for storytelling. For example, *Left Behind* is a film developed through Project Empathy, an effort put together by Benefit Studio made up of

entertainers, technologists, and journalists interested in social justice. The award-winning film

follows a young girl who is placed in a foster home after her mother is incarcerated. Many of the digital storytelling VR experiences mostly focus on inducing empathy. There is limited research

to support or refute this goal, but a recent study by Bang and Yildirim (2018) did not find

significant differences in empathy levels for individuals watching a documentary about inmates in VR versus on a *YouTube* video. Nonetheless, this could offer instructors additional content for

class that is almost always free.

There are a few authoring tools that provide more of a point-and-click approach to VR

development, but these options are very limited. *Sansar*, by Linden Lab, offers monthly

memberships so users can use the software to customize their own virtual environment within their simulated world. This is comparable to *Second Life* but is more immersive. *AltVR* allows

individuals or groups of participants to come together to meet, watch videos, and/or play multiplayer games. *Facebook Horizon* is currently available in beta form. This platform allows users to build their own environments and socialize with others in the virtual space.

The most flexible way to create simulations is to use VR engine software such as *Unity* or *Unreal*. These software programs have been around since the early 2000s and were originally

created specifically for gaming. They can be used to create either 2-D or 3-D virtual and/or

augmented reality experiences. Specially trained developers code each simulation using C# or

other scripting languages. While very flexible, these solutions take significant development time

and resources. This may be cost prohibitive for many schools unless they have an existing

resource.

**Space**

Another consideration might be finding physical space for those wanting to use VR in their traditional, on-campus classes. A main goal for the VR experience is to minimize the student’s awareness of the real world around them. Increasing presence and immersion during the simulation might require students to walk around a room while wearing the HMD. In this situation, the room should be free of objects they can run into or knock over. A traditional classroom often has dozens of desks making this more difficult. The exact physical space requirements will differ, however, according to the technology being used.

Mobile-VR and *Go* require the least amount of space due to limited interaction during the

simulation. Students can sit at desks or have just enough room to rotate 360 degrees. The *Vive*

and *Rift* require a dedicated space that can be customizable but can range up to 16 square feet per

each set of room sensors. The *Quest* does not require the room sensors like the other advanced

headsets. Participants can set the parameters to whatever size they want. A unique feature to this

HMD is that it shows users a view of the real world if they step out of the defined space.

The actual space needed for a class depends on the experience (software) and HMD

(hardware) being used and the level of interaction desired. A dedicated class space for VR is

optimal. Many universities are developing VR-Labs specifically for this purpose. These labs offer ample space so students can participate in a safe space with enough room to maneuver the

simulation as required. Those who do not have a dedicated space can create physical borders in a

traditional classroom to ensure safety. This might be accomplished by simply moving desks.

Addressing the space requirement might hinder some schools or impact the impressiveness of the

experience.

**Accessibility**

There are considerations regarding the accessibility of the VR simulations. Cavanaugh and Blomeyer (2007) offer a variety of suggestions for making learning environments more accessible, including using large text and visual cues for students who have low vision. Captions may also be necessary for those who have auditory deficiencies. This could be difficult to address using VR.

At this point, most VR experiences do not directly address these issues. Effective

translators and translating software may be required for those who have accessibility needs but

these are not inherent in the software or hardware used for VR. Using outside resources for

auditory or visual needs can address these issues but may also impact immersion and presence.

How the technology is specifically used for these students must be carefully considered. This can

be overcome, but will require additional consideration during curriculum development.

**Usability and Training**

Most VR programs that would be used in a VRLE provide a user-friendly interface so

anyone with basic computer knowledge can use it. Some individuals, however, may not be

amenable to learning new technology. Another concern may be for additional support for those

who are having problems with the technology. Students or faculty may need one-on-one tutoring

and other computer-based training if they have problems with understanding how the technology

works (Slavin, 2006).

Furthermore, educators must be intentional in designing lessons plans when creating a

VRLE. It is important to optimize the features of the virtual environment and provide additional

resources to students. Subject matter experts can train instructors on how to maximize the

environment to achieve specific objectives. Students can be provided documentation to address

the various questions that might arise. This can assist in minimizing confusion.

**Cybersickness**

Any potential physiological responses to the simulation should also be considered. Someusers experience what is referred to as *cybersickness*. The symptoms include eye strain, headache, and vertigo. Cybersickness occurs when the quality and response time of the graphics are poor. Some research suggests age, gender, and existing medical conditions may also play a role (LaViola, 2000). Students will need to be supervised, especially during initial simulation

exposure, to see who is affected and to reduce the likelihood of injury. Discussing and posting a

sign on the symptoms can also be helpful.

An additional suggestion is to limit exposure time. Bailenson (2018) recommends a virtual simulation lasts no more than 20-30 minutes per session. Extended exposure to a simulation may interrupt the learning experience or impact knowledge acquisition if the content is found to be too overwhelming to those who experience it. Another option would be to connect the HMD to an external monitor via the HDMI port on the connected computer. Students viewing the content on the monitor won’t actually experience the simulation the same, but they can observe their classmates. While not ideal, this option would allow these students to participate in discussions.

**Examples of Constructivism within a VRLE**

As discussed, learners take an active role in the constructivist paradigm. They absorb new information and connect it with previously learned knowledge to construct new knowledge. In

order to achieve this, learners must reflect on the activities and observations provided during class. By reflecting on these experiences, learners integrate previously acquired knowledge with newly found observations. VRLEs provide students with various opportunities for reflective thinking. While still growing, several studies have explored how VR can be used under a constructivist perspective.

As one of the early adapters, Spalter and colleagues (2002) used immersive VR to create a direct experience for the Museum of Color. Students conducted several experiments in a CAVE-based recreation of the museum. They could travel to different floors that mimic the layout of the original museum to interact with objects and learn concepts such as value and saturation and the visualization of color spaces. They found that the knowledge acquired persisted outside of the virtual environments.

Swan and O’Donnell (2009) evaluated exam scores of students who used Virtual Biology

Laboratories (VBLs) during their coursework compared to students who had more traditional

learning. Students who were exposed to virtual environments performed better on tests that

focused on the ideas and procedures presented in those particular environments. There were no

significant differences between the students on more general exam formats, however.

Lee, Wong, and Fung (2010) sampled students who were tasked to learn biology in a non-immersive virtual simulation focused on dissection. Students could probe a frog and were asked to create lab notes about their observations. While they were careful to note that there were a number of factors related to learning, such as personal goals and cognition, they did find that using a virtual simulation under a constructivism perspective did significantly impact active learning, reflective thinking, and motivation. They also noted several cognitive benefits such as perceived learning effectiveness, understanding of the material, and overall satisfaction with the simulation.

Di Blas and Paolini (2014) incorporated the concepts of constructivism, situated learning,

and sociocultural theory to engage students in quests related to cultural history. Results showed

that using blended learning programs with students aged 12 -18 were relevant to desirable student outcomes when six key features were met. Specifically, knowledge acquisition occurred when students achieved meaningful overarching goals, completed practical tasks, gained

interdependence, had role variety, participated in mandatory collaborative activities, and were

exposed to multi-perspective topics.

Another notable study was conducted by Kim, Park, Cozart, and Lee (2015). High school

students were surveyed three times in mathematics courses offered by the virtual high school they attended. The purpose of the research was to see if any statistically significant differences in effort regulation, motivation, and engagement could be found between high performers and low

performers. Throughout each survey administration, high performers had significantly higher

effort regulation, self-efficacy, and resilience than low performers who took the same online

courses.

Lin and Lan (2015) studied the use of VR for learning a new language. The found that the most important factors for knowledge acquisition included interactive communication and task-based instruction. Ozkan (2017) also studied the use of VR for language education. Students in this study found the use of VR to be motivating and interactive. Teachers were also more

motivated to teach when using the technology.

Madathil and colleagues (2017) studied technical college students using a VR simulation

focused on identifying safety hazards in a manufacturing environment. Outcomes included knowledge gained and engagement. While no significant findings were found for knowledge

gained between their groups, students found the use of VR assisted with comprehension. They

were motivated by the active learning exercises in the simulation. Huang and Liaw (2018) tested

several concepts commonly associated with constructivism: perceived self-efficacy, interaction,

and motivation. Their study focused on e-Commerce courses at a university. Of these, perceived

self-efficacy and interaction had significantly positive effects on perceived ease of use and greatly impacted motivation. The idea that motivation, self-efficacy, and interactivity can play a significant role in learning is corroborated by Ramirez-Arellano et al. (2019) in their predictive study about blended learning within higher education environments. Huang and Liaw (2018), however, went further by concluding that virtual reality is an effective tool for student learning under a constructivist paradigm.

VR is increasingly being used for educational purposes. This has been brought about by

the development of more powerful HMDs, enhancements in usability, and the increased

availability of broader content covering more areas. VR allows students to be immersed in

authentic contexts while providing a safe and control environment to practice and develop new

knowledge. VR aligns well with the goals under constructivism; however, additional concerns

must be taken into consideration as the practice and research in this area continues to grow.

**Discussion and Recommendations**

Given the results, how can educators develop effective, engaging, and standardized procedures concerning VRLE and the constructivist paradigm? The answer lies within the area of critical thinking. Critical thinking generally refers to the following activities: Identifying key information, interpreting data, making inferences, generating conclusions, and giving evaluative feedback (Al-Ghadouni, 2021). All these areas of critical thinking can be seen from the results, which include practices from constructivist classrooms and research. To incorporate constructivism in the classroom along with critical thinking and VRLE, here are seven essential steps:

1. Create a plan about the virtual learning environment to explore.
2. Choose relevant participants (permissions).
3. Have active, designated sessions of open-ended exploration or partially facilitated interactions.
4. Allow time for critical evaluation and reflection.
5. Document participants’ responses and discoveries.
6. Determine if more interaction is needed to enhance the learning experiences.
7. Compare and contrast the suggested environment with other virtual learning environments.

The implementation of these steps do not have to be linear. For instance, a plan could be created after emergent exploration occurs. Comparing and contrasting could occur during exploration. Table 1 lists the typical times where each step occurs in terms of classroom instruction.

**Table 1: VRLE Activity Decision Table**

|  |  |  |  |
| --- | --- | --- | --- |
| Steps for VRLE Implementation | Before | During | After |
| Create a Plan | ✓ | X | ✓ |
| Choose Participants | ✓ | X | X |
| Have Active Learning | ✓ | ✓ | ✓ |
| Reflection and Evaluation | ✓ | ✓ | ✓ |
| Document Responses | X | ✓ | ✓ |
| Determine Next Steps | X | X | ✓ |
| Compare and Contrast | X | ✓ | ✓ |

*Note.* A table listing when steps should be done to implement a VRLE in the classroom, either before the activity, during the activity, or after the activity. ✓ = Yes; X = No.

We generally decide to create plans for a VRLE before using it in the classroom and after it is implemented. We may decide to use it again or recommend it to a colleague. We have an idea of the participants needed before implementation. Active learning, when looking through a constructivist lens, needs to occur as much as possible. Learning does not stop once students are outside of the classroom. The activities inside of the classroom need to connect with decisions made outside of the classroom.

Reflection and evaluation are supposed to be subjective. They can happen on the spot, or they can be preplanned. Whenever a person wants to create notes, comments, memos, drawings, charts, maps, games, and other works based on how they make sense of the world, that is part of the reflection and evaluation processes. The difference is that reflection is active thinking about events, which may or may not include evaluation. Evaluation is a subjective process of judging how good or bad something is. Reflection is a necessary part of all evaluations. Evidence can be created for both reflection and evaluation, but these can both be strictly mental exercises. When documenting students’ responses and reactions about a VRLE, it needs to happen during or after the actual experience. Then the next steps need to be decided after the activity has occurred. This decision would take into account how students respond, as well as other factors that could potentially influence instructional time. If teachers decide to include comparison and contrast as part of their objectives for lessons, these skills would be practiced during the activity and after it as part of the reflection process. The next sections discuss empirical examples and personal practices concerning the seven steps.

**Create a Plan**

Planning relevant lessons, units, and sessions pertaining to VRLE has to happen at some point in the learning and teaching processes. For constructivist-based learning methods, guidance should be kept at a minimum unless the activities require frequent communication to process information. The idea is to give participants structure without taking away their ability to make their own meaning out of what they learn. In this way, students are able to actually critically think about situations they encounter.

One good example is Chien (2022), where the question, observation, and organization (QOO) approach was used to enhance learning about foreign cultures. Students explored a spherical video-based virtual reality environment. They were asked questions about the environment to scaffold learning. They then observed the environment with mobile phones and HMDs to make sense of what was being asked. After observing the environment, students discussed their observations with one another and made an online mind map of their thoughts.

Another example of this can be found in Kengne et al. (2018). Action-Centered Exposure Therapy was used to help a particular case where the participant had trauma associated with a burning truck. There was a 3-step plan: Trivialize the Trauma, Make the Environment More Realistic, and Expose the Participant to the Trauma Indirectly. The participant experienced different scenarios to gain confidence about facing the fear. Without essential planning for what would happen in the VRLE, these activities would have failed.

From our experiences as researchers and educators, a plan has meant the difference between success and failure. There has to be some idea of direction before, during, and after lessons, and usually we have to write about our plans before actually implementing activities. Sometimes even when we have planned everything out in advance, there are problems in implementation. We do not always get to do what we would like to do with students, and from a constructivist perspective the best thing we can do is subjectively look at the situation, see what went wrong, take responsibility, and do better next time. In a constructivist world, knowledge is subjective. Students are the creators of the meaning. So even though there is planning, there is also encouragement not to plan when students need to explore a VRLE or when it would be better for them if we do not say anything. Knowing when to plan and when not to plan is something that comes with a good mindset, skillset, and experience level.

**Choose Participants**

It is possible to choose participants based on an overall plan or create a plan based on the participants chosen. Making meaning about what occurs in a VRLE is not a one-way process. There are different activities that can help get to a goal or objective that needs to be reached. Soliman et al. (2021) takes a general approach to explaining this by saying that past approaches for teaching were more passive, but this has changed given how students learn and how education has progressed. Current approaches in education favor active learning, blended learning, problem-based inquiry, visualization, and other constructivist-leaning strategies that require more interaction than traditional lecture. A more specific example would be Huang and Liaw (2018), who conducted research on an E-commerce virtual environment that included a 3d shopping mall. The environment was specifically implemented for undergraduates in information management.

For us, this step is probably one of the easiest parts because our plans involve learners in education. The grade level may change depending on the appropriateness of the information. Now, if we have to present at a conference or conduct professional development meetings, those are learning experiences where teachers in the audience are like students to a certain extent. For this article, we mainly talk about implementing a VRLE within higher education, but the concept itself is not limited to higher education. Meaning and interpretation are vast areas. Students should get the sense that they can explore who they are and how they think without being criticized harshly by authority figures.

**Have Active Learning**

Active learning is a requirement for constructivist activities where students are able to make meaning out of what they learn in an authentic way. Active, meaningful learning within a VRLE means that students are participating in the following ways: hands-on interaction, direct engagement with the environment, investigation of problems, or communication with others for clarification (Chen, 2009; Chien, 2022; Mackin et al., 2012; Soliman et al., 2021). The more immersive the environment, the better it is for students to make their own meaning without having outside influences make it for them. Critical thinking can occur when exploring word relationships, different points of view, evidence for or against an issue, and training programs (Al-Ghadouni, 2021). Chis et al. (2018) found that students performed best using problem-based learning in combination with a flipped classroom, which occurred during interaction with arrays within a software application. They did not perform as well with the lecture and practice method, which would be passive learning. Gautam (2018) actually had a 3d immersive environment that replicated an actual location on a college campus. Sensors, monitors, and servers were used to display the location in real time at another location. This made interactivity and social presence more accessible for those who were not actually at the real location.

Inside and outside of the university setting, there has been demand for authenticity. We need to know that people can understand what they are doing and have experiences that will prepare them for anything that may happen in the future. When we were growing up, we experienced more lecture-based learning than goes on today. Receiving information in a passive way, through lecture or demonstration, prescribes meaning to students. The student is told what is good and bad, right and wrong, fair and unfair. Well imagine asking them, “Well what do you think is good about collaboration with others? Would this strategy be right for you? What is fair about this ecosystem you are experiencing virtually? Can this problem be solved?” Students explore the ideas and make decisions for themselves just like any adult would in the real world. Responsibility is in their hands, and they can ask for help when needed. The world is a similar situation where we deal with issues and ask for help if we cannot find the solutions ourselves. We have to communicate and collaborate to get things done.

**Allow Reflection and Evaluation**

Participants need to understand how they organize concepts within their mind. They need to be able to reflect on what they already know, what is new to them, and what they hope to learn in the future. Within a constructivist paradigm, learning must have non-linearity. This means that learners can draw their own conclusions in a way that is not done for them. There is no set, prescribed way to make meaning out of an environment. Spiers et al. (2022), for instance, created a study for three virtual-reality environments that were combined to make the Museum of the Future. They were implemented with the HTC Vive Pro and Oculus Quest 2. The consequences and choices within the museum depended on what the learner decided to do while exploring.

Virtual reality is often utilized within non-English majors, especially within the areas of healthcare, biology, computer science, astronomy, and fire training (Oyelere et al., 2020). A study done by Wen and Fu (2021) showed that English majors were able to understand the capabilities of VR when explained within a college course and could better explain it when compared to their counterparts. Survey research was implemented to get students’ feedback about what they learned within a college-level VR course.

What we like especially about VR is that it can cross different cultures and subject areas. It can be a made-up culture or something very familiar to real life. The idea that a student can travel just about anywhere with the right program and equipment is a great thing in terms of growth and development. Integrating the STEM areas into the Arts and vice versa is something that is encouraged within the education sector right now. With the demand for more people and more diversity in STEM jobs, this is not going away anytime soon. Non-linearity, while not a new concept, can be good or bad depending on the outcome teachers are trying to reach. In a constructivist classroom, being exploratory is a great thing, but it is not always the default option if the concept for the day requires students to understand specific terms and formulas. Students will have opportunities to make meaning out of problems, but it has to be done within the context of what needs to be accomplished.

**Document Responses and Reactions**

While exploration of environments can be fun, the responses about those interactions need to be documented. This can be done in a variety of media, such as audio recordings, video interviews, chat logs, surveys, or personalized forms. Zhang (2021), for example, used quizzes, an interview, and a questionnaire to determine what participants found important for three immersive VR storytelling experiences. The environments were designed with Unity 3d and displayed using an Oculus Quest 2 VR system. Interactivity was most important for engagement, and novelty was essential for the experiences themselves.

Vergara et al. (2020) supports this by finding that interactivity decreases as students get used to experiences from a VRLE. Having them view a new version of a VRLE returns the interactivity to high levels until the novelty wears off over time. Although the VRLEs in this study were non-immersive, surveys were used to provide feedback on how to improve them over time. Baxter and Hainey (2020) used a questionnaire with undergraduate students and found they perceived VR as something that was very innovative, enhanced learning, enhanced skills, and enhanced self-efficacy. Males were more enthusiastic about its potential than females.

Within our own educational practices, we are not strangers to documentation. Research about VR would be difficult to carry out without some proof and verification of what the participants are saying. It would be hard to get funding without evidence that something works or that something is getting done within our areas of expertise. Sometimes samples help teachers to look back and determine what happened and why. Technological glitches can happen, and it is easier to resolve an issue if there is someone who has had experience with the issue. There are countless times when a simulation has been slow, a program just crashes, or there is a special event being held on a day when there was not supposed to be one. Hardware can overheat due to difficulty processing information and graphics. Sometimes unexpected moments help students make meaning out of learning in a way that is supported by constructivism. For instance, if a headset stops working for a student, that student has to find ways to address the issue. The student has to make choices on the spot. They might discuss the issue with a teacher and possibly other students. A conclusion has to be reached about the problem. If somebody is sick for a day when a VR lab session is scheduled, decisions have to be made based on the absence of that particular person. Does the student need to go to the lab independently to make up the activity later? Can someone give the student help outside of class to catch them up on the information? Does an alternative activity need to be created? These are questions that are typical during semesters when people are unexpectedly absent due to illness.

**Determine the Next Steps**

Sometimes what needs to be learned cannot be completed within one or two days. There may need to be a period of review or enrichment for participants to get the most out of their experiences. Vergara et al. (2020) used a second, similar VRLE that not only was a review of the old VRLE system but an enhancement of the new VRLE. Kawulich and D’Alba (2019) used Second Life as a way to teach ethnographic research to doctoral students. The students explored a variety of simulations within Second Life, made multiple observations about them, and conducted interviews with people participating in the environments. The environments had to be revisited repeatedly to gather the necessary data for the research projects.

Doerner and Horst (2021) taught a semester long AR/VR course in phases that required lecture, presentations, prototyping, demonstrations, experimentation, and tutoring. Out of what is listed, the constructivist-based activities within the course were the presenting, prototyping, and experimentation. Sometimes formal training or professional development may be required for specific VR environments. For instance, Mystakidis and Christopoulos (2022) surveyed primary and secondary teachers about using a virtual reality escape room for teaching purposes. They tested the game themselves, and it was discovered that technological competency, language familiarity, and formal training about the game were all needed in order to get the most out of it. This would take more time to accomplish, but students and teachers would have more favorable experiences with the game in the long run.

Constructivist teaching, from our perspective, requires ongoing evaluation since it is mainly concerned with the subjective. This would be in the form of formative and summative evaluations. A VRLE in and of itself would likely include assessment and evaluation of the formative nature, but a summative test, survey, chat, or interview could be held in that environment to conclude lessons. There are different factors that can influence a decision as to whether or not to extend a lesson beyond what is considered normal for class time, including constraints that are financial and time-based. When deciding to extend coverage for an activity, we often have to change up our plans. Maybe more time is given to the creation of models for a project and less time is given to discussing a chapter that is required reading for an assignment. Some activities could be posted online to be completed as homework, while other activities can be done in class.

**Compare and Contrast Environments**

Now that participants have had experiences with at least one VRLE, it is important to give them time to find similarities and differences among other environments. Virtual environments can provide more engagement, empathy, creativity, and complexity than traditional environments (Hu-Au & Lee, 2017). Diversity is a key component within successful VR experiences because more opportunities encourage individuals and groups to create additional meanings that connect worlds together (Barrie, 2022). The order in which strategies are presented may influence the amount of engagement and satisfaction individuals have with the learning process. Liaw et al. (2019) determined that out of web-based instruction, face-to-face simulation, and virtual reality experiences, the face-to-face simulations had the highest results in terms of authentic learning and learning satisfaction. When presented within a blended learning context, the best order for self-efficacy was web, simulation, and virtual reality. The worst was simulation, web, and virtual reality. Students preferred web, virtual reality, and simulation, which was the most engaging.

We note here that comparison and contrast can be completed between and within environments. They need to be skills that are done almost automatically when entering a VRLE. In other words, we should not have to tell students to think for themselves. They are not there to think for the teacher. They are there to make sense out of the information and document their perspectives. We naturally want students to analyze an environment and organize that environment according to how they make sense out of information. It is alright to give students a prompt to take notes about things that stand out for them. They can make connections to real-world environments or to other virtual environments. Concept mapping electronically or in writing would be evidence of students’ organization of information.

**Conclusion**

There have been several exploratory studies on how VR can be incorporated into student

learning. Constructivism is one learning theory that explains why VR is a useful tool for the

classroom and how it can be utilized for educational purposes. VR simulations expose students to a variety of experiences, provide ample opportunity for reflection, allow instructors to assess

learning outcomes, and provide a mechanism for feedback. While there are several important

considerations in curriculum development with VR, the technology has been shown to be a useful tool for learning. VR can be used to strengthen current teaching approaches, thus providing educators with additional opportunities to increase motivation, engagement, and learning outcomes.

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