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Immersive Virtual Reality as a Tool to Make in K-12 Environments

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Immersive Virtual Reality as a Tool to Make in K-12 Environments

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Education at Virginia Commonwealth University.

by

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Table of Contents

List of Tables

List of Figures

Abstract

IMMERSIVE VIRTUAL REALITY AS A TOOL TO MAKE IN K-12 ENVIRONMENTS

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Immersive Virtual Reality (VR) is beginning to be implemented into K-12 contexts. As this technology makes its way into more learning environments there is a need to not only understand how to address curricular goals with this technology, but which frameworks for learning best inform the use of this tool. In addition, previous research has called for a need to begin to explore how immersive VR can be used as a tool for creation in K-12 classrooms (Maas & Hughes, 2020). This multiple-case study aimed to address these needs by examining the use of VR as a tool to create digital artifacts with high school science educators through a professional development experience.

Chapter 1: Introduction

Statement of Problem

Fully immersive Virtual Reality (VR) is an interactive technology which includes a head-mounted display (HMD) and an internal or external computer that allows the user to interact with the virtual world with physical movements or with controllers or a joystick (Lee & Wong, 2014; Maas & Hughes, 2020; Southgate et al., 2016). Immersive VR technology is being brought into the K-12 educational space in terms of practice and educational research, which has led to a need for research examining the possible affordances for student learning (Billingsley et al., 2019; Mass & Hughes, 2020). These affordances include making the impossible possible (Freina & Ott, 2015; Ludlow, 2015; Majid & Shamsudin, 2019), active learning (Ludlow, 2015; Papanastasiou et al., 2019), motivation to learn (Clark, 2006; Majid & Shamsudin, 2019), and differentiation (Levin, 2011; Ludlow, 2015). Additionally, VR technology allows for not just data consumption but for creation as well, and this shift may be important as VR is integrated into K-12 environments.

To understand the educational affordances of immersive VR, a clear definition must be articulated. Research studies have been inconsistent in differentiating between the levels of immersion that VR provides the user (Maas & Hughes, 2020). Experiences incorporating desktop user interfaces such as virtual environments (i.e., Second Life or virtual schools) are not differentiated from immersive HMD technology (i.e., HTC Vive, Oculus Quest, or Google Cardboard paired with a smartphone). A clear delineation of various types of VR systems is imperative to establish a clear line of research in the field.

Rationale for Study of Problem

Though virtual environments are not new to education, immersive interactive virtual reality experiences are more recently making their way into education. In order to find the full potential of immersive interactive VR in education it has to be tested (Martirosov & Kopecek, 2017). However, focusing on how VR is tested in education in terms of curriculum connections and appropriate pedagogy should not be lost. It is important to pair effective pedagogy with the technology in K-12 environments (Maas & Hughes, 2020). While VR has been seen as a technology that has the potential to change education, aside from training simulators for surgeons, pilots, and military personnel VR has not been applied to education at large (Jensen & Konradsen, 2018). Though the possibilities of incorporating VR into education are seemingly endless and exciting, it is important to remember technology is not inherently educative and it is essential to design instructional activities that help to determine the educational value technologies could bring to learning (Burbules, 2016; Papert & Harel, 1991; Selwyn, 2015; Tan, 2018; Toyama 2015).

Technology is a tool that when combined with effective pedagogical practice can lead to affordances for learning in and out of the classroom. Virtual reality is no different and should be examined through a lens that combines effective pedagogy, high quality learning experiences, and the use of the technology. Not only does successful technology integration in education require knowledge of the possible affordances of a technological tool, and knowledge of how to design instructional activities, but it also hinges upon knowledge of the content at hand (Billingsley et al., 2019).

The current state of immersive interactive VR in education focuses on students consuming knowledge in VR environments (Maas & Hughes, 2020). However, this tool can be used as a creative tool for learners to make digital artifacts of their learning. Of the few available studies using HMDs with secondary education examined in the literature review published by Freiena and Ott (2015), one focused on helping teachers with classroom management (Silva et al., 2014), one experience was a physics simulation (Civelek et al., 2014), and one was an interactive chemistry lab (Ali et al., 2014). Two of the three previous studies focused on providing students an alternative experience where safety was a main focus, the other allowed teachers to experience scenarios that allowed them to hone their classroom management skills. None considered creation. The possibilities of using VR as a tool to create are currently unexplored in educational research despite how this could allow students to engage in learning in powerful new ways. The framework of maker-centered learning may help to understand VR as a tool with which to create.

The current study examined the experience of science educators learning to use VR as a tool for educational creation and developing learning activities aligned with their curriculum. VR has previously also been used for teacher professional development. However, in their literature review focused on VR use in pre-service and in-service teacher professional development Billingsley et al. (2019) found only seven studies focused on this topic; two used VR to help develop classroom management skills, two dealt with knowledge of special education topics, two worked to enhance participants' awareness of students' emotional needs, and only one used VR to increase content-area learning. Using VR as a tool for creation that aligns with curricular goals is an identified gap in the literature which this study addresses. The present study was developed through pairing creation in immersive VR environments with focused attention to content-specific learning (Billingsley et al., 2014) and addressing the questions of how and for what VR using head mounted displays should be used (Jensen & Konradsen, 2018).

Significance

The cost of VR tools is decreasing while ease of use is increasing, leading to interest in where this tool fits into educational research and practice (Martirosov & Kopecek, 2017). Not long ago, access to VR equipment hinged on large budgets and specific skill-sets (Baya & Sherman, 2016). However, the increased accessibility to low-cost VR experiences has accompanied the rise and increased ubiquity of smartphone technology (Ralph, 2015). Though VR is still an emerging technology and even more so in educational contexts, the increasing affordability and promising preliminary research (Civelek et al., 2014; Freina & Ott, 2015; Jowallah et al., 2018; Kwon, 2019; Ludlow, 2015; Majid & Shamsudin, 2019) has shown it is important for teachers to understand how best to integrate this technology into their instruction. This shift from access to VR experiences relying on high budgets and skill-sets to being built off of smartphone technologies (e.g., Google Cardboard and the Oculus Quest), these technologies and experiences will begin to make their way into K-12 learning contexts. Frannsson and colleagues (2020) suggest that there will be a drive to increase the use of immersive VR in educational contexts even with the content and feasibility of using the technology are still being understood. With this being the case, it is important to understand how these technologies can be leveraged to address student learning. The results from this study can be used by school districts, departments of education, and professional development providers. This study directly adds to the literature focused on how VR can be used in classrooms.

Context of the Study

With the increased affordability and ease of use of immersive VR it is important to understand the reported affordances of VR, making the impossible possible (Freina & Ott, 2015; Ludlow, 2015; Majid & Shamsudin, 2019), active learning (Ludlow, 2015; Papanastasiou et al., 2019), motivation to learn (Clark, 2006; Majid & Shamsudin, 2019), and differentiation (Levin, 2011; Ludlow, 2015). Not only must current research and practice focused on the use of VR in educational settings keep the affordances in mind, it is important to directly connect the use of these technologies to student learning and teacher goals in the classroom. As these tools are becoming more prevalent in K-12 settings, it is the perfect time to evaluate the current implementation of the technology, reflect on the affordances, and look for new opportunities to leverage these tools for learning.

Using immersive VR in classrooms to simply replace or replicate existing technologies such as video does not capitalize on the possible affordances of the technology. Finding the appropriate frameworks that not only help to maximize leveraging the possible affordances of immersive VR, but to begin to shine new light on how these tools can be used in K-12 educational contexts to address student learning and outcomes is necessary to establish where and how immersive VR can be used in schools. In addition to learning frameworks to implement immersive VR into K-12 settings, it is important to include the voice and perceptions of K-12 educators. Allowing current practitioners to use immersive VR technology to address student learning, and reflect on where these tools fit into their classrooms will add to the field.

Statement of Purpose

The purpose of this study is to determine the affordances VR tools bring to educational experiences when paired with creating artifacts of learning. I collaborated with secondary science teachers at County High School (CHS, pseudonym) in a professional development experience focused on using VR to align with curricular goals and encourage maker-centered learning in their lesson development. This novel use of VR in a K-12 environment will contribute to the literature examining the possible affordances of VR in education. In addition, the current study began to explore the role VR may play in maker-centered learning.

Research Background

The research background includes information on the maker movement, maker-centered learning, and virtual reality in education.

The Maker Movement

The maker movement has been defined by Halverson and Sheridan (2014) as "...the growing number of people who are engaged in the creative production of artifacts in their daily lives and who find physical and digital forums to share their processes and products with others" (p.496). This movement includes hobbyists, tinkerers, engineers, hackers, and artists who creatively design and build digital and physical objects for both playful and useful ends (Martin, 2015). Though the idea of making is not new to humanity, the current maker movement in general is distinguished from previous iterations of making through the use of digital desktop tools, the cultural norm of online collaboration and sharing ideas and designs, and embracing common design standards which in turn leads to increased sharing and iteration (Anderson, 2012, Halverson & Sheridan, 2014). Those who participate in the maker movement, engage directly with materials in hands-on creation have been termed makers. Makers not only create artifacts with a variety of tools, but they also share their artifacts with a public audience. The shared artifacts are usually accompanied by how-to directions, or editable digital plans that can be remixed and iterated upon. Making can be physical (e.g., constructing something out of wood, metal, or cardboard) or digital (e.g., coding or 3D design).

Virtual Reality in Education

There are two distinct types of VR experiences, non-immersive and immersive (Carmigniani et al., 2011; Freiena & Ott, 2015; Maas & Hughes, 2020). Head mounted displays paired with hand-held controllers for movement are used to provide fully immersive experiences with 3D virtual environments (Lee & Wong, 2014; Maas & Hughes, 2020; Southgate et al., 2016). Immersion and presence are both important aspects of immersive VR. Formally, immersion is achieved by using immersive technology (Jensen & Konradsen, 2018). Users can experience a sense of presence when engaged in immersive VR experiences. This sense of presence, or the user's sense of being in the virtual environment (Martirosov & Kopecek, 2017), is something that can provide novel experiences and methods of interacting for the user. In turn, an increased sense of presence has been shown to correlate with better learning outcomes (Jensen & Konradsen, 2018; Martirosov & Kopecek, 2017).

Learning using virtual environments is not a novel idea, the first recorded use of a digital VR system was in 1966 by the United States air force for flight simulation training (Kavanagh et al., 2017; Page, 2000). In addition, Bricken (1990) noted presence as one of the main benefits of learning in virtual environments and constructivism as the theoretical model supporting learning in virtual environments (Mikropoulos & Natsis, 2010). However, research on immersive VR in education is still emerging. Immersive VR experiences are quickly developing as the technology becomes more affordable and user friendly (Freiena & Ott, 2015). Immersive and interactive VR has the potential to turn users into active participants as opposed to passive observers of virtual environments (Checa & Bustillo, 2019).

Some marked benefits of incorporating VR include increased content understanding when learning about spatial structure and functions, language learning, improved physical task performance, and an increase in engagement and motivation when learning (Bacca et al., 2014; Jensen & Konradsen, 2018; Lee, 2012; Lindgren & Johnson-Glenberg, 2013; Maas & Hughes, 2020; Radu, 2014). Using VR in education makes the learning process more enjoyable by allowing learners to explore hidden phenomena or distant locations, and manipulate objects that would be impossible in the physical world (Martirosov & Kopecek, 2017).

Theoretical Framework

Research examining the pedagogical affordances of the maker movement on education is emerging, especially in the context of formal schooling (Nemorin, 2016). Clapp et al. (2017) coined the term maker-centered learning which places an emphasis on learning and is more nuanced than simply making. There are three pillars of maker-centered learning; characteristics related to community, characteristics related to process, and characteristics related to environment (Clapp et al., 2017). Clapp et al. (2017) explain that environmental characteristics include, “open spaces, accessible spaces, and tool- and media-rich spaces” (p. 8). Makerspaces, the embodiment of the maker-movement, possess these characteristics and are being implemented within schools and classrooms. When implemented in schools, these spaces can be found in and out of the classroom and are places for learners to construct knowledge rather than receiving direct instruction from teachers (Paganelli et al., 2017). When learners participate in making, they learn by constructing mental models and physical objects (Trust et al., 2017). Learning in this way transcends content areas, and increases student engagement (Civelek et al., 2014; Jowallah et al., 2018; Parong & Mayer, 2020; Patterson & Han, 2019; Schrader & Bastiaens, 2012). Implementing learning through making has the potential to engage all learners through active, hands-on learning that emphasizes critical thinking, problem solving, creativity and collaboration (Hsu et al., 2017; Trust et al., 2017). Maker-centered learning fosters an environment where the learner is an active creator of knowledge and not a passive recipient of information (Trust et al., 2017).

Cross-curricular instruction in formal learning environments could be promoted through maker-centered learning. Making activities are driven by interest-based topics that combine humanities, arts, and STEM (Davee et al., 2015; Oliver, 2016a; Oliver, 2016b). Cross-curricular learning has the ability to increase motivation as well as encourage new ways of thinking (Beckmann, 2009).

Participating in maker-centered learning allows learners to select how they learn and promotes student choice (Trust et al., 2017). Student choice could positively impact learning outcomes by increasing student engagement, promoting student agency, and providing students ownership over their learning (Clapp et al., 2017). This agency cultivated through maker-centered learning and an iterative learning process could help learners overcome challenges in and out of the classroom. One of the benefits of promoting student ownership over learning is students can infuse their interests with their learning.

Research Questions

1. How do CHS science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content through a professional development experience?

2. How do CHS science educators perceive the benefits and limitations of using Virtual Reality to facilitate maker-centered learning activities which address K-12 science content through a professional development experience?

Methodology

In order to identify the affordances of VR when paired with maker-centered learning, data from multiple sources will be collected and triangulated. Semi-structured Mini VR Maker Faires will be conducted while the high school science teachers are exploring the technology and developing lessons with the VR tools aligned with their content areas. In addition, individual post-PD interviews will be conducted with each participant in order to individually debrief, reflect on the process, describe the connections between VR and supporting their goals as science educators, and reflect on the possible perceived benefits and limitations of VR aligned with content. Teacher created artifacts of learning will be collected and analyzed. Finally, the lessons developed by participants will be evaluated using the principles of maker-centered learning, affordances and limitations of VR when integrated into a K-12 learning experience, and the intersection of VR and maker-centered learning.

Using a qualitative adaptive single-case case study methodology, I will seek to uncover the perceptions of the participants involved in the study when learning the VR tools and developing learning experiences using these tools. Collecting data points from multiple sources and triangulating the data will be essential in the investigation of this contemporary phenomenon (Yin, 2018).

Summary

As VR enters the realm of K-12 education there is a need to understand how to connect this technology to content taught in the classroom as well as high quality pedagogy. Additionally, one promising pedagogical use for VR needing further research is using VR as a tool for creation in educational contexts. Focusing on creating artifacts of learning with VR will contribute to understanding affordances the technology has for education and maker-centered learning. This aligns with recommendations posed by Maas and Hughes (2020) who stated a need for future research to consider this technology as a means of creation and discovery. Providing the opportunity for educators to explore VR technology and developing VR curricular activities will address identified gaps in the literature while exploring VR as a tool for maker-centered learning.

Definition of Terms

Words that may be misinterpreted or unknown to the reader are defined in the following section.

Head-mounted Display. A device that a user can wear on their head while engaging in Virtual Reality to increase presence and immersion.

Immersive Virtual Reality. Virtual Reality which incorporates a head-mounted display to create an environment where the user feels as though they are actually present.

Makerspace. A place where informal learning takes place through the creation of digital and physical artifacts.

Maker-centered Learning. A learning framework developed by Agency by Design and their work through Project Zero at Harvard University which draws upon the maker movement, constructivism, and constructionism.

Maker Movement. A global effort which began outside the realm of K-12 education that emphasizes collaboration and creating digital and physical artifacts.

Chapter 2: Review of Literature

As immersive virtual reality (VR) is incorporated into K-12 learning environments, there is a need to understand how to encourage active learning as opposed to passive VR experiences (Checea & Bustillo, 2020). While VR technology is still in its infancy and adoption in K-12 schools is only emerging, researchers have already expressed the need for learners to use VR as a tool to create and not just consume (Maas & Hughes, 2020). Active creation using VR may be supported by maker-centered learning and its emphasis on constructing and sharing artifacts of learning (Halverson & Sheridan, 2014). Through a review of the literature, we aim to explore how maker-centered learning and immersive virtual reality (VR) technology may be used to support K-12 teaching and learning.

Immersive Virtual Reality

Immersive VR combines the visual with the physical. With VR, the user can provide feedback from their body movements in immersive, realistic, three-dimensional environments (Aarseth, 2001; Majid & Shamsudin, 2019). However, defining VR has proven a complicated task (Jowallah et al., 2018). Though definitions vary, most describe a digital representation of a three-dimensional object and/or environment (Kavanagh et al., 2017), and an emphasis on multisensory experiences (Fuchs et al., 2011; Jowallah et al., 2018). VR technology also allows for communication through text or speech (Burdea & Coffit, 2003; Ludlow, 2015), and provides opportunities for real time interactive feedback in graphic images generated by computers (Majid & Shamsudin, 2019). Technologies that provide an altered sense of reality can be classified along a continuum developed by Milgram et al. (1994); true virtual reality, mixed reality, and augmented reality (Ludlow, 2015). Immersive or true VR devices needed to engage in immersive experiences are becoming increasingly affordable and accessible (Freina & Ott, 2015). Michael

Abrash, one of the creators of the Oculus Rift VR system, has stated that VR is the next major technology platform and placed an emphasis on the notion of reality being nothing more than experiences interpreted by the brain which is no different in the physical real world or a virtual world (Ludlow, 2015; Solon, 2015). It is reported that in time, augmented reality (AR), mixed reality (MR), or virtual reality (VR) will be defined as XR, but this term XR is also used to define experiences that combine aspects of AR, MR, or VR (Joyce, 2018).

VR technologies have been used in military situations to prepare for combat, in the medical field to teach procedures, and by engineers for product design and development (Kapp & O-Driscoll, 2010; Ludlow, 2015). These fields, including the aviation field, have set the stage for future development and implementation of VR in other fields (Jowallah et al., 2018), which has been limited due to technical restrictions (Bracken & Skalski, 2010; Kwon, 2019). Research has called for a more explicit definition of VR and suggests a shift from virtual realities to immersive virtual realities (Fransson et al., 2019; Lorenzo et al.,2019; Šašinka et al., 2019). The term *virtual reality* has typically encompassed desktop experiences using a computer monitor and immersive VR experiences using head-mounted displays (HMDs). VR allows the user to have first-person experiences that are not only immersive because of the use of HMDs, but also interactive because of the use of tactile gloves, controllers, and motion sensors (Martín-Gutiérrez et al. 2016; Papanastasiou et al., 2019). Fransson et al. (2020) express the importance of distinguishing between 2D VR experiences in virtual environments using a computer monitor such as Second Life and 3D VR experiences through mobile and computer driven HMDs. These two technologies engage users differently and these differences are not always acknowledged in research (Fransson et al., 2020). In their review of the literature, Maas and Hughes (2020) explained one challenge in reviewing VR technologies in K-12 education is the lack of differentiation in desktop and immersive VR experiences; often the terms were used interchangeably. This review of the literature will focus on immersive VR using HMDs, which will provide clarity to the field and follow the guidelines expressed by Fransson et al. (2020).

Immersion, interaction, and involvement are three basic principles which characterize VR (Majid & Shamsudin, 2019; Pinho, 2004). Being transported into an alternate context that feels realistic (Dede, 2005; Buchanan, 2006) is how Martirosov and Kopecek (2017) explain immersion. VR requires hardware and software powerful enough to create an immersive 3D spatial experience (Martín-Gutiérrez et al., 2016; Papanastasiou et al., 2019), one in which the real world is fully replaced with a computer-generated virtual world (Orlosky et al., 2017; Papanastasiou et al., 2019). One form of immersive technology is an HMD which has an internal computer or is connected to one externally (Maas & Hughes, 2020) and immerses the user in a fully 3D environment. The use of HMDs in VR maximizes realistic and immersive experiences with 3D images (Patterson & Han, 2019) by removing any visual connection to the real world (Carmigniani et al., 2011; Maas & Hughes, 2020).

The psychological sense of presence is linked with the concept of immersion. Though these terms have been used interchangeably in the literature, immersion is the result of multiple impressions while presence is a subjective experience and the reason users feel more psychologically present in the virtual world (Bailenson et al., 2008; Dede, 2009; Mikropoulos & Natsis, 2011). Users experience a sense of presence in immersive VR environments which can provide novel experiences and methods of interacting for the user. This sense of being in a virtual world as a separate entity can transform users into participants in an alternate world (Mikropoulos & Natsis, 2011). Due to the fact that different people will perceive experiences differently, presence is a very subjective experience (Checa & Bustillo, 2020). Presence can also lead to less distractions from outside of the virtual world (Hite et al., 2019). There is a range of immersion provided by different technologies; Desktop computers or printed books provide a lower level than immersive VR using HMDs (Parong & Mayer, 2020). This vivid and spatial experience that is provided in immersive VR is closer to the experience of actual reality than what is provided by desktop computers or traditional computer games (Kwon, 2019). Interaction refers to the ability to directly manipulate objects using devices such as gloves, controllers, or more recently with one's hands (Majid & Shamsudin, 2019). This allows users to break away from symbolized interaction methods provided by other types of desktop computer experiences such as a joystick, keyboard, mouse, or trackpad (Kwon, 2019). Being able to interact with virtual objects may promote a better understanding of how things work (Martirosov & Kopecek, 2017), and allow users to manipulate objects that are otherwise impossible to manipulate in the real world (Martirosov & Kopecek, 2017). Users can not only move objects that are too heavy or large to move in real life, but also suspend the limits of physics and place objects in midair. Further, users can get haptic feedback from these objects in the form of vibrations (Civelek et al., 2014), which is one way to increase the effectiveness of real-world simulations (Civelek et al., 2014; Fisch et al., 2003).

Involvement is closely related to interaction in that it refers to the user's ability to navigate the virtual world (Majid & Shamsudin, 2019). Immersive VR provides this experience either by using a controller or by having the user physically move. Pairing interaction and near-realistic involvement by physically walking can lead to the VR experience being felt as an actual experience (Kwon, 2019).

Maker-centered Learning

The maker movement is a global effort that began outside the realm of education. This movement is made up of do-it-yourself (DIY) tinkerers, hackers, designers, and inventors has been increasingly expanding (Eriksson et al., 2018; Vossoughi & Bevan, 2014). Making is not limited to a specific tool-set, but instead involves anyone who ideates, designs, and produces a physical or virtual object in the world (Blikstein, 2013; Vossoughi & Bevan, 2014). Halverson and Sheridan (2014) define the maker movement as, "...the growing number of people who are engaged in the creative production of artifacts in their daily lives who find physical and digital forums to share their processes and products with others" (p. 496). The maker movement has the potential to democratize access to the skills and abilities needed to become a producer of artifacts, especially when those artifacts use 21st-century technologies (Halverson & Sheridan, 2014).

Incorporating the maker movement into K-12 education could transform how we understand what counts as learning, what it means to be a learner, and what makes up a learning environment (Halverson & Sheridan, 2014). *Maker-centered learning* draws upon the maker movement as well as the theories of constructivism and constructionism (Clapp et al., 2017). According to Clapp and colleagues (2017) see the connections between constructivism and maker-centered learning lying in tinkering and figuring things out because both actions start with a personal idea that becomes further shaped and developed through direct, experiential action. Constructionism, developed by Seymour Papert, places an emphasis on learning-by-making (Papert & Harel, 1991). Learning-by-making is more about how learners engage with materials as well as technology, it places importance on giving learners good things to do with these tools so they can learn better than they could before (Papert, 1980).

There are both primary and secondary benefits of maker-centered learning (Clapp et al., 2017). These range from learner agency and mindset shifts to developing STEM and other content knowledge (See Table 1).

Table 1.
The primary and secondary benefits associated with maker-centered learning (Clapp et al. 2017, p. 41)

Primary Benefits of Maker-Centered Learning	
Developing Student Agency	
Stuff Making	Finding opportunities to make things that are meaningful to oneself and taking ownership over that process of making.
Community Making	Finding opportunities to make things that are meaningful to one's community and taking ownership of that process of making, either independently or with others.
Building Character	
Self-Making	Building competence as a maker, building confidence in one's maker abilities, forming a maker identity.
General Thinking Dispositions	Supporting various patterns of thinking that are perceived as being beneficial across domains.
Secondary Benefits of Maker-Centered Learning	
Cultivating Discipline Specific Knowledge and Skills	Fostering the development of knowledge and skills within the STEM subjects and other disciplines.
Cultivating Maker Specific Knowledge and Skills	Fostering the development of knowledge and skills with regard to maker-specific tools and technologies.
	Fostering the development of knowledge and skills with regard to maker-specific processes and practices.

These benefits also lead to a cultivation of a sensitivity to design, which is the central focus of the pedagogical framework for maker-centered learning (Clapp et al., 2017). According to Clapp and colleagues (2017), sensitivity to design means, "being attuned to the designed dimension of objects and systems, with an understanding that the designed world is malleable" (p. 117). This sensitivity to design not only requires the learner to understand how things fit together, but they also must possess the agentic know-how to see their impact on the world around them. Clapp et al. (2017) identify three interrelated, non-sequential, maker capacities that are important in all phases of making, designing, or redesigning.

1. Looking Closely - Close, careful, and mindful observation that is sustained in order to see beyond first impressions.
2. Exploring Complexity - Examining the relationships between objects or systems, consider how an object is used and by whom, and develop a deep understanding of how the object was made.
3. Finding Opportunity - Seeing the potential for building, tinkering, re/designing, or hacking.

Researcher Identity

As a researcher and practitioner, I have been interested in the possible educational affordances maker-centered learning could bring to K-12 education. This interest and experience in both researching and implementing maker-centered learning brought a balanced perspective to the study. Though I am no longer in the classroom, as a classroom teacher I saw how having students create digital and physical artifacts in the classroom could positively impact their learning. I kept this idea with me as I changed roles to a coach and now division administrator and researcher. I am curious in investigating the possible educational affordances of maker-centered learning when it is tied to curricular goals.

More recently with the release of more affordable immersive VR I have been interested in where or if this tool could fit into maker-centered learning. I have noticed how at times designing digital artifacts with a traditional computing setup using a trackpad/mouse and keyboard could hinder a student's productive use of the tools. Though immersive VR is a relatively new tool to me as an educator it seems as though it could have a place in maker-centered learning.

My interests in both maker-centered learning and VR brough a personal and professional connection to the topic of the current research. However, I addressed any potential biases I brought to the study in a number of ways. The biases were addressed through writing reflective memos following each interaction with the participants. In addition, all questions asked throughout the study were open-ended and avoided leading the participants to answer a certain way.

Review of Literature

Method

The Academic Search Complete, Library, Information Science, and Technology Abstracts, Education Research Complete, Library Literature and Information Science Index, Computers and Applied Sciences Complete, Art Full Text, and Education Resources Information Center (ERIC) databases were utilized to examine how immersive VR is being used in educational contexts for maker-centered learning. The search was constrained from the years 2005 to 2020. Starting with the year 2005 was a purposeful decision to align with the first published issue of Make Magazine. Though this date does not mark the beginning of the maker movement, Make Magazine has been credited as a force used to popularize the maker movement in the general population (Martin, 2015). The following terms were used in the search: (Virtual Reality) AND (Makerspace). The second search was conducted with the search terms (Virtual

Reality) AND (Maker Movement). The third search conducted the same day used the search terms: (Virtual Reality) AND (Maker*).

After examining the literature from the first three searches, it became evident that using VR as a tool for making was yet to be examined but frequently noted as an important next step in the field. Researchers noted a need for creation and creative pursuits when using VR in K-12 education (Ludlow, 2015; Maas & Hughes, 2020). This need, analogous to other instructional technologies, suggests a shift from learners simply consuming data to becoming producers of data in virtual environments (Maas & Hughes, 2020). K-12 educators are still in early exploration of how VR can be integrated into their classrooms (Minocha, 2017) and have yet to engage in large scale testing, curating, and reviewing VR experiences that can be pedagogically beneficial for students (Fransson et al., 2020). As no articles were located focusing on VR as a tool for making other than listing it as a focus for future research, one additional search was conducted to survey the use of VR in education more generally with the aim that literature may be located to provide guidance for integrating making with VR in K-12 environments. The fourth and final search conducted used the following search terms: (Virtual Reality) AND (K-12 Education).

Table 2.
Process of Review

1. Aim	To determine research performed on VR and education that overlaps with themes of the maker movement in education.
2. Search Strategy	Boolean searches using: Virtual Reality AND Makerspace; Virtual Reality AND Maker Movement; Virtual Reality AND Maker*; Virtual Reality AND K-12 Education
3. Inclusion Criteria	Empirical and conceptual research focused on the use of fully immersive virtual reality experiences using head-mounted displays in K-12 educational contexts including classroom use with students and teacher professional development. Formal and informal (e.g., museums and libraries) learning

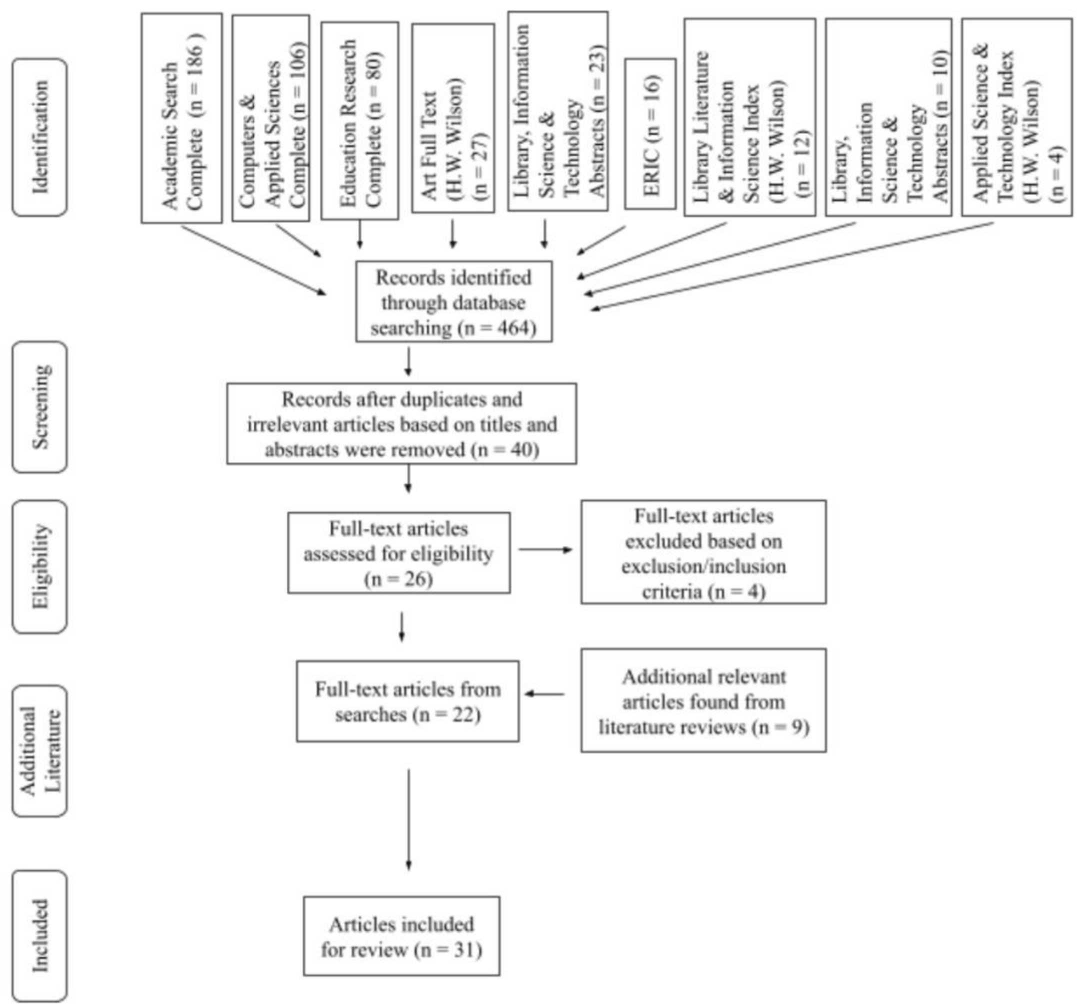
	environments will both be included. Full text (if an abstract is found a full text article will be requested), peer-reviewed, scholarly articles written in English and published between the years 2005-2020.
4. Exclusion Criteria	Articles focusing on the use of desktop non-immersive virtual reality (e.g., Second Life, virtual worlds), augmented reality, or mixed reality, studies focusing on higher education, and studies written in languages other than English
5. Data Extraction	Read studies and collect relevant information.
6. Synthesis of Data	Identifying themes in order to create across study connections.
7. Report	Results analyzed and summarized to demonstrate the empirical research performed on the virtual reality and K-12 education.

Study Selection

Four searches were conducted using different search terms in order to glean the most results. Following each search, all duplicate articles were removed and each abstract was read by the author. Inclusion and exclusion criteria were applied based on the abstract. If it was unclear from the abstract if an article fell within the scope of this review it was read in full to determine inclusion.

Figure 1.

Literature Inclusion Process



In order to increase the inclusion of relevant articles while removing duplicates a strategic process was followed. The search procedures were conducted as follows: the initial searches with the identified search terms, duplicates were removed, reading of each article title, reading of article abstract (if the title seems applicable), and reading of the entire article (if the abstract seems applicable). As noted in Figure 1, combining the four separate searches returned a result of 464 articles. The articles were imported into the Zotero reference management system in order to identify duplicate articles. Once the duplicates were removed the remaining articles were exported from Zotero into a Google Sheet where the researcher went through each article title. Following the importing of the articles into Google Sheets, each article title was read with the application of the inclusion and exclusion criteria. After removing articles that fell beyond the scope of the project based on the title, each article abstract was read from the remaining articles. Through reading the abstracts the researcher kept any article with the terms virtual reality, head-mounted display, immersive, or education. This process left 40 articles to read in full. The inclusion and exclusion criteria were applied to each article read. In addition to the inclusion and exclusion criteria, if articles solely focused on augmented or mixed reality and did not mention immersive virtual reality using head-mounted devices (e.g., Oculus Quest, HTC Vive, Google Cardboard, etc.) they were removed. If an article focused on multiple types of technologies, but included immersive virtual reality it was included.

Once the inclusion and exclusion criteria were applied to the 40 remaining articles, 22 articles fell within the scope of this project. In order to ensure the full picture of the field was represented in the selected literature the references of the previous literature reviews were examined for possible inclusion in the present literature review. The 11 literature reviews included in the search results were separated from the other 11 articles. The cited literature in each review was thoroughly analyzed using the same inclusion and exclusion criteria applied to the other articles. This process yielded nine articles that met the inclusion criteria which were not included in the previous searches. This process concluded with a total of 31 articles which informed the review of the literature and informed the current study (See Table 3).

Table 3.
Articles Reviewed

Author(s)	*Year*	*Population*	*Methods*
1. Billingsley & Scheuermann	2014	Students &	Literature

			Teachers	Review
2.	Billingsley et al.	2019	Students & Teachers	Literature Review
3.	Checa & Bustillo	2020	Students & Teachers	Literature Review
4.	Civelek et al.	2014	Students	Quantitative
5.	Detlefsen	2014	Students	Qualitative
6.	Fransson et al.	2020	Teachers	Qualitative
7.	Freina & Ott	2015	Students & Teachers	Literature Review
8.	Hite et al.	2019	Students	Quantitative
9.	Jensen & Konradsen	2018	Students & Teachers	Literature Review
10.	Jowallah et al.	2018	Students & Teachers	Conceptual
11.	Kao	2009	Students	Conceptual
12.	Katz	1999	Teachers	Quantitative
13.	Kavanagh et al.	2017	Students & Teachers	Literature Review
14.	Klopfer	2018	Students	Conceptual
15.	Kwon	2019	Students	Quantitative
16.	Lim et al.	2019	Students & Teachers	Conceptual
17.	Ludlow	2015	Students	Conceptual
18.	Maas & Hughes	2020	Students & Teachers	Literature Review
19.	Majid & Shamsudin	2019	Teachers	Quantitative
20.	Martirosov & Kopecek	2017	Students & Teachers	Literature Review
21.	Merchant et al.	2014	Students	Meta-Analysis
22.	Mikropoulos & Natsis	2011	Students &	Literature

			Teachers	Review
23.	Nocentini et al.	2015	Students & Teachers	Literature Review
24.	Papanastasiou et al.	2019	Students	Literature Review
25.	Parong & Mayer	2018	Students	Quantitative
26.	Parong & Mayer	2020	Students	Quantitative
27.	Passig	2009	Students & Teachers	Literature Review
28.	Passig	2011	Teachers	Mixed-Methods
29.	Passig & Moshe	2008	Pre-Service Teachers	Quantitative
30.	Patterson & Han	2019	Teachers	Qualitative
31.	Ray & Deb	2017	Students	Quantitative

Data Analysis

A thematic analysis (Braun & Clarke, 2006) was conducted on the data in order to identify, analyze, and report themes. The use of a thematic analysis can provide a rich, detailed, and complex view of the data (Braun & Clarke, 2006). In order to establish a complete understanding of the data, data-driven themes were derived. The six phases of conducting a thematic analysis outlined by Braun and Clarke (2006) were followed in the present review (See Table 4).

Table 4.
Phases of a Thematic Analysis (Braun & Clarke, 2006)

1.	Familiarize Yourself with the Data	Immerse yourself in the data through repeated readings in order to search for meaning and patterns.
2.	Generate Initial Codes	Develop theory-driven or data-driven codes.
3.	Search for Themes	Sort codes into categories.

4.	Review Themes	Identify patterns within the themes; what the different themes are, how they fit together, and the overall story they tell about the data.
5.	Define and Name Themes	Organize the data extracts for each theme into a coherent and internally consistent account with accompanying narrative and identify subthemes.
6.	Produce the Report	Go beyond description of the data and make an argument in relation to research questions.

Themes

The following primary and secondary themes emerged from the literature included in this review:

1) Integrating Virtual Reality into K-12 Education
    a) Affordances of Virtual Reality
    b) Designing Instruction
    c) Connecting Virtual Reality to Content
    d) Integrating Virtual Reality into Science Instruction.
2) Virtual Reality and Teacher Experience
    a) Teacher Professional Development
    b) Teacher Perceptions
3) Barriers of Implementing Virtual Reality into K-12 Education
    a) Student Learning
    b) Lack of Content

Using these themes as a guide the information was synthesized and important phenomena were identified in order to analyze trends.

Integrating VR into K-12 Education

Affordances of VR

As VR experiences become more commonplace, people will become more comfortable with this technology and perhaps come to expect this technology in educational settings (Ludlow, 2015). Though some believe virtual tools will replace books and manipulatives (Ludlow, 2015; Walker, 2013), others believe VR should not be a replacement for high-quality face-to-face instruction but rather an enhancement to learning (Jowallah et al., 2018). No matter the case, the possible affordances of VR technology are an important topic in education.

Making the Impossible Possible. VR allows for the user to experience phenomena that are otherwise too difficult, impossible, or too expensive to experience in real life (Freina & Ott, 2015; Ludlow, 2015; Majid & Shamsudin, 2019). Being able to interact with and scale virtual objects for a better understanding and visiting places virtually that time, distance, or safety concerns would prohibit are made possible with VR (Papanastasiou et al., 2019). This allows learners to interact with virtual objects in ways that are not possible in the real world such as copying, scaling, deforming, and automatic fixing (Civelek et al., 2014). Students can use VR technology to engage virtually with dangerous materials without fear of making mistakes, having serious accidents, or wasting materials (Civelek et al., 2014; Santos & Carvalho, 2013). VR can also provide virtual experiences or events that are not able to be accessed physically such as exploring the solar system by freely moving around planets (Detlefsen, 2014) or gravity, magnetism, and planetary motion (Merchant et al., 2014). Virtually travelling to distant or dangerous places through VR is a possibility because virtual learning environments can simulate any location without leaving the classroom (Parong & Mayer, 2020; Patterson & Han, 2019).

Active Learning. Utilizing VR can create a shift from passive to active participation in learning when learners interact with virtual objects (Papanastasiou et al., 2019) which can be used to provide interactive and situated learning experiences (Ludlow, 2015). When the experiential nature of VR is paired with interactivity these learning experiences are able to break free from conventional learning paradigms (Christou, 2010; Kwon, 2019; Papanastiasiou et al., 2019) which can be useful in K-12 educational contexts (Dede, 2009; Ludlow, 2015). Immersion paired with interactivity is required to achieve high learning rates in students (Checa & Bustillo, 2020). Not only can this shift to active learning through virtual reality give students hands-on practice with virtual objects (Civelek et al., 2014), but it can create powerful effects on motivation and learning (Hite et al., 2019) and make learning more enjoyable (Martirosov & Kopecek, 2017).

Motivation to Learn. Using VR in the classroom could create learning experiences that are more interesting and fun (Clark, 2006; Majid & Shamsudin, 2019). The immersiveness (Parong & Mayer, 2020), presence (Martirosov & Kopecek, 2011; Mikropoulos & Natsis, 2011), and haptic feedback (Civelek et al., 2014) associated with VR may lead to increased motivation and learning outcomes. Students have reported positive experiences with VR lessons (Parong & Mayer, 2018), warranting further research in this area (Makransky et al., 2017; Moreno & Mayer, 2004; Parong & Mayer, 2018; Parong & Mayer, 2020). In addition, learners have reported positive feelings of enthusiasm and impressiveness while using VR in the learning process (Mikropoulos et al., 1998; Papanastasiou et al., 2019). Kavanagh et al. (2017) reported VR has been shown to increase students' intrinsic motivation, increased time on task (Huang et al., 2010; Johnson et al., 1998), enjoyment (Apostolellis & Bowman, 2014; Ferracani et al., 2014), motivation (Cheung et al., 2013; Jacobson et al., 2005; Sharma, Agada & Ruffin, 2013), and deeper learning and long-term retention (Huang et al., 2010; Rizzo et al., 2006). Finally, students can also work collaboratively with others in a VR environment, which has been shown to positively impact motivation (Martirosov & Kopecek, 2017).

Differentiation. Integrating VR into educational contexts has the ability to provide differentiation for students. VR can provide learner-centered conditions, creating environments and activities which address the individual needs of students (Levin, 2011; Ludlow, 2015). Learners can go at their own pace or pursue their own interest while using virtual reality (Civelek et al., 2014), and there are currently VR applications designed for differently abled students (Ludlow, 2015; Strangeman & Hall, 2002).

Designing Instruction

When immersive VR learning experiences are well-designed, they may support learning environments that are multi-sensory and allow students to make sense of physical space and perceptual phenomena (Papanastasiou et al., 2019; Salzman et al., 1999). Further VR experiences can be effective if they are individualized and the skills are practiced repeatedly (Dieker, et al., 2014; Ludlow, 2015). In order to create effective VR learning experiences teachers should be involved in the lesson design. Patterson & Han (2019) found when teachers co-designed VR learning experiences they developed a sense of ownership which encouraged the sustained implementation of VR-infused lessons. Technology companies and developers should work alongside educators, curriculum developers, instructional designers, and policymakers to identify and follow best practices for the use of virtual reality (Jowallah, 2018).The inclusion of educators in the lesson design process will help align these learning experiences to high-quality pedagogical practices.

In order for VR-infused lessons to be successful the use needs to be pedagogically justified (Fransson et al., 2019; Häfner et al., 2018). Though immersive VR may not be useful as a replacement to traditional video (Parong & Mayer, 2020), the pedagogical affordances of its primary elements (i.e., immersion, interaction, involvement) warrant further research. To assist in this endeavor, frameworks for analyzing and assessing if using VR in education is appropriate, when to use VR in education, and how to use VR in education are needed (Fransson et al., 2019; Häfner et al., 2018; Minocha, 2015).

Though VR has become increasingly popular in education, one challenge identified by Lim et al. (2019) was the development of theoretical frameworks for instructional design strategies to assist in creating meaningful and authentic learning experiences. To meaningfully integrate VR into the classroom, educators must consider how to fuse pedagogy and technology within a balanced framework (Jowallah et al., 2018). In one single-case case study, Patterson and Han (2019) found including the teacher in the designing of a VR learning experience in his fourth-grade class contributed greatly to the development of his technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2009). Using TPACK as a framework for understanding when, why, and how to incorporate technology into learning creates an awareness of the affordances of whichever technology is being integrated into learning (Billingsley et al., 2019). These three knowledge bases—technological, pedagogical, and content knowledge—must all be present and seamlessly overlap in order for an educator to display the attributes needed to integrate technology into learning experiences (Jowallah et al., 2018). Without the strong alignment of pedagogy and technology learning experiences infusing virtual reality will be limited in their validity (Jowallah et al., 2018). Fransson et al. (2019) found teachers wanted to avoid using virtual reality for solely the wow-factor it provides and aimed to incorporate VR to coherently address content as well as curricular aims and goals.

Connecting Virtual Reality to Content

Integrating VR into teaching and learning can create engaging and interesting learning experiences, but without helping students reach the standard or goal of the lesson the technology does not serve in the process of their education (Jowallah et al., 2018). Fransson et al. (2019) found when incorporating VR into lessons teachers noted the importance of curricular alignment, learning outcomes, content, and assessing student performance. Teacher desire to connect VR to curricular goals has shown promising results. However, VR use has still been limited in addressing core academic concepts in K-12 education (Chang et al., 2010; Ludlow, 2015). As teachers begin to integrate VR in their instructional practices it will be important for them to align the use of the technology to curricula, syllabi, and their professional knowledge (Fransson et al., 2019). VR has been found to engage students, but when meaningfully integrated into instruction and aligned to the purpose of the lesson the possible impact of the technology may be much greater (Patterson & Han, 2019).

Integrating VR into Science Instruction

Though VR is in the early stages of adoption in K-12 educational settings, science has emerged as a content area of growing interest. This interest in connecting VR with science content may be due in part to VR’s potential for facilitating exploration of natural phenomena in both large- and small-scale environments (Hite et al., 2019; Jones et al., 2014). VR can expose students to simulations not constrained by the limitations found on Earth such as gravity (Kwon, 2019). Teachers can also give students hands-on practice and trips to various locations, which may be more engaging (Bulunuz, 2012; Civelek et al., 2014). The virtual hands-on experience when working on interactive labs has distinct advantages when compared to text lessons (Parong & Mayer, 2020), and can transfer to students' gains in knowledge and inquisitiveness as Markowtiz et al. (2018) found when incorporating VR in learning about climate change (Parong & Mayer, 2020).

Within science, physics has emerged as a popular content area for incorporating VR into instruction. Because VR allows learners to make observations, interact with objects, and experience phenomena in unique ways, it may promote deeper understanding of physics compared to non-immersive learning environments (Civelek et al., 2014). Kozhevnikov et al. (2013) found when comparing two groups of students learning concepts covering relative motion, the students who engaged in learning through immersive virtual environments using a head-mounted display performed significantly better on transfer tests than those who engaged in learning on a desktop virtual environment displayed on a computer screen (Parong & Mayer, 2020). Immersive 3D experiences while learning physics concepts have been found to be aligned with more feelings of presence which is positively associated with performance on transfer tests as well as increased motivation and engagement (Parong & Mayer, 2020; Schrader & Bastiaens, 2012).

Virtual Reality and Teacher Experience

Teacher Professional Development

In order for teachers to make informed decisions regarding the integration of VR into their curriculum it is important to provide them opportunities to critically scrutinize, curate, and adapt this technology for educational purposes (Fransson et al., 2019; Holmberg, 2019; Schön, 1987). Teachers need to be exposed to the benefits of VR in the classroom as well as hands-on training for including VR in lesson development (Majid & Shamsudin, 2019) which can both be addressed through professional development.

Professional development experiences focused on integrating VR into the classroom must provide sustained time and support with the technology. VR intimidates many teachers, and designing or enhancing lessons with this technology is a complex task (Patterson & Han, 2019) which requires consideration of how the technology can add pedagogical value (Fransson et al. 2019). Teacher professional development needs to not only include time and support for teachers, it also needs to be sustained and ongoing (Lorenzo et al., 2013; Papanastasiou et al., 2019). In a study by Fransson et al. (2019), researchers suggest time and support are important factors contributing to the success of teachers' implementation of VR in their classrooms. Participants had too few experiences with HMD VR to adequately identify the possibilities of this technology in specific teaching and learning contexts (Fransson et al., 2019). Before teachers can consider incorporating VR and ensuring the learning experiences are aligned with their content, they need to have sustained experiences with the technology as well as selected applications.

Teacher Perceptions

Sustained professional development could allow teachers to not only form ideas about how to incorporate VR into their classrooms that align with content, but could also shape teachers' perceptions around the value of VR for instruction. Majid and Shamsudin (2019) assert that teacher's perceptions impact the productive use of VR for instruction, and exposure to the technology through hands-on experiences could encourage positive perceptions (Majid & Shamsudin, 2019). Findings presented by Patterson and Han (2019) align with this research noting the participant in their single-case case study increasingly took more risks, reflected on lesson planning, and adopted the unfamiliar tools as he became more familiar with the VR tools. Alternatively, Fransson et al. (2019) found participants in their study possessed minimal knowledge of the VR tools which limited their ability to explore the affordances VR could bring to teaching and learning.

Hurdles of Implementing VR into K-12 Education

Student Learning

Several hurdles to integrating VR have been identified in the literature. First, educators may have difficulty identifying measurable learning outcomes when incorporating virtual reality into learning (Fransson et al., 2019). Second, when implementing VR learning experiences teachers cannot easily see what students are experiencing which makes it difficult to provide real-time feedback, scaffolding, or problem-solving assistance (Fransson et al., 2019). Third, learners' unfamiliarity with the VR technology may negatively impact their learning (Parong & Mayer, 2020). Fourth, while learning in immersive virtual reality environments, students may become distracted by extraneous stimuli within the virtual environment (Parong & Mayer, 2020). Engaging in VR environments could create excessive arousal that in turn could detract from learning (Parong & Mayer, 2020). Even though immersive VR can create environments that are associated with a higher sense of presence by the user, this increase in presence can potentially lead to cognitive overload and less learning (Fransson et al., 2019; Makransky et al., 2019). Lastly, there are possible negative physical reactions to virtual reality that can also hinder student learning. Using VR and HMDs can cause dizziness which can then lead to nausea or headaches (Fransson et al., 2019; Kawai & Häkkinen, 2019; Kwon, 2019; Oak, 2018; Rebenitsch & Owen, 2016) which can impede student learning outcomes and have a negative effect on the sense of presence (Kwon, 2019).

Lack of Content

Currently, much of the VR content that exists has been created for stand-alone learning experiences that cannot be differentiated for students or be incorporated into curricular goals of the teachers (Fransson et al., 2019). The VR content that is available but not directly tied to educational goals is primarily designed for entertainment purposes and often requires technical skills most teachers do not possess (Fransson et al., 2019). For these reasons, aligning HMD VR experiences with content specific learning goals is a difficult task (Fransson et al., 2019; Jensen & Konradsen, 2018; Kwon, 2019). Developing VR applications that align to learning goals teachers have for their students could be an expensive endeavor that may lead to the continued development of applications with limited scope (Fransson et al., 2019).

Gaps in the Literature

The following gaps were identified in the literature focused on incorporating immersive virtual reality into K-12 learning contexts: Lack of Research and Content Alignment and Learning Outcomes.

Lack of Research

The research focused on VR use in K-12 contexts is still immature (Patterson & Han, 2019). Little research has been conducted examining the impact, benefits, and risks of VR in these environments (Fransson et al., 2019; Ralph et al., 2017). Since this technology is becoming increasingly affordable and accessible it is important to find potential uses in terms of enjoyment, education, and training (Martirosov & Kopecek, 2017). Most research involving immersive VR using HMDs has focused on contexts outside of K-12 education (Fransson et al., 2019; Kavanagh et al., 2017). In their literature review focused on augmented, mixed, and virtual reality in K-12 education Maas and Hughes (2020) found the lack of scholarly research focused on mixed and virtual reality in K-12 environments impacted their ability to balance the articles across all three technologies included in their review. The authors went on to state their greatest challenge while conducting the literature review was the lack of existing K-12 educational content available to study (Maas & Hughes, 2020). As VR technologies become more user-friendly and more affordable, they will likely be used in increasingly creative ways (Ludlow, 2015). As VR becomes more widely available, it is reasonable to expect that this technology will make its way into K-12 classrooms (Fransson et al., 2019; Kwon, 2019; Minocha et al., 2017), and it is important for educational researchers to explore the possible affordances of this technology.

Content Alignment and Learning Outcomes

There is little research on aligning VR technology with curricular goals of educators, which is paramount to its adoption in K-12 education (Paraong & Mayer, 2020). In this review of the literature only nine studies (Civelek et al., 2014; Detlefsen, 2014; Fransson et al., 2020; Hite et al., 2019; Kwon, 2019; Parong & Mayer, 2018; Parong & Mayer, 2020; Patterson & Han, 2019; Ray & Deb, 2017) evaluated student learning outcomes that connected to curricular goals. This lack of research focused directly on using immersive VR experiences as a tool to address curricular goals and knowledge leaves much to be done in the field (Maas & Hughes 2020).

One possible area of focus for future research based on the literature to address this gap would be to incorporate VR into science instruction (Hite et al., 2019; Civelek et al., 2014). This specific area of focus on integrating VR into the science curriculum aligns with the one of the possible affordances of maker-centered learning in that maker-centered learning experiences could have the potential to increase learners' proficiency in STEM subjects (Clapp et al., 2017). In addition, Schlegel et al. (2019) found incorporating maker-based experiences into science instruction helped minority students to form positive formative STEM-related self-perceptions. The possible connections between VR, maker-centered learning, and possible affordances for science instruction make for a natural next step in the field.

Conclusion

Passive experiences in VR are unlikely to produce significant learning and skill development (Checa & Bustillo, 2020). Mikropoulos and Natsis (2011) posited that the research trends in the field of VR in education would move towards focusing on interactivity. While some studies did examine the interactivity of VR, none examined the use of VR in creating new artifacts of their learning. When searching for VR and making, the articles discussing creating in VR only listed this as a possible next step for VR use in education. There have not been any studies to date focused on this use of VR in K-12 education. Learners need the opportunity to create using VR as opposed to simply consuming instruction, and research in this important area is warranted (Maas & Hughes, 2020) to realize projections about the affordances of VR in promoting creative thinking (Parong & Mayer, 2020) as well as facilitating assessment. The creative use of technology aligns with the maker movement in education in that the role of the learner shifts from a consumer to producer and an emphasis is placed on constructing and sharing creative artifacts (Halverson & Sheridan, 2014). This also aligns with maker-centered learning both in terms of stuff making and developing agency (Clapp et al., 2017).

Chapter 3: Methodology

The purpose of this qualitative case study was to examine the perspectives of K-12 science educators about the educational affordances of using VR technology and maker-centered learning activities to address the K-12 science curriculum. Through artifact analysis, semi-structured Mini VR Maker Faires, and semi-structured post-PD interviews, an understanding of the educators' perspectives emerged based on their experiences with using VR as a tool with which to create artifacts of learning that align with curricular goals. Following a sustained hands-on professional development experience using HMD VR to both create artifacts and lesson plans aligned to the teachers' curriculum, the insights gained through data analysis will significantly inform the literature on VR in education.

As VR is decreasing in cost and increasing in ease in use, where this technology fits into education research and practice is of great interest (Martirosov & Kopecek, 2017). There is a need for moving from passive VR educational experiences to active and interactive VR experiences (Checa & Bustillo, 2020; Mikropoulos & Natsis, 2011). When using VR in educational settings, learners need the opportunity to create (Maas & Hughes, 2020). In addition, there is a need for the alignment of curricular goals with educational affordances of VR. (Paraong & Mayer, 2020; Maas & Hughes, 2020). For these reasons, it is logical to incorporate HMD VR into maker-centered learning experiences where learners create artifacts of learning that lead to increased proficiency in STEM subjects (Clapp et al., 2017; Schlegel et al., 2019). This study examined the perceptions of educators who used VR in a maker-centered context to address curricular goals, including perceived benefits and limitations of the instructional use of VR.

Context

The data sources for the present case study consisted of interviews, lesson plans, and digital artifacts constructed using VR from seven science educators who teach at County High School (CHS, pseudonym). According to the state Department of Education, the racial makeup of CHS consists of approximately 75% students who identify as White, 14% as Black, 7% as Hispanic, 3% as Multiple Races, and 1% as Asian. In addition, approximately 20% of the student population have been identified as being economically disadvantaged and 2% of the students are English Language Learners.

Study Design

A multiple-case case study design was used to address the research questions. Case study methods are relevant to explain a contemporary circumstance (Yin, 2018). The use of a case study will allow for an in-depth focus on the case while providing a holistic perspective (Yin, 2018). Through a case study design the characteristics of a group were observed deeply in order to analyze various phenomena in relation to the unit of study (Bassey, 1999; Suryani, 2008). When behaviors cannot be manipulated and when the focus of the study is on a contemporary event, a case study methodology is preferred (Yin, 2018). Using a case study methodology can offer larger details about a particular phenomenon (Suryani, 2008). This study design is appropriately aligned with the research questions this study seeks to answer. Because this study seeks to find how a group of high school science educators design maker-centered learning activities to address their content, as well as their perceived benefits and limitations of using VR in this context, a multiple-case case study allowed for the perspectives of the individual participants to be brought to the forefront.

Multiple sources of evidence—Mini VR Maker Faires, artifacts created using VR, lesson plans. and post-PD interviews—were used for triangulation, a strategy suggested by Yin (2018). The benefits of triangulation of multiple data sources helps to strengthen the construct validity by providing multiple data points focused on the same phenomenon and increases confidence in accurately reporting the events in the case study (Yin, 2018). It is necessary to use triangulation through the use of these multiple data sources in order to avoid misinterpretation (Suryani, 2008).

Positionality

In order to create an environment in which the participants felt comfortable to reflect on and share their experiences using VR as a tool to create artifacts aligned with their curriculum, I attempted to keep all personal thoughts on the affordances of the technology to myself. By doing this the thoughts, feelings, and perceptions of the educators involved in the study were able to be brought to the forefront without the influence of my beliefs on the subject. Though I work in the same school division as the participants, my work location is not the same as the participants. I am located in Central Office as the Coordinator of Technology Integration and Innovation. In this role I support innovative initiatives throughout the division, so my role in this project is a natural fit. Even though I do not work directly with the participants this relationship remained at the forefront through all stages of this project. However, my personal connection with CHS made this study feasible. The participants were comfortable speaking with me and being honest about their perspectives throughout the study. This was due to my role in the school division. In addition, my familiarity with how teacher PD is structured in the school and division allowed the study to feel natural from the start of the process. This study was made possible due to my close relationship the school, educators, and PD in the school division.

Though I have worked in public education for the past ten years, none of my experience has been at the high school level. While I have positive feelings toward science, my relationship with high school level science is far removed since I have not engaged in high school science since I was in high school myself. In addition, as an educator I have been involved in maker-centered learning in terms of both research and practice for many years. In addition, I have been engaged in incorporating VR into K-12 learning environments. I am curious about the possible role VR might have in terms of both student learning, but also the role VR could play in maker-centered learning. This close relationship to the subject matter and technology integration remained in check through the use of reflective memos after each interaction with the participants.

The Case

This research study focused on the perceptions and experiences of seven science educators in the same department teaching in the single rural public high school (CHS) in the school division. Participants were recruited through attending a short informational interest meeting where the project, timeline, and goals were shared. The science teachers' subject matter expertise assisted in examining the possible affordances of VR for creating artifacts in order to show content mastery. Each participant in this group of seven high school science teachers was identified as an individual case with those outside of the case study becoming the context (Yin, 2018).

To recruit the participants for the study I collaborated with the school administration as well as the science department chair to gauge interest in the science department. I met with the principal and science department chair of CHS to explain the project plan. I then inquired about the possible interest of the science department participating in this project. Following the approval from the Internal Review Board, I emailed participants details of the present study

(Appendix F), including information regarding the ability to withdraw at any time. Following replies from the participants an informational meeting was held to discuss the specifics of the study. During this meeting we also discussed a schedule for the initial one-on-one interviews and the VR Mini Maker Faires to protect our time together. A meeting was held with the science department where I explained the project, time commitment, and goals. Once the seven science teachers were identified the project began. In order to avoid the participants feeling coerced in both recruitment and throughout the study, I consistently reminded the participants that they could exit the study at any time without negative consequence. In addition, in all of communication with the participants I reminded them that their participation is completely optional.

Procedures

Structure of the Professional Development Experience

The elements of effective professional development as outlined by Darling-Hammond, Hyler, and Gardener (2017) were followed when designing the PD experience. First, the PD was content focused and aligned with the science content the participants are responsible for in their classrooms. The participants engaged with maker-centered practices, but ultimately, they connected these practices to the science content they teach. Once becoming familiar with the new tools, technology, and maker-centered learning practices, the teachers applied this to their content area through the development of a maker-centered instructional activity using VR paired with a lesson plan including the instructional activity. The direct alignment of the PD activities and the content area of the participants assisted in ensuring relevance throughout the process.

The PD incorporated active learning. Engaging in focus groups throughout the PD as opposed to lecture style presentation allowed the participants to connect what was being learned directly to their practice. Throughout the experience, participants designed and tried out strategies in the same style of learning they were designing for their students. The participants explored the creative use of VR and created artifacts using VR in ways that aligned with curricular goals. In addition, the participants created lesson plans that directly connected what was learned in the PD to their teaching practice. Purposefully focusing on instructional approaches connected with instructional practices the participants can apply to their classrooms allowed participants to engage in the PD with the mindset of being able to apply what is learned to their classrooms.

The weekly Mini VR Maker Faires and debriefs promoted collaboration among the participants. The collaborative structure of the PD experience allowed participants to learn from each other while learning the new VR technology. Participants were able to share experiences and what they learned with the group to help foster understanding of the technology as well as possible areas for application in the classroom. This collaboration across the science department in the high school allowed the opportunity for the participants to adopt and implement new teaching practices in an entire department in a school. The collaborative structure of the PD experience created opportunities for coaching and expert support to be provided throughout the entire experience to help meet the individual needs of the participants.

Feedback and reflection were both woven throughout the PD experience in both group and individual settings. There was dedicated time built into the eight-week PD experience that allowed teachers to reflect and engage in receiving feedback which helped in the learning process. The participants were able to use the focus group sessions as a space in which they can honestly reflect on the process of learning and incorporating VR into their curricula. The focus group sessions fostered discussion around the learning process, creation of artifacts using VR, and the alignment of these activities with their science learning objectives.

Finally, the PD was of sustained duration which allowed the participants time to learn, practice, implement, and reflect on the new strategies learned. The eight weeks dedicated to this process was enough time to meaningfully introduce VR as an educational tool for creating artifacts of learning, begin to connect this to curriculum, and reflect on the entire process. There was flexibility built into the structure of the PD experience which allowed for any necessary topics from technical to pedagogical questions to be discussed and explored. In addition, time was built into the structure to allow participants to engage in all parts of the PD independently and as a group.

The structure of this PD experience was informed by my previous research in maker-centered learning PD (Jones et al., 2019; Jones et al., 2020a; Jones et al., 2020b) and the role of constructionism in maker-centered learning (Caratachea & Jones, 2020). Learning from previous research in terms of structure, content, and time in terms of what can be successful and meaningful was an important consideration. Teachers need time and space to engage not only with maker technologies, but with the concepts of maker-centered learning as well. When engaging in maker-centered learning concepts in a PD experience it is important for educators to build a community where learning from one another is an integral part of the experience. In addition, teacher choice in the artifacts made throughout the experience is important, but also connecting these practices to the classroom and the curriculum each teacher is responsible for is equally important.

The study spanned an eight-week period with specific goals and objectives being present each week. The overarching goal of the PD experience was to introduce VR and maker-centered learning to high school science educators in a scaffolded and sustained way that focuses on alignment to their content area. In addition, the specific goals of the PD aligned with PD activities and outcomes are provided in Table 5.

Table 5.
PD Goals

PD Goal	PD Activity	PD Outcome
Introduction to VR	● Weekly tasks using VR ● Mini VR Maker Faires for sharing and debriefing	● Participants increased their knowledge on how to incorporate VR into their science curriculum
Infusing VR and maker-centered learning	● Creating artifacts using VR that incorporates both choice and curricular goals	● Participants viewed VR as a tool which can be used to create artifacts of learning
Aligning VR and maker-centered learning to science curriculum	● Creation of lesson plans	● Participants connected VR and maker-centered learning practices directly to science content they are responsible to teach

In order to work toward this goal, the professional development experience was split into eight weeks (see Table 6). This eight-week structure was developed using previous research as a guide (Jones et al., 2019; Jones et al., 2020a). Each week the participants worked towards the PD goals and outcomes (Table 5). Five of the eight weeks incorporated semi-structured Mini VR

Maker Faires, and all but two weeks included tasks for the participants to work on between the weekly meetings.

Table 6.
Weekly Breakdown of Professional Development Experience

Week	Description of Activities	Tasks for the Week
Pre-PD	Before beginning the PD, each participant engaged in a one-on-one pre-PD interview	No tasks for the week
Week 1	Group introduction to the Oculus Quest and Gravity Sketch ● Oculus Quest basics ○ Charging ○ Internet connection ○ Navigation ○ Accessing Gravity Sketch ○ Screen recording ● Gravity Sketch Basics ○ Starting a project ○ Using the basic tools ○ Saving Show the participants the Schoology group that we used for much of the communication—in order to streamline communication, provide opportunities for collaboration and troubleshooting, and to easily share video files ● Due to COVID-19 health concerns the majority of the interaction took place virtually Distribute a copy of *Maker-Centered Learning* (Clapp et al., 2017) and an Oculus Quest to each participant	● Explore the Gravity Sketch App ○ Communicate questions through Schoology ○ Share interesting findings in Schoology ● Read a section of *Maker-Centered Learning* (Clapp et al., 2017)
Week 2	Semi-structured Mini VR Maker Faire ● Purpose of this is to: ○ Learn how their first week of using the new tools went ○ Address any questions that were or were not posted in Schoology	● Create something using Gravity Sketch to share with the group ○ This could be anything—it could relate to content you teach or not ○ Upload a short screen recording (1-2 mins tops) of you explaining what

	○ Have anyone share successes for the week ○ Share any artifacts made by the participants	you made to Schoology
Week 3	Semi-structured Mini VR Maker Faire ● Purpose of this is to: ○ Address any questions that were or were not posted in Schoology ○ Have anyone share successes for the week ○ Share artifacts and explain how you were able to create what you did	● Make another artifact in Gravity Sketch and record a short video showing off what you made similar to last week ○ Upload video to Schoology ● Begin to look at the science content you teach (this could be upcoming content or something you've already taught) ○ Think about how HMD VR and Gravity Sketch could be used to address curricular goals in the classroom
Week 4	Semi-structured Mini VR Maker Faire ● Purpose of this is to: ○ Address any questions that were or were not posted in Schoology ○ Have anyone share successes for the week ○ Share artifacts and explain how you were able to create what you did ○ Share content connections and plan	● Begin working on artifact that connects to content
Week 5	Semi-structured Mini VR Maker Faire ● This focused on the lesson plan format we used ○ The goal is to be simple yet effective	● Continue working on artifact that connects to content ● Begin working on lesson plan write up
Week 6	No semi-structured Mini VR Maker Faire (unless something comes up in Schoology)	● Finish artifact ● Finish lesson plan write up ○ Record video explaining the artifact and content connections

		○ Upload to Schoology
Week 7	Semi-structured Mini VR Maker Faire ● Group reflections on the process ● Share videos of final artifacts and lesson plans	No tasks for Week 7
Week 8	Individual semi-structured post-PD interviews ● More in-depth questions about the process	No tasks for Week 8

Data Collection

According to Yin (2018) one of the major strengths of using a case study methodology is including multiple sources of data in order to be both in-depth and contextual. The data sources for the current study were pre-PD interviews, artifacts, Mini VR Maker Faires, and post-PD interviews (see Table 7). Using these multiple sources of data allowed for the development of converging lines of inquiry, or triangulation (Yin, 2018).

Pre-PD Interviews

Before the PD experience began, each participant engaged in a one-on-one semi-structured interview. The purpose of this interview was to gain important background information (See Appendix A). This background information provided insight into each participant's current knowledge and comfortability with both VR technology and maker-centered learning. Though the current study is not a program evaluation, collecting these data was an important step in going as in-depth as possible. Not only were the interviews important for data collection purposes, these interviews also provided the participants an opportunity to reflect on where they are with VR technology and maker-centered learning, as well as what that would like to get out of the experience.

Artifacts

During the PD experience participants created artifacts both in and out of VR. Participants constructed two artifacts of their choosing using the application Gravity Sketch and an Oculus Quest VR system to become familiar with both technologies. They captured screen recordings using the Oculus Quest explaining their artifacts once they are constructed. Each screen recording addressed a series of questions (See Appendix B) and was shared with the group through the learning management system Schoology. Though these initial two artifacts were constructed for the purposes of the PD experience, they were not analyzed in the current study.

The participants also constructed one final artifact using Gravity Sketch which related to their curricular goals. This final artifact created using HMD VR and the Gravity Sketch app was collected and analyzed in the current study. Each participant also developed a lesson plan (See Appendix C) to accompany the final constructed artifact.

Mini VR Maker Faires

There were five semi-structured Mini VR Maker Faires conducted during the eight-week professional development experience (See Appendix D for protocol). These informal meetings focused on sharing artifacts allowed for collaboration between the participants in terms of what they are learning and making using VR. Though there were areas of focus for each of the Mini VR Maker Faires, the main goal of each meetup was to provide a space for the participants to share what they have been making, bring questions they had to the group, and check in with each other. The initial Mini VR Maker Faire focused on the use of both the Oculus Quest and Gravity Sketch. The second and third Mini VR Maker Faires focused on the experiences the participants have had creating artifacts in VR using Gravity Sketch and any questions that may have come up while working. The fourth Mini VR Maker Faire focused on the development of the lesson plan that accompanied the final artifact created in VR. The fifth, and final, Mini VR Maker Faire gave the participants an opportunity to reflect as a group on the process as well as share their final artifact created in VR which addresses a curricular goal and aligns with their lesson plan. Though the focus group protocol was developed before the PD took place, the questions and topics brought up in the focus group were also informed by the group needs which came out of the Mini VR Maker Faires and researcher memos.

The Mini VR Maker Faires were an important part of study in multiple ways. These informal meetups proved to be a safe place for the participants to not only share what they have created, but also to get tips and tricks from the other participants. The Mini VR Maker Faires took the artifacts the participants created and made them public artifacts (Papert & Harel, 1991). This time together gave participants encouragement in their creative use of VR, inspiration for their next artifact to construct, and answers to questions that could have hindered their use of the tools if they went unanswered.

Post-PD Interviews

At the end of the study the participants were interviewed individually to debrief, reflect on the process as a whole, describe the connections between VR and supporting their goals as educators, and reflect on the possible perceived benefits and limitations of VR aligned with content (See Appendix E). The individual semi-structured post-PD interview allowed participants to share any remaining details that they may not have been comfortable with sharing in a group setting. The post-PD interviews allowed questions focused on each participant’s lesson plan and final artifact to be asked. In addition, during the post-PD interviews participants’ perceptions on how maker-centered learning principles were possibly adopted throughout the PD experience were explored. Though the post-PD semi-structured interview protocol was developed before the PD takes place, the questions and topics addressed in the post-PD interviews were also informed by the focus group sessions and researcher memos.

Table 7.
Data collection and analysis aligned with research questions

Data	Analysis	Research Question
1. Lesson Plan	Artifact Analysis	How do high school science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content?
2. Mini VR Maker Faires	Inductive and Deductive Coding	How do high school science educators perceive the benefits and limitations of using Virtual Reality to facilitate maker-centered learning activities which address K-12 science content?
3. Pre- and Post-PD Interviews	Inductive and Deductive Coding	How do high school science educators perceive the benefits and limitations of using Virtual Reality to facilitate maker-centered learning activities which address K-12 science content?
4. VR Artifact Aligning with Science Content	Artifact Analysis	How do high school science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content?

Data Analysis

In order to analyze data from multiple sources it was important to organize what has been collected into codes and themes that cross each of the data sources (Creswell & Creswell, 2018). This was done to break the data apart and rearrange them into meaningful segments which can be used for comparison and the development of theories (Maxwell, 2013). Deductive codes driven by the theoretical framework (Clapp et al., 2017) and previous research (Caratachea & Jones, 2020; Jones et al., 2019; Jones et al., 2020a; Jones et al., 2020b) were used in the data analysis (Miles et al., 2014). This also aligns with Saldaña's (2021) recommendations for first cycle codes, using descriptive coding for documents and artifacts as a detailed inventory of their contents. In addition, inductive codes which were developed through careful reading of the entire corpus of research. Inductive codes allowed for important themes and factors to be uncovered while placing importance on what the site has to say in addition to previous research (Miles et al., 2014). These deductive codes were coded in vivo using the participants' own language (Miles et al., 2014). A theme for the current study constituted as at least half of the participants sharing similar ideas. If fewer than half of the participants reported ideas that were identified as important by the literature, this constituted a theme as well because of the importance of the topic explained in the literature. Each code and theme were developed inductively and deductively to develop patterns and themes following the recommendations suggested by Creswell and Creswell (2018, p. 193):

1. Organize and prepare the data for analysis
2. Read or look at all the data
3. Start coding all of the data
4. Generate a description and themes

5. Representing the description and themes

Following the first cycle codes, Saldaña's (2021) recommendations of using pattern coding for the second cycle coding methods were followed. Carefully following this process aided in providing a holistic account of the data which included multiple perspectives while painting the larger picture that emerged (Creswell & Creswell, 2018).

The artifacts, Mini VR Maker Faires, and post-PD interviews were coded using Dedoose, an online software used for qualitative data analysis, to aid in data management and analysis. Dedoose was used to analyze videos and transcriptions of interviews. Each artifact and transcript were uploaded to Dedoose and coded in vivo in order to retain the language of the participants (Miles et al., 2014). A start list of codes (See Table 8) based on the theoretical framework (Clapp et al., 2017) and previous research (Caratachea & Jones, 2020; Jones et al., 2019; Jones et al., 2020a; Jones et al., 2020b) was developed as recommended by Miles et al. (2014). After one transcript was coded a second researcher was brought in as a peer debriefer in order to increase the validity of the study.

Table 8.
Start List of Codes for Data

Code	Source	Research Question
Agency ● Exhibiting Agency ● Planning for Student Agency	● Maker-centered learning (Clapp et al., 2017) ● Jones et al., 2019 ● Jones et al., 2020a	How do high school science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content?
Community Making ● Exhibiting Community Making ● Planning for Student Community Making	● Maker-centered learning (Clapp et al., 2017) ● Jones et al., 2020a	How do high school science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content?

Self-making ● Building Competence as a Maker ● Building Confidence in Maker Abilities ● Forming a Maker Identity	● Maker-centered learning (Clapp et al., 2017) ● Jones et al., 2019 ● Jones et al., 2020a	How do high school science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content?
Cultivating Discipline Specific Skills ● Fostering STEM Knowledge ● SOL Strand	● Maker-centered learning (Clapp et al., 2017) ● Caratachea & Jones, 2020	How do high school science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content?
Affordances of VR	Emerging	How do high school science educators perceive the benefits and limitations of using Virtual Reality to facilitate maker-centered learning activities which address K-12 science content?
Limitations of VR	Emerging	How do high school science educators perceive the benefits and limitations of using Virtual Reality to facilitate maker-centered learning activities which address K-12 science content?
Intersection of Maker-centered Learning and VR	Emerging	How do high school science educators perceive the benefits and limitations of using Virtual Reality to facilitate maker-centered learning activities which address K-12 science content?

All of the initial one-on-one interviews, VR Mini Maker Faires, the audio from the recorded videos of each participant's artifact, and one-on-one post-professional development interviews were digitally recorded and transcribed using Otter.ai. Each transcript was reviewed for errors following the transcription by listening to the recording while reading over the transcription.

The completed transcripts were imported into the Dedoose software package and coded for themes based on the framework used for this study (See Table 8). I coded one transcript independently, then utilized an external researcher to evaluate the accuracy of the codebook. The external researcher took the code weight test in Dedoose, the differences in codes were discussed, and the codebook was updated to reflect the new insights. The rest of the transcripts were then independently coded using Dedoose, and the results were exported into Google Sheets for further analysis. Themes and subthemes emerged and were organized to report the data in a clear, concise, and effective manner. The following chapter aims to distill these themes into a narrative separated by research question.

Pre-PD Interviews

Prior to the PD experience, each participant took part in one individual semi-structured interview focused on their current familiarity with VR technology and maker-centered learning, as well as what they would like to get out of the experience. The semi-structured interview questions were based on elements of maker-centered learning (Clapp et al., 2017), possible connections between VR and maker-centered learning, and the educators' perceptions of the role VR and maker-centered learning could play in their classrooms. The interviews were recorded, transcribed, and coded based on themes connected to maker-centered learning and VR (See Table 7). In addition, emerging themes were coded and analyzed.

Artifacts

The analysis of the screen recordings sharing each participants' final artifact constructed using VR was informed by the maker-centered learning framework and my previous research (See Table 8). Aspects of agency and character (Clapp et al., 2017; Jones et al., 2019; Jones et al., 2020a) and discipline specific knowledge (Caratachea & Jones, 2020; Clapp et al., 2017) were used to analyze the artifact. Using this framework and previous literature to analyze the VR final artifacts created by the participants informed not only the use of VR in maker-centered learning environments, but incorporating maker-centered learning into formal learning environments as well. In addition, emerging themes including affordances of VR, limitations of VR, and intersection of VR and maker-centered learning were coded as they arose.

Recursive transcription as recommended by Ramey and colleagues (2016) was used to transcribe the video artifacts recorded in VR by the participants. While transcribing the video into text transcriptions for coding non-verbal activities were translated into narrative verbal descriptions (Ramey et al., 2016). Visual transcription was used when participants interacted with their VR artifact in a way that went beyond the explanation of the digital artifact. This is similar to the recommendations provided by Saldaña (2021) in terms of live-coding where the researcher manually codes data while listening to or watching an audio or video recording. In addition, Ramey and colleagues (2016) and Saldaña (2021) place an emphasis on the importance of capturing a participant's engagement with material and physical objects. Though the objects in this study were digital, the ways in which the participants interacted with the objects were similar to how to participants would interact with physical objects due to the immersive and interactive nature of VR. Saldaña (2021) relates the transcription of video to translation of subtitles on a movie which was the way the transcription of the video was approached in this study.

The lesson plan developed by the participants was also analyzed. Using the maker-centered learning framework and previous research the lesson plan allowed the connections between maker-centered learning, specifically discipline specific knowledge, and VR to be brought to the forefront. Content connections and SOL strands were coded in the lesson plans in order to determine affordances of VR when implemented with a maker-centered learning lens in terms of the connections to content knowledge.

Mini VR Maker Faires

Semi-structured interview questions based on elements of maker-centered learning (Clapp et al., 2017) and my previous research (Caratachea & Jones, 2020; Jones et al., 2019; Jones et al., 2020a) were used for each of the five focus group sessions (See Appendix D for interview protocol). Each of the Mini VR Maker Faires were recorded and transcribed to ensure fidelity. Following the transcription each focus interview was coded based on themes identified through maker-centered learning (Clapp et al., 2017) and previous research (Caratachea & Jones, 2020; Jones et al., 2019; Jones et al., 2020a). In addition, emerging themes including affordances of VR, limitations of VR, and the intersection of VR and maker-centered learning were also identified and coded (See Table 8).

Post-PD Interviews

Following the PD experience, each participant took part in one individual semi-structured interview focused on the entirety of the experience. The semi-structured interview questions were based on elements of maker-centered learning (Clapp et al., 2017), previous research (Caratachea & Jones, 2020; Jones et. al, 2019; Jones et al., 2020a; Jones at al., 2020b) possible connections between VR and maker-centered learning, and the educators' perceived benefits and limitations of VR aligned with content (See Appendix E for interview protocol). The interviews were recorded, transcribed, and coded based on themes connected to maker-centered learning and VR (See Table 7). In addition, emerging themes were coded and analyzed.

Validity and Trustworthiness

Threats to validity, including researcher bias and reactivity, were addressed throughout the study by following recommendations of Maxwell (2013), Creswell and Creswell (2018), and Yin (2018). Rich data were collected through verbatim transcripts of the interviews (Maxwell, 2013). Rich data paired with thick descriptions provided a detailed discussion of the findings and offered various perspectives that may emerge (Creswell & Creswell, 2018). By using rich data and thick descriptions reporting the data were more nuanced and realistic which reflected what truly occurred during the study.

Respondent validation through feedback about the data and conclusions from the participants increased the validity of the study (Maxwell, 2013). Allowing the participants to view parts of the near-finished product added to the validity of the study by ensuring the accuracy of information included (Creswell & Creswell, 2018). During the VR Mini Maker Faires participants were asked follow-up questions during the discussion in order to validate their perceptions in the moment. In addition, a portion of the results section of the study was sent to each participant in order to validate each participant's perceptions following data analysis.

Searching for discrepant evidence and negative cases and addressing these rival explanations increased the internal validity of the study (Yin, 2018). When instances arose that were not aligned with the theoretical framework of this study they were explored. For example, if the participants described feelings of a lack of agency or community through the process this was included in the reporting. Even though two goals of maker-centered learning are promoting a sense of agency and community, if participants did not feel this in the structure of the PD experience or in the technology tools it was brought out in the data analysis and reporting. In order to represent the complex nature of the content while including all perspectives that are present created a more realistic and valid portrayal of the data (Creswell & Creswell, 2018). In order to identify biases and check for flaws in logic or methods when addressing negative cases, it is important to receive feedback from others (Maxwell, 2013). In order to do this member checking was an important part of the data analysis process. As negative cases arose, follow-up conversations with the participants took place.

Triangulating the findings using multiple data sources present in the study increased construct validity (Yin, 2018). Using different data points in the study reduced the risk of systematic biases present in any particular data collection method (Maxell, 2013). Triangulation also increased the validity of theme development using multiple data sources (Creswell & Creswell, 2018).

It is important to recognize and clarify any bias that the researcher brings to the study (Creswell & Creswell, 2018). The validity of the study was positively impacted through self-reflective memoing throughout the research process due to increased reflexivity (Creswell & Creswell, 2018). Engaging in how my positionality as a researcher and my past experiences shaped the way in which the data are viewed was a meaningful exercise throughout the process and increased the validity of the study. Throughout the research process I reflected on the process through the consistent writing of memorandums. Engaging in the writing of memos allowed me to reflect on each stage of the research process while addressing my positionality. This reflection shaped each Mini VR Maker Faire as well as the post-PD interviews. As the participants brought ideas, concerns, and successes to the Mini VR Maker Faires I reflected on this through memoing and changed the semi-structured focus group and post-PD interview protocols as appropriate. In addition, writing memorandums allowed for reflexivity in the process and helped to shape the development of codes and themes in the data (Creswell & Creswell, 2018).

According to Maxwell (2013) because participant reactivity is present in every study and impossible to eliminate, the goal of a qualitative study is not to eliminate the influence of the researcher, but to understand and use this phenomenon productively. Participants in this study, though honest in sharing their experiences and perceptions, were influenced by my presence during data collection. Because the participants were not regularly engaging in VR use prior to this study and my role as Coordinator of Technology Integration and Innovation in the school division, the participants could have associated my role with a desire to come out with positive findings. However, throughout the process I made sure to address this by not asking leading questions (Maxwell, 2013) and reminding participants that I only want their honest opinions and perceptions, both positive and negative.

Being the sole researcher and being the person implementing the professional development experience it was important to recruit a second researcher to analyze a subset of the data. As recommended by Creswell and Creswell (2018), an outside researcher assisted in peer debriefing in order to improve the accuracy of the account. I have collaborated with the peer debriefer on previous research focused on maker-centered learning. Our prior work together ensured knowledge on the subject matter and a productive working relationship. This second researcher helped to ensure reliability and accuracy of coding through the coding of one interview using the established codebook. Following the coding the second researcher and I met to debrief about the alignment of our coding. After this check the codebook was updated to reflect the debriefing with the second researcher. Collaborating with an outside researcher on data analysis increased the validity of the study.

Limitations

Even with a strong focus on validity, there were still aspects of the study design that inherently lead to limitations. First, I was the sole person implementing the professional development as well as studying the outcomes. Due to the fact that I work in the same school division where the research took place this could impact the openness and honesty of the participants. With there not being another outside party to run the PD experience this could have led to the participants' feeling a need to please. However, the established relationships and the position I hold in the school division could have been beneficial to the research. We easily began the PD without the formalities that may be necessary for people who are not as familiar with one another. In addition, in my position I am involved in the majority of teacher PD. This familiarity could have helped the participants feel comfortable in the process.

The teachers did not have the opportunity to immediately use the skills they have learned with their students. One factor that was a barrier in participants using the skills and knowledge developed through the PD experience is a lack of equipment. The school division did not have access to enough VR headsets for teachers to begin to implement these skills in their classrooms. With COVID-19 still being present in the community, the school division has strict policies on sharing equipment. With VR headsets directly touching the user's face it was not safe to share devices such as these among groups of students. However, this PD experience allowed teachers to not only experiment with this technology, but to plan learning experiences that connect directly to the content they are responsible for teaching. Following this PD, the participants could use their knowledge and skills to make the case for the school division to purchase additional equipment for their students if the participants view this as a beneficial tool for learning.

Finally, the data collected in case studies, including the present study, are subjective and based on description, opinion, and feeling (Suryani, 2008). Though these data can give insight to the experiences of the participants, they are subjective. In order to address this inherent limitation in the selected methodology, triangulation methods were used (Maxwell, 2013; Stake, 2005; Yin, 2018). A case study methodology aligns with the research questions in the present study. However, future research using other qualitative or quantitative methods could be used in order to answer different research questions on the subject of using VR in maker-centered learning contexts in teacher PD experiences.

Chapter 4: Findings

This multiple-case case study research study proposed to examine the perspectives of K-12 science educators about the educational affordances of using VR technology and maker-centered learning activities to address the K-12 science curriculum. Based on the research reviewed for the present study, it was clear that focus on interactive educational experiences is a needed area of study (Checa & Bustillo, 2020; Mikropoulos & Natsis, 2011). In addition, there was a marked need to focus on creation and creative pursuits when integrating VR into educational spaces (Maas & Hughes, 2020; Parong & Mayer, 2020). The gaps that this study seeks to address include lack of research and content alignment. Maas and Hughes (2020) stated a general lack of research in the area of the use of VR in educational contexts. This study contributed to the literature in this area. Research suggests that as VR becomes more ubiquitous in and out of classrooms, research in the area focused on education is needed (Fransson et al., 2019; Kwon, 2019; Minocha et al., 2017). This study also contributed to existing literature by addressing science content alignment. Research suggests a need to focus on how VR integrated into curricular goals of teachers is among the top needs in the field (Maas & Hughes, 2020; Parong & Mayer, 2020). Research has specifically identified science as an area for research to be conducted focusing on VR in educational contexts (Hite et al., 2019; Civelek et al., 2014). This study contributed to the literature on integrating VR in science learning experiences.

The study was conducted through an eight-week professional development experience which included one-on-one pre-professional development interviews, six VR Mini Maker Faires, the write up of a lesson plan using VR as a tool to create artifacts, an example of the artifact which aligns to the lesson, and one-on-one post-professional development interviews. The participants were all science educators from one rural high school in the southeastern United

States. The following research questions served as a guide for the study:

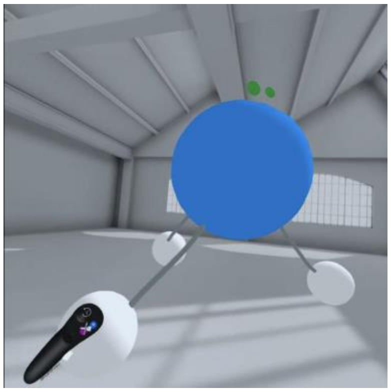
Q1: How do CHS science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content through a professional development experience?

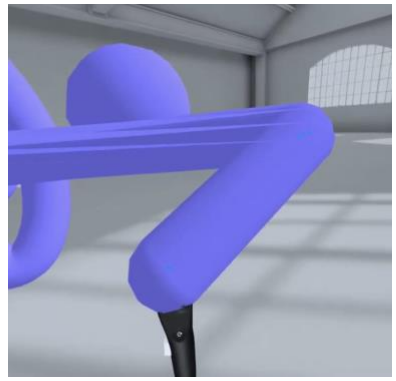
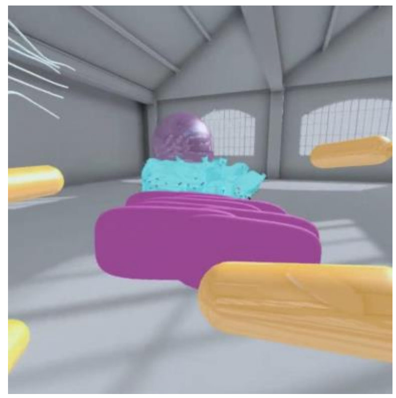
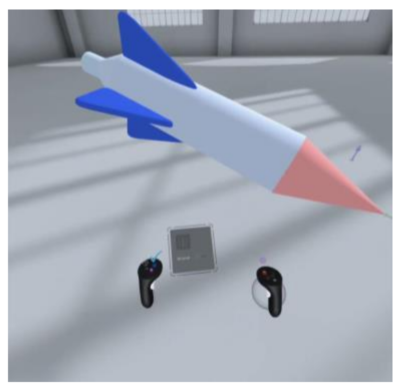
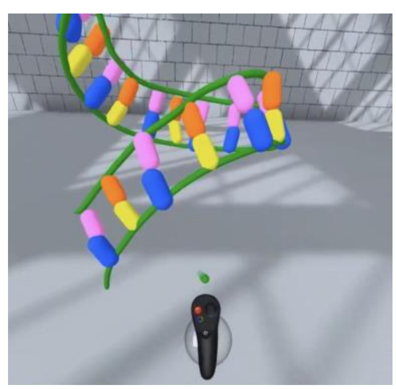
Q2: How do CHS science educators perceive the benefits and limitations of using Virtual Reality to facilitate maker-centered learning activities which address K-12 science content through a professional development experience?

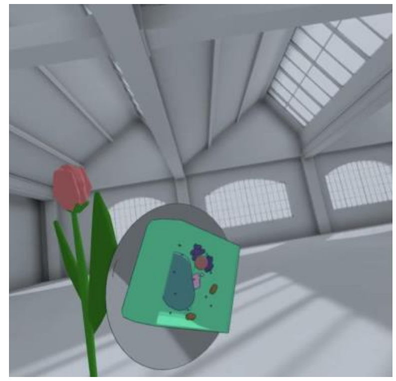
School and Participant Demographics

The participants in this study were six of the seven science educators at a rural high school in the southeastern United States. The one science educator who did not participate in the study was in the process of moving and would be teaching at a different school the following year. Due to this, she opted to not participate in the study. Five participants were female and one participant was male, (See Table 9 for more demographic information). The high school has an enrollment of approximately 840 students.

Table 9.
Participant Demographics and Artifacts

Pseudonym	Years of Experience	Picture of Final Artifact
Ella	8	 (Molecule)

Janet	30	 (Lever - Simple Machine)
Lynne	11	 (Animal Cell Tour)
Mark	4	 (Rocket Prototype)
Misty	11	

		(DNA)
Ruby	3	 (Plant Cell - Energy Flow)

Analysis of Results

The present study examines the affordances VR tools bring to educational experiences when paired with creating artifacts of learning in one rural high school in the southeastern United States. The following research questions guided this study:

1. How do CHS science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content through a professional development experience?
2. How do CHS science educators perceive the benefits and limitations of using Virtual Reality to facilitate maker-centered learning activities which address K-12 science content through a professional development experience?

The analysis of the data using the maker-centered learning framework led to five major themes: (1) Planning for Student Learning, (2) The Role of the Teacher, (3) Fostering STEM Knowledge, (4) Affordances of Virtual Reality, and (5) Limitations of VR. Several sub themes emerged from each of these themes. The themes and sub themes can be seen in Table 10.

Table 10.
Themes and Sub Themes

Research Question	Theme	Sub Theme
1: How do County High School (pseudonym) science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content through a professional development experience?	• Planning for Student Learning	• Learning Through Making and Iteration • Direct Teaching of VR Technology • Differentiation • Students Collaborating
	• The Role of the Teacher	• Teacher as Facilitator • Difficulty Giving Up Control
	• Fostering STEM Knowledge	
2: How do County High School (pseudonym) science educators perceive the benefits and limitations of using Virtual Reality to facilitate maker-centered learning activities which address K-12 science content through a professional development experience?	• Affordances for Student Learning	• Virtual Reality as a Creative Tool • New Perspective on Content • Possibly Engage More Students • Ability to Save Models for Continuous Work
	• Affordances for Teachers	• Teacher Using Virtual Reality as a Creative Tool • Assessment
	• Limitations of Learning Curve	
	• Limitations of Access to Equipment	

Research Question 1: How do County High School (pseudonym) science educators use Virtual Reality to design maker-centered learning activities to address K-12 science content through a professional development experience?

Research Question 1 addressed how the science educators participating in this study plan to use Virtual Reality to design maker-centered learning activities. Three themes emerged when answering this research question, (a) planning for student learning, (b) the role of the teacher, and (c) fostering STEM knowledge.

Planning for Student Learning

Four sub themes emerged when discussing student planning for learning: (a) learning through making and iteration, (b) direct teaching of Virtual Reality technology, (c) differentiation, and (d) students collaborating.

Learning Through Making and Iteration

Participants gained knowledge of the VR technology and tools through making their own artifacts. Not only did the participants learn the new tools through creating and iterating, they also found that creating artifacts could be a way for students to communicate ideas and concepts. In addition, the participants seemed to value the idea of iteration while planning for student learning. Many of the participants carried this method into their planning for designing maker-centered learning experiences using VR. In her lesson plan write up, Misty explained that students would come out of her lesson "understanding the structure of DNA and how the parts of the nucleotide join together" through creating models of DNA using Gravity Sketch in VR. In addition, students could also "add onto the model and show DNA replication or protein synthesis."

Though the direct content connections were different, Ella and Janet also planned for students to learn through the creation of models, and in addition included student communication as an important aspect of showing content mastery. In her lesson plan, Ella explained students would create molecules but would need to focus on "the relative size of the atoms involved (i.e., nitrogen should be larger than hydrogen), the correct number of bonds and lone pairs, and approximate bond angles." She planned on having students record videos explaining their molecules, and it would be through these videos that students would be assessed. Janet planned on having students create models of simple machines to present to their classmates. During their presentation, Janet placed a focus on students sharing how their simple machine moves using movement in Gravity Sketch.

Ruby combined this idea of communication and creating models as well. However, she explained that students would be "communicating ideas to others through the use of modeling." Using Gravity Sketch, students would create models that showed the transformation of light energy to chemical energy, and these models would communicate the ideas.

Mark planned to have students create a design plan for a rocket they would be using to create a physical working version later. He focused on using design in VR to give students the opportunity to engage in the engineering design process while focusing on iteration. In his lesson plan write-up Mark explained that "design iterations will be explored and confirmed virtually before moving to the physical model in each cycle of the process." He hoped this would bring an awareness to students that VR has applications outside of gaming.

Through learning the tools through making and iteration themselves, the participants also planned for their students to learn through making and iterating as well.

Direct Teaching of Virtual Reality Technology

Participants noted the affordances of including direct instruction on the technology to assist students who may be unfamiliar with it. This was a contrast in how the participants learned the technology in the study which was through creating artifacts. In their lesson plans, Mark and Janet both included that students will come into the lesson with background knowledge using VR headsets and Gravity Sketch. When discussing having students use VR in class during the third Mini VR Maker Faire, Mark shared that his big takeaway was, "it's gonna be five instructional periods of training [students] before they can even use it. If we could see what they're doing, and walk them through it, so you can watch them maybe in the casting." Misty also mentioned directly teaching students certain techniques when introducing VR to her students, "one of the tools I would teach them first is how you delete a single object, and this is how you copy a bunch of objects." Lynne discussed how the school division leadership has been planning to go something closer to a year-round calendar with embedded intersessions. She had the idea of bringing interested students "in for the intercession and learn the VR program, or Gravity Sketch."

Misty and Lynne both had concrete ideas on how to teach their students to use the VR tools. Misty said she would begin by saying, "this is VR, this is how we're gonna use VR for this project" and take three class periods where students "get free rein [and] creativity to build whatever they want." Lynne shared that she could use the "last 10-20 minutes of class for a week or two in the beginning of the year for students to mess around with [VR], do whatever they want and play with it." During the study, Misty had her daughter, age 6, create a model using Gravity Sketch and an Oculus Quest. During the sixth Mini VR Maker Faire, Lynne shared, "Oh my gosh, there's so many different ways that we can use this in class and yet, there's still that factor of how are our kids going to learn, but after watching [Misty's daughter] make a flower I think they are gonna be okay." Misty agreed and said, "See that's what I was trying to say. I think they're more intuitive about it than we are." Misty shared,

> I think if you do a screencast first and show the kids, this is how you do it. These are the basics of it. And then have at it I think they would be really...I think honors kids would be fantastic at it, depending on how well they pay attention. And the regular students [too], because you'll have some who would be really

artsy. So they'll be really, really into it and they would pick it up really fast as well.

Participants seemed to want to find a balance of direct instruction and learning the tools through play, creation, and community. However, the participants did not come to a consensus on how involved the learning process might be for their students.

Differentiation

Participants planned for student learning using VR in differentiated ways by providing a starting model for students to manipulate or add on to, or by allowing students to start with a blank canvas. In Ruby's plant cell lesson, she shared "You can automatically instill some differentiation...for students who aren't honors, they might need to have [the flower and plant cell] already made for them. Her reasoning for this was "to have all of the stuff made that's really difficult to make so [students] don't get frustrated." The students who had the flower and plant cell model made for them could "do what [Misty's daughter] did, use the drawing tool and they could draw and explain [the flow of energy through the process of photosynthesis]." The "higher-level students [would] create their own cell and organelles (chloroplasts)."

Misty also planned to differentiate for her students by including some premade objects if necessary. She wrote in her plan, "This could be easily differentiated depending on the type of student you had. You could start with all the pieces already there for students to put together and label, OR you could give them a set of DNA bases they had to create the base pairs to match it." She also further extended the activity, "You could get really high level with AP Biology students and start with DNA, but students have to take it apart (unzip the DNA) and show replication, and lead into protein synthesis."

Though only two participants specifically touched on using immersive VR as a way to differentiate instruction, the literature has identified this as an important aspect of the tools. Both Ruby and Misty planned ideas to scaffold not only the use of VR, but engaging in the material as well.

Students Collaborating

Learning the VR technology through student collaboration was noted by participants. The participants learned VR through creation and sharing in the weekly Mini VR Maker Faires, and this collaboration extended to how students could learn the tools either through capitalizing on individual student interest and skill to lead a group, or through breaking the class into smaller groups to learn in a station model. Janet structured her simple machines lesson similar to a lab. She had specific reasoning for planning this way. She shared that she thought, "being exposed to VR through group work…[would help] students that are most hesitant...want to try it." In addition, "in a lab situation you can assign different jobs, then it's fine that [certain students may not be] comfortable using the equipment because there's something else that we can give them to do."

Misty and Mark both thought stations would be the ideal way to introduce VR into their classrooms, but for different reasons. Misty shared that she would run stations so she could "have one set of kids doing a headset at a time, so I could help them." She also expressed an interest in "having a set of kids who are trainers and every time we do something with [VR] they can help the [other] students." Mark, on the other hand, was taking into account that VR headsets may be limited in availability. He shared that he thought "the station idea is a good idea with [VR headsets] because you might not have 25 of them."

Participants identified how students collaborating could not only increase student comfort with the novel tools, but addressed how to implement this in their classrooms with limited access to the immersive VR tools.

The Role of the Teacher

Two sub themes emerged from the theme role of the teacher including (a) teacher as facilitator and (b) difficulty giving up control.

Teacher as Facilitator

Participants noted how they planned to facilitate and guide students in their learning as opposed to providing direct instruction. In their lesson plans, four of the participants described the role of the teacher during the activity as that of a facilitator. Janet mentioned the teacher "may provide redirection or focus" to students when it is needed. While students build their molecule models using Gravity Sketch and a VR headset, Ella wrote that she would "be assisting students plan their structure and building their structure." Misty and Mark both wrote that the teacher would "monitor" students as they constructed their models.

Difficulty Giving Up Control

Though some participants planned to act as a facilitator in student learning, others shared how taking this role as a teacher was out of their comfort zone. This difficulty of giving up control stemmed from both the novelty of the technology as well as the participants noting this type of instruction is not something they do in their classrooms. The participants experienced learning a new tool through making, both focused on choice and science content. In addition, each participant designed a maker-centered lesson using VR as a tool to create. However, two of the participants, Ruby and Ella, both noted that thinking about teaching in this way could be difficult for them if put into practice. Though she said she is getting better at it, Ruby shared, “VR still freaks me out a little bit as far as students doing it, because I’m not going to give [up] control.” She went on to say “technology is not usually my friend, but in this scenario, I felt like I was good enough” and she would want to incorporate VR maker-centered activities in her classroom.

Ella shared that it was “unclear” for her whether or not she would be “getting kids into VR.” She went on to say, “I think that’s kind of idealistic for me at this point.” This was partially due to the fact that she was “not ready yet to give up that control.” Though she felt this way, Ella shared “a lot of value for me as a teacher came out of this situation.”

Fostering STEM Knowledge

The participants of the study identified four areas where the use of VR could foster STEM knowledge throughout the duration of the study. These four areas were (a) biology, (b) chemistry, (c) physics, and (d) physical science. The STEM area identified by the participants was aligned with the content area covered by each teacher, with one exception. At the time the present study was conducted, physical science, a middle school level course, was not taught by any of the participants.

Participants created lessons and artifacts that directly addressed biology content including animal cells, plant cells, and DNA. While reflecting on the process of connecting science content to VR maker-centered activities, Lynne shared, “it was very easy to connect what we do in our classes to that, like I could probably think of something I could do in every single unit with VR.” For her final artifact, Lynne created a cell parts tour focusing on an animal cell. When creating her artifact, she shared, “It’s pretty cool, but being able to make [a cell] and have your kids make one and then go through it...pretty awesome.” Though her final artifact aligns with her cell unit, she envisions students continually working on this model, “you can do a whole bunch of stuff with all of these different parts in here, and I think it would actually be very useful.”

Ruby also focused on cells for her final artifact, but she created a plant cell and highlighted the energy transfer occurring during photosynthesis. Ruby was inspired by Lynne, during the last VR Mini Maker Faire, Ruby said, “when you said [you were going to do an animal cell] I stole your ideas. I was like, oh a cell, and I could have them show me stuff in the cell.” Lynne replied, “I’m glad you did a plant cell. Because if I had enough time, I was gonna do a plant cell with my animal cell!” Ruby created a flower for her first artifact so when she began her final artifact, she explained, “I took my flower because it’s not done me wrong yet, so let me keep the flower going.” She went on to explain her thought process:

> I wanted to think about what I would teach in biology. So I thought, well, we need to zoom in on the flower and look at the actual structure of the cells within the leaf. And so then I've got a plant cell and I made all the little organelles and then focused on chloroplasts. So then my goal for students was going to be to teach me about photosynthesis and chloroplasts.

Ruby described how she could use this activity in different ways. Depending on the level of the student, they could complete more or less of her idea. More advanced students could create the flower and plant cell model, while other students could start with a pre-made flower and cell model. All students would then model the process of photosynthesis. Ruby shared, “I want [the students] to show me. They can draw me a sun [using] the stroke tool...then they tell me that sunlight is being absorbed by the chloroplasts.” She went on to show how students could show how “water is coming in [so students can] draw some roots on the plant.” Once they draw that, students could show the flow of water and light energy in the plant.

Misty also tied making in VR to biology content with her final artifact of a DNA model. Her idea involved differentiation for students similar to Ruby. She stated, "you can either copy [the DNA pieces] and have the kids build the model in there for themselves, or you can have them start from scratch." Misty further expanded on her idea for more advanced courses as well, "I just got to thinking about AP Bio and DNA replication, you can literally grab on [and] split it apart and then you can add in the enzymes for DNA polymerase and show this is how DNA replicates." She continued by adding, "So eventually, we could do not only DNA replication, but we could do protein synthesis with that. So students had to take the DNA model and then turn it into RNA and then make a protein."

One participant, Ella who teaches chemistry, addressed chemistry content by creating an artifact and lesson plan focused on the construction of molecule models. Ella "built a molecule of ammonia, so nitrogen with three hydrogens off of it, their bonds in between and a lone pair up top." In her activity, Ella shared that she "would assign a molecule to students and they would make their own model." While creating their models of molecules using VR, Ella explained "you can have students build from scratch [focusing on] the relative sizes of atoms, like your nitrogen is bigger than your hydrogen." Not only could students represent the relative sizes of the atoms, but they could also model "connections with bonds and approximate bond angles" and a way to represent "the shape of a molecule according to VSEPR Theory."

Modeling molecules was not Ella's only idea of how to connect making in VR to her content area. She shared in the final VR Mini Maker Faire that she "wanted to do intermolecular forces and either have the kids build the molecules themselves or have molecules waiting for them." Once the students had the models of molecules created in VR they could "arrange them as to how they hold hands and draw the dotted line with intermolecular forces between them." This would help students "really see the three-dimensional forms" in chemistry.

Mark, the only participant who teaches physics, addressed his content differently than the other participants. He planned to use VR as a tool to create prototype models for rockets students would build. Every year Mark's physics students create rockets and see how various design choices can impact the flight of their rockets. For Mark's final artifact and lesson plan he used VR to create a prototype of one of these rockets. When sharing the activity at the final VR Mini Maker Faire Ella asked, "This is a prototype for the rockets that the kids build?" Mark replied, "Yeah, if they were going to hash out some of the design processes ahead of time, they could do that." In his lesson plan write-up, Mark explained, "Students will use VR to design a water-propelled rocket as part of the Engineering Design process. They will collaborate on the design and come to a consensus before moving to construct it physically."

Though she does not currently teach this content, Janet focused on creating models of simple machines. During the final VR Mini Maker Faire, Janet shared she did not go in with a plan of what to make, "I went kind of freeform and then I came up with something I could use. What I kept coming up with was some kind of simple machine thing." She shared that even though she taught this in the past and not currently, she was inspired because "at one point, I had this gear thing, and none of this was done on purpose, then I just got this [to start] rotating." In Janet's plan she states that students will "explore at least one simple machine...and cooperatively construct a model of their simple machine within Gravity Sketch, preferably one that shows movement."

Research Question 2: How do County High School (pseudonym) science educators perceive the benefits and limitations of using Virtual Reality to facilitate maker-centered learning activities which address K-12 science content through a professional development experience?

Research Question 2 addressed the perceived benefits and limitations of science educators participating in this study when planning to use Virtual Reality to design maker-centered learning activities. Four themes emerged when answering this research question, (a) affordances for student learning, (b) affordances for teachers, (c) limitations of learning curve, and (d) limitations to access to equipment.

Affordances for Student Learning

The themes which emerged from the affordances for student learning were (a) virtual reality as a creative tool, (b) new perspective on content, (c) possibly engaging more students, and (d) ability to save models for continuous work.

Virtual Reality as a Creative Tool

Participants noted how VR could be used in classrooms as a tool to view the student creative process and how this tool enabled the participants to create aesthetically pleasing models. Both Janet and Lynne touched on how VR could be used creatively by students in class. Janet shared “this is another tool to use with [students] to ignite that creative process, and they will come up with things I never even thought of” when reflecting on the process after it had ended. In addition, she included “a hands-on introduction to the technology of VR and the importance of creating models to represent and study phenomena” in her VR lesson plan write-up.

Lynne and Ruby both made cells for their final artifacts. However, each participant had a different approach to planning their lesson and creating their artifact. Lynne shared, “It was neat because I made an animal cell and [Ruby] made a plant cell. So not only were they different types of cells, but creatively they came out differently [as well].” She also explained how:

> The aesthetics, everything was just really pretty. Most of the time, everything turned out really pretty. I think that’s one of the things that’s going to draw the kids in too, like when they’re interested in something when something’s pretty [and] shiny, it catches your attention.

New Perspective on Content

Participants noted how creating models in VR allowed them to take flat 2D content and bring it into a three-dimensional world while providing a more flexible hands-on experience for students. In addition, participants compared the flexibility of creating models using VR to the rigidity of traditional science model kits. Janet identified one of the aspects of VR that could benefit student learning as being able to “take our learning from a 2D kind of flat world to a 3D world.” Misty agreed with this point and expanded on this idea by sharing, “kids have such a hard time, especially at the molecular level, to visualize what I’m talking about because they only see it in a 2D form.” She continued by sharing how using VR to build models of DNA as opposed to the more traditional way of building DNA models with paper could benefit student learning, “I think if [students] can physically get in there and walk all the way around it, and add these enzymes and proteins, rather than trying to just puzzle piece paper shapes together [it] would make a lot more sense to them.” In addition to creating models, Misty thought VR could be:

> another cool tool to use in the classroom that may be hard for us to see. Our microscopes aren't high powered enough to see atoms, so this is another way to get [students] to see them in a much more physical form than what I can provide in the classroom.

Misty also created a food chain using VR. When sharing how teachers could have things pre-built in Gravity Sketch for their students to interact with she said, "You could throw all the animals in the room and [tell students] you need to rearrange these and put arrows where they're supposed to be." She explained that this would give students the opportunity to have "physically have more of a hands-on experience of food chains and webs" and that it would "be more fun for [students] rather than just looking at a flattened diagram in the classroom."

Ella discussed the amount of thinking that would go into her students building models of molecules using VR as she did for her final artifact by explaining while designing students have to "keep in mind their atoms need to be relatively sized and their bond lengths." This is an improvement on the traditional model kits she uses in her classroom, because "having [students] build a model out of a chemistry model kit, the angles are already predetermined, the sizes of the atoms are already predetermined." She explained during the final VR Mini Maker Faire that the flexibility in Gravity Sketch could also make things more difficult for students because "they can't get precise angles...there is no way to kind of snap that angle into place." However, using this tool would still be beneficial because "students can move and manipulate the molecule and really see its three-dimensional structure."

Lynne created a model of an animal cell that could be explored by walking through the cell membrane and into the cell. While creating her model, Lynne also demonstrated how modeling in VR can offer a new perspective. Lynne created mitochondria in her animal cell by using a cylinder and using the stroke tool to create the matrix cristae. She placed the drawing of the matrix cristae into the cylinder and when she placed her head into the cylinder, she could see the inside of the mitochondria, while she does this she said, "and then I can just drop it in there. So now when you look in there, you can see it. Isn't that cool? Ahh!" When reflecting on the process, Lynne explained, "instead of making a physical [cell model], students can make a 3D one, which I think is even better, because I found it really cool how you could walk into it." She also shared how the perspective of what she was modeling using VR was more flexible than other mediums, "It was really neat to be able to rotate things and see them from all angles...when you drew a line it wasn't just a line, you could get the whole 360 view of the line."

Possibly Engage More Students

Participants indicated not only could using VR in maker-centered learning experiences engage students who were otherwise disengaged in the classrooms, but using this tool in the classroom could also expose students to future careers. In the final one-on-one interviews conducted with the participants, Janet shared a story about a student she had this year. Janet said,

> I will share a little story with you. I have a student that did not pass my environmental sciences class. This year, he graduated. So he got all of his major credits, but he did not pass my class. And I noticed when I was reviewing grades, that one of his strongest classes was his VR. And I thought, you know, if this were a different year, and if we had more time, I would have seen if maybe this student could have created something in VR, that was associated with the class, and I could have made his I could have differentiated for him. And I could have made his marking period four an independent project. And that would have been

> so much more meaningful for him than what we were able to do. So I think there are implications like that, that maybe nobody is even thinking about right now.

Mark also shared that using VR in the science classroom could positively impact students in multiple ways, “I think in terms of engaging students and exposing them to an industry that is growing, and making them aware, for our kids who are really into this stuff, that’s a service to them.”

Ability to Save Models for Continuous Work

Participants remarked how VR could be used to create models to be added on by students throughout the school year. Ruby, Lynne, and Misty all explained how they could have students create a model that could be continually added onto over time. Ruby shared, “If you make something in [Microsoft] Paint, you could save it and reference it again or add to it later... this was a step up from that, it’s something we could go back in and add to.” Lynne shared the same sentiment, “another thing that I liked about it is that you can go back to your projects and build on them in the future.” She went on to say, “...students could start with one or two organelles that we talked about and continuously build on that cell. You don’t have to build it all at once.” When discussing how she use the DNA model throughout multiple units, Misty shared:

> So eventually, we could do not only DNA replication, but we could do protein synthesis with [Gravity Sketch]. So students would have to take the DNA model and then turn it into RNA and then make a protein. I think it'd be a really cool thing to keep building on this one particular model, because it could be used with multiple units in biology and an AP Biology which would be really neat.

Affordances for Teachers

The three themes which emerged from the affordances for teachers were (a) teachers using Virtual Reality as a creative tool and (b) assessment.

Teacher Using Virtual Reality as a Creative Tool

Though the study focused on how students could use VR as a tool while engaging in maker-centered learning experiences, participants noted how not only did the tool make them feel more creative, but they also shared how they as teachers could use the tool to create artifacts themselves to be used in the classroom with students. Misty shared that using Gravity Sketch in VR, “made me feel more artistic than I really am.” She continued by saying she does not paint or take part in similar creative pursuits, “so to go into a world like that, you’re like yeah I could do this, I can build this 3D model.” Misty also added, “it’s so open-ended which is nice. So you can basically use it for whatever you need it for, especially the Gravity Sketch program.”

Ella, Lynne, and Ruby built onto this idea of being able to create things using VR as teachers. Ella said, “Even if I’m not ready yet to give up that control, I can make stuff in it that we can use in class for a reference point.” For example, “let’s look at a model and walk through some visual 3D representations that we wouldn’t otherwise be able to see because molecules are [so small].” Lynne also shared how VR could be used for “making tutorial videos for [students] for content...like [for a] quick and dirty recap.” Ruby also said that she could use VR for “a quick review. I could make a cell, zoom in on it, walk through each organelle, and talk about them. That would be a great review for [an assessment] or for somebody who just forgot that from biology.”

Assessment

Participants shared how using VR as a tool to create gives students an opportunity to demonstrate their knowledge in a way that allows for a deeper understanding of content. Ella and Ruby both shared possible affordances of using VR to create artifacts in terms of assessment. Ella said using VR in this way allows students to "demonstrate their knowledge of those, those connections and how all of those pieces you know, interact...it lends itself to deeper knowledge and mastery that I didn't really consider or think about before." She also shared, "There's something to be said for a visual representation of content and what's going on and that really challenges your understanding. I really liked that in a tool like this, you can really assess those things."

Ruby also shared her thoughts on how creating in VR could be used as a way to assess student knowledge. She said:

> I think this could be pretty cool, especially if I write out a really good explanation of what I want [students] to show and exactly what I expect for them to show for the light dependent, and then for light, independent [reactions]. So then they're showing me all the reactants that go in, and then the products that come out...I guess that would be in the rubric, because I'd say well, I need so many arrows going in, I need so many arrows coming out. And then that would accurately portray, or you would be modeling the process of photosynthesis

Limitations of Learning Curve

Participants shared not only knowing how to navigate the learning curve with their students, but also what it was like dealing with the learning curve themselves. However, participants also noted that once past the learning curve the tools became easier. In addition, one participant shared how creating in VR using Gravity Sketch was an intuitive process. Many of the participants shared that the learning curve of using the Oculus Quest and Gravity Sketch was a hurdle for them. Janet said she "had a steeper learning curve than anybody else, because I'm not technology oriented." However, she was not the only participant who expressed this idea of a steep learning curve. Ruby shared, "I think just starting was the hardest part. Just getting the Oculus on my head and making sure I felt comfortable understanding how to [use the technology]." Lynne echoed this sentiment when reflecting on what the most difficult part of the experience was, "it was honestly the learning curve. Trying to figure out how to work things, the different tools, and doing things like that." When thinking about implementing the creative use of VR in his classroom, Mark shared, "I still don't know how to handle the learning curve, it would be a major obstacle to figure out how to navigate." He went on to say, "The learning curve [is] the number one deterrent. I'm just not gonna get anything done, especially in this class. You're concerned about that time also."

Janet, Ruby, and Ella all described a physical reaction to the learning curve they experienced. Janet shared, "the most difficult aspect was the physical for me. Overcoming getting used to the equipment on my head." However, she said she "was actually more anxious before I did it. Then when I got it on and got used to it after a few minutes of being comfortable, I kind of got lost in that world." Ruby shared that she "couldn't really do the standing and walking too much because I was always just paranoid, I was gonna hit something." She elaborated, "It didn't make me feel scared or anxious, It was more like, uncomfortable." However, Ruby overcame this issue while learning to use the technology, "I just started sitting down and it was way more accessible to me. I'd sit in this chair and just spin around if I needed to turn to [face] things." Ella also described how she felt as she started to use VR, "the anxiety and overload, personally I don't feel anxiety often, but it was almost like there's this weird kind of tunnel vision. Then I'm dizzy, but things are not spinning. It was like I'm dizzy on the inside." She would then tell herself, "no you're good, nope there's a solid floor underneath you." Ella was worried she would not be able to overcome this, but "then the second week, I put the headset on and was like, oh I've done this before. I'm good. And it went away at that point."

Ella also shared, "I got through [the learning curve] better than I thought I would. I feel decently competent with it now, whereas I wasn't sure at the beginning that was going to be where I ended up." She was not the only one who was quickly able to address the learning curve. In her final interview, Lynne said:

> When I made my cell, I'd already hashed out what I wanted to do in my head. It wasn't just going in there blind trying to do something anymore. I had an idea of what I wanted and how to do it, so it came a little easier.

Misty, on the other hand shared "I thought it was intuitive once you get started with it. The first time was a little rough, but then by the third time I was like, oh man this is easy!" Misty, like Mark, was thinking about what it would be like to introduce these tools to her students, "I think if you just projected it on your screen at the very beginning and were like these are the basic buttons you need to do stuff, they will intuitively pick it up as well." When Misty shared with the group during a VR Mini Maker Faire that her six-year-old daughter picked up the basics of Gravity Sketch right away Lynne said, "there's still that factor of how are our kids going to learn [the tools], but after watching Misty's daughter make a flower, I think they're gonna be okay." Misty responded, "See that's what I was trying to say! I think [the students] are more intuitive about it than we are."

Limitations of Access to Equipment

Participants also noted how the limited availability of VR equipment they could use in their classrooms was a major limitation in being able to implement maker-centered learning experiences using VR as a tool to create. Lynne and Misty both shared similar thoughts, Lynne said “not having it for our classroom would be one [hurdle for implementation]. Misty also shared, “I think the biggest concern is having the availability of the equipment.” During a VR Mini Maker Faire, Ella said, “my concern is the logistics of it—having enough headsets, enough room, other kids doing it at the same time.” Misty replied, “so I would run it as a station.” While this is a cost-effective solution, Mark brought up a good point about the current state of the COVID-19 pandemic, “I’m worried about passing it from kid to kid to kid, especially in the modern age, everybody’s worried about communicable diseases and stuff.”

Conclusion

Each participant was able to successfully create a lesson using VR as a creative tool and construct an artifact using the Gravity Sketch app and an Oculus Quest. Even participants who felt there was a steep learning curve were successful in this endeavor. Ruby explains the process of designing a learning experience with these tools, “I thought the most difficult thing would be, what am I going to do in the classroom? Usually, I try to think about the hardest thing [and] tackle that, but that one didn't end up being that hard.” In addition, the participants were able to design maker-centered learning experiences using these tools that put the teacher in the role of the facilitator.

Through the process of using VR as a tool to create, the participants were able to identify many affordances these tools could bring to formal learning experiences. Taking part in this study in this way allowed the participants time to explore the tools and reflect on how they could be integrated into the classroom. Though the tools were used in a very specific way, the participants were able to not only identify affordances and limitations in a maker-centered learning context, but were starting to wonder how this could apply to other contexts as well.

This professional development experience not only exposed the participants to new technologies and new ways of creating in the classroom, but it also allowed the participants time and space to reflect on how maker-centered learning could look in their classroom. However, the participants did not stop there, there was a desire to use these tools as a teacher to create artifacts which assist in student learning.

Chapter 5: Discussion, Conclusions, and Recommendations

Discussion

This study sought to contribute to the body of knowledge of immersive VR as a tool to make in K-12 environments with respect to: (a) teachers designing maker-centered learning experiences using Virtual Reality and (b) teachers' perceived affordances and limitations of using VR in maker-centered learning environments. Significant findings are synthesized below.

Teachers Designing Maker-centered Learning Experiences Using Virtual Reality

This study contributes to the literature focused on motivation to learn, designing student-centered instruction, connecting virtual reality to science content, and teacher professional development.

Motivation to Learn

The use of VR as a creative tool was a new concept to all of the participants in the study. The participants did experience a quick demonstration of VR technology as a department earlier in the year prior to participating in the current study. However, this demonstration focused on pre-made experiences where the participants did not create artifacts. Because using VR in this way was so new to the participants there was a learning curve present. The theoretical framework of maker-centered learning was not only present in the data analysis, but also in the structure of the data collection. Participants learned the tools through not only creating artifacts directly tied to their content area, but sharing these artifacts publicly. When the study began, some of the participants shared their learning curve and framed their learning curve in the perspective of the possible learning curve that the students may face when learning the technology. However, as the participants spent time with the VR headset and Gravity Sketch app this learning curve began to flatten. When beginning, the participants seemed to lack confidence in their ability to successfully create using these tools, but this did not last long. The weekly VR Mini Maker Faires allowed the participants to share their successes and struggles with the tools.

It was during these weekly times for sharing that the participants expressed many feelings that align with previous literature in the field. Each week the participants were excited to share their breakthroughs or prepared questions on how to complete a certain task using the technology enthusiastically. This enthusiasm has been cited in previous research (Mikropoulos et al., 1998; Papanastasiou et al., 2019) in terms of student learning, and held true for teachers learning the tools. The participants were also motivated (Cheung et al., 2013; Jacobson et al., 2005; Sharma, Agada & Ruffin, 2013) to learn the technology so they could design educational experiences using VR tools. Though previous research in this area focused on student learning and not teacher learning, these findings show when learning to use VR and incorporating this into planning for student learning teachers are motivated to not only learn the tools, but to plan for their students learning and using the tools.

Designing Student-Centered Instruction

This study was designed with the previous findings from Patterson and Han (2019) in mind. They found in order to create effective VR learning experiences; teachers need to be involved in the planning process (Patterson & Han, 2019). This recommendation was placed at the forefront of planning this study and the participants were tasked with creating learning experiences using VR. Structuring the study in this way allowed the participants to see where and how these tools could be pedagogically justified (Fransson et al., 2019; Häfner et al., 2018) and allowed the participants to plan within a particular framework which is a needed area of study (Fransson et al., 2019; Häfner et al., 2018; Jowallah et al., 2018; Lim et al., 2019; Minocha, 2015).

Previous research suggested that immersive VR may not be a useful replacement for traditional video (Parong & Mayer, 2020), which is why when designing this study an emphasis was placed on the possible affordances of VR's primary elements (i.e., immersion, interaction, involvement). The participants did not use VR as a way to passively engage in curricular content. Each participant actively engaged with the tools to create artifacts that directly related to curricular goals. Participants were excited to share the affordances that using these tools in this way brought to student learning experiences. The findings of this study align with the findings of Fransson and colleagues (2019) in that the participants focused on using VR to coherently address content as well as curricular aims and goals. Each participant was successful in not only learning the VR technology, but they were also able to plan lessons that meaningfully incorporated these tools into planning for student learning. The participants capitalized on the affordances of virtual reality to develop learning experiences for students that went beyond replacing traditional video in the classroom. The integration of VR in the lessons was a meaningful inclusion and went beyond the wow factor that Fransson and colleagues (2019) found that teachers aimed to go beyond when planning learning experiences using VR.

The current study not only aligned with previous research in terms of teachers designing instruction incorporating VR, but adds to the literature on incorporating frameworks when planning for instruction using VR. Previous research suggested the need for the use of frameworks in addressing when and how to use VR in the classroom (Fransson et al., 2019; Häfner et al., 2018; Minocha, 2015). This study used maker-centered learning as a framework for using VR in the classroom and this framework proved to have promising results. Because this framework for learning focuses on the idea of learning-by-making (Papert & Harel, 1991), it was an appropriate framework not only capitalizing on the affordances of VR, but it also gave a framework for the participants to learn the new technology. Using this framework addressed the call made by Jowallah and colleagues (2018) when they shared the need of a framework for educators to plan learning experiences using VR in a way that allows educators to fuse pedagogy and technology.

Connecting Virtual Reality to Science Content

The current study was designed to address how VR has been limited in addressing core K-12 concepts (Ludlow, 2015). Additionally, because science is emerging as a promising area of focus (Civelek et al., 2014; Hite et al., 2019; Jones et al., 2014; Kwon, 2019; Parong & Mayer, 2020) when connecting VR to core K-12 concepts the focus was placed on science content. This allowed for the exploration of the use of VR when addressing curricular goals of science teachers from different disciplines. Though each of these disciplines was approached from the perspective of maker-centered learning, this still allowed for a diverse range of curricular connections. Participants left this study with concrete ways they could address curricular goals in biology, chemistry, physics, and physical science. This diversity in science content adds to the current literature on using VR to address curricular goals. Though this study did not focus on the affordances of VR beyond using it as a creative tool, each participant was successful in creating a lesson plan that allowed students to create virtual artifacts through which students learn science concepts.

When reflecting on the process of connecting these tools to curricular goals the participants have for their students, they shared that they were easily able to develop ideas where this could be useful in their classroom. This was even the case for participants who reported not being comfortable with facilitating maker-centered learning experiences in their classroom. This could be due to the structure of the study where the participants learned the tools in a maker-centered process, learning through making and the sharing of public artifacts. Engaging in learning this way could have positively impacted the participants' ability to grasp how to use the tools, but also how to connect the use of these tools to their specific content area. However, because this study focused on teachers planning for the use of these tools in their classrooms, and not the the actual use, it is not clear if these types of immersive 3D experiences also relate to increased performance on transfer tests as reported in previous studies (Parong & Mayer, 2020; Schrader & Bastiaens, 2012).

Teacher Professional Development

Previous research emphasized the need for teachers to be provided time to critically scrutinize, curate, and adapt VR for educational purposes (Fransson et al., 2019; Holmberg, 2019). In addition, there is a need for teachers to experience hands-on training for incorporating VR into lesson development (Majid & Shamsudin, 2019). This study incorporated both of these recommendations and found both recommendations to hold true. The eight-week experience with a single VR application (i.e., Gravity Sketch) allowed the participants to deeply engage with the tools as well as grapple with how to meaningfully incorporate the tools into student learning. Each of the participants previously had too few experiences with immersive VR just as Fransson and colleagues noted (2019). However, by the end of this sustained experience with the tools the participants reported an increased confidence and competence with VR and Gravity Sketch. This sustained experience aided in the participants being able to identify how VR could be used in classroom settings. This showed that giving teachers extended time focused on the use and integration of one VR application could lead to different results as shared by Fransson and colleagues (2019). By the end of the current study, participants were comfortable incorporating the VR tools into planning for student learning which is not what previous research indicated (Fransson et al., 2019).

The way the participants learned and shared progress learning throughout the study provided an opportunity to learn as a community which seemed to positively impact not only the progress with the tools themselves, but also increased the participants' ability to incorporate these tools into planning for student learning. Time and the hands-on experience were important factors to the success of the participants, but community proved equally important. Janet, for example, explained how if it wasn't for the community aspect of the study, she may not have been successful with even putting on the VR headset. The weekly Mini VR Maker Faires allowed for a safe space that was used by the participants to share important discoveries with the tools and bring questions to the group. Because the group was learning together, they were not only excited to share their progress, but they were excited to learn together. The group meetings allowed for the participants to also encourage each other with the learning process. While participants shared their artifacts the group audibly encouraged and cheered each other on through the process.

Teachers' Perceived Affordances and Limitations of Using VR in Maker-centered Learning Environments

This study contributes to the literature focused on teacher perceptions of incorporating virtual reality into instruction, affordances of virtual reality, hurdles to student learning, and lack of content.

Teacher Perceptions

Previous research conducted by Majid and Shamsudin (2019) found that sustained professional development could shape teachers' perceptions of the value of incorporating VR in instruction. These findings were also present in the current study. The sustained experience with VR and focus on one application allowed teachers to distill where there may be value in incorporating this technology into student learning. Some participants were cautiously optimistic when beginning this experience, but by the end were able to identify where using VR could positively impact student learning. Mark shared at the end of the study he was able to see the utility VR could bring to student learning and Lynne made a point in the final VR Mini Maker Faire to share how happy she was to participate in the experience and she was planning on sharing the experience with other teachers across the school division. These two examples could not have been possible if the study was not structured with enough time for the participants to explore the technology, share their experiences in a group setting, and use the technology to plan for student learning.

Patterson and Han (2019) found that the more familiar their participant was with the VR tools the more risks they took in lesson planning. This was also the finding of the present study. One participant in particular, Ella, came into the study unsure of not only how to incorporate VR, but also a general uneasiness of moving from direct instructor to facilitator in her classroom. She leaned on the fact that her content area—chemistry—"had not changed in the past 100 years". However, by the end of the study the lesson that Ella planned not only incorporated student creation using VR, but also moved the teacher role from direct instructor to facilitator. This shift in Ella's view of the role of teacher and student was made possible through the sustained experiences with VR and the community aspect of the study.

Affordances of Virtual Reality

The findings of this study align with prior research in relation to making the impossible possible, active learning, motivation to learn, and differentiation. Participants created artifacts using VR tools and interacted with these artifacts in ways that would not be possible in the real world, in particular copying, deforming, and scaling as references by Civelek and colleagues (2014). While creating his final artifact, Mark scaled his model as large and as small as he could. He was impressed with the seemingly infinite possibilities in scale while designing. While designing, many of the participants altered the scale while designing as well. At times it appeared to increase the ease of designing to alter the scale of the artifacts. Many of the participants used the duplicating function in Gravity Sketch to complete their artifacts. This allowed them to perfectly replicate various shapes within their designs. There were also times when the participants also deformed shapes by altering the vertices within Gravity Sketch. This functionality allowed Ruby to create the petals of her tulip she constructed as part of her final artifact as well as trees and rocks which she created for earlier artifacts.

Creating using VR seemed to bridge the digital and physical in a way other tools have yet to do. Though these affordances—copying, deforming, and scaling—can be performed using a traditional computer interface, the participants reacted to this ability to perform these tasks in VR with a new appreciation. The enthusiasm with which the participants engaged in creating in VR and capitalizing on the affordances reflected the importance of immersion and interactivity on creating hands-on experience with virtual objects, impacting motivation, and making learning more enjoyable in previous research (Checa & Bustillo, 2020; Civelek et al., 2014; Hite et al., 2019; Martirosov & Kopecek, 2017). Though previous research focused on student use of VR and the potential of using these tools to learn, these findings aligned with the experiences of the science teachers participating in this current study.

One major addition to the field in terms of affordances of using VR in educational contexts is the use of VR as a tool for creation. Maas and Hughes (2020) stated the need for future research to consider VR technology as a means of creation and discovery. The findings of this study not only showed how VR could be used as a creative tool for student learning when paired with the concept of maker-centered learning, but the teachers who participated in the study also began to explore the ways in which VR could be used as a creative tool for teachers to use as a tool in their classrooms. One of the research questions sought to be answered through this study focused on how teachers planned for maker-centered learning experiences using VR as a tool to create. The participants came up with many ideas including prototyping for physical models, creating tours of a cell, modeling the process of photosynthesis, and creating models (i.e., molecules, DNA, and simple machines). Each participant planned a learning experience that not only focused directly on the content they are responsible for teaching but also incorporated VR as the tool which students would use to create digital artifacts.

The participants also reflected on how VR could be used by the teachers as a tool to create artifacts to use in their instruction. This finding aligns with the recommendations for future research presented by Maas and Hughes (2020). Though the focus in this study was on student learning, the participants saw possible value in creating artifacts for students to experience the content in their classrooms from a new perspective. The participants began to brainstorm how they could record videos of the artifacts they created for students to use as a review or to use as reference for later in the course. Though the participants have not implemented this idea for this novel use of VR as a creative tool in teacher instruction it could be a future area of research in the field.

Hurdles to Student Learning

There are a number of hurdles cited in previous research when using VR to address student learning. Fransson and colleagues (2019) state educators may have difficulty identifying measurable learning outcomes when incorporating VR into learning. This is not consistent with the findings of the current study. The participants in this study were able to identify specific measurable outcomes for students when using VR as a tool in maker-centered learning contexts. This discrepancy in findings could be due to the maker-centered learning structure of the professional development, or because the final artifact created by the participants accompanied a lesson plan write-up.

Fransson and colleagues (2019) also stated that they found when implementing VR learning experiences teachers cannot easily see what students are experiencing which makes it difficult to provide real-time feedback, scaffolding, or problem-solving assistance. Though the participants in the current study did not implement their lessons, they did plan learning experiences for students. The participants did not share any of these concerns shared by Fransson and colleagues (2019). This could be because of the structure of the study where the participants saw how casting from the VR headset to a computer is possible, or how videos can be recorded within the VR headset and easily shared. When designing learning experiences for students, many of the participants used the structure of the study to plan for a community aspect in their lessons which relied on students collaborating with one another, providing real-time feedback, and assisting in problem solving. This strategy directly addresses the concerns raised in previous literature (Fransson et al., 2019).

A possible hurdle in student learning raised by Parong and Mayer (2020) was reflected in the current study, but not fully. Parong and Mayer (2020) state learners' unfamiliarity with VR technology may negatively impact their learning. The current study showed how it is possible for individuals to learn the technology and be productive with the tools. However, this productivity could be due to sustained experience with the tools. The participants also raised concerns about their students learning the tools, but this was not a universal feeling. Misty explained how she thought using Gravity Sketch in VR was an intuitive process and could see her students being successful with these tools without much trouble.

Parong and Mayer (2020) also shared that learning in immersive environments could lead to distractions from extraneous stimuli. This was not a finding of the current study. This could be because of the application as well as how VR was used in the study. Gravity Sketch is not an application with extraneous stimuli. The user is placed in an empty room similar to a warehouse, which can also be changed to a variety of simple backgrounds. This environment allows the user to focus on the task at hand—creation—as opposed to being distracted by extraneous stimuli. In addition, VR was used as a tool to create as opposed to consume content. Because of this the only virtual aspects in the experience are those created by the user. If VR was used in other ways the findings could align with that of previous research.

Some participants reported physical reactions to VR—dizziness and disorientation—that align with previous research (Fransson et al., 2019; Kawai & Häkkinen, 2019; Kwon, 2019; Oak, 2018; Rebenitsch & Owen, 2016). However, these negative physical effects did not last long for the participants. This quick adjustment reported by the participants could be due to the sustained nature of the study. One participant, Ruby, discovered she was more comfortable sitting down while creating in VR, while others reported just adapting to the novelty of the experience. Allowing the participants to orient themselves to the technology while outside of the group environment could have led to this finding.

Lack of Content

Research notes a limitation in the VR experiences that have been created for student learning. These experiences can be difficult for teachers to incorporate into curricular goals

(Fransson et al., 2019) or technical skills not possessed by educators (Fransson et al., 2019) which can lead to a difficulty aligning VR experiences with specific learning goals (Fransson et al, 2019; Jensen & Konradsen, 2018; Kwon, 2019). This was not a finding of the current study. This discrepancy is likely due to the way VR was used. Previous research relied on pre-made VR experiences to incorporate into student learning, but the current study used VR as a tool to create. Because of this distinction, the participants easily incorporated the technology and skills gained through the process into planning for student learning experiences. This reported lack of content by previous research was not found in this study because the learning does not require a pre-made experience; rather, the learning happens through using VR to create artifacts.

Implications

The results of the present study connect with many implications for both research and practice.

Practical Implications

The findings of this study lend themselves to implications for practice. The practical implications of this study include concrete ways to connect VR through a maker-centered learning approach to science content, the possible affordances of VR for educators, and the possible importance of a Maker Faire structure in professional development.

The participants came out of this study with six concrete ways to connect VR through a maker-centered approach to science content. Each participant was able to develop a lesson with an accompanying example artifact constructed using VR. The participants did not report finding the aspect of connecting this technology to their content area difficult. In the VR Mini Maker Faires the participants came up with more ideas on how to use VR to address their curricular goals through maker-centered learning.

One implication that was not planned for was the possible affordances VR could have for teachers designing instructional materials for their students. The participants were not only able to develop ways their students could learn through creating using VR, but they were also able to brainstorm ideas how they as teachers could use VR to create educational materials for their students. There are a number of factors why this implication could have arisen. The structure of this study was heavily influenced by the ethos of maker-centered learning. The participants engaged in learning in a maker-centered way which could have begun to instill a maker mindset. In addition, with the study taking place during the COVID-19 pandemic, the participants' students were engaging in some form of virtual learning. With this being the case, the participants were creating much of their own educational materials to aid in the virtual instruction of their students. These factors could have influenced the participants and inspired them to view these tools as a way to present educational content to students.

The weekly VR Mini Maker Faires proved to be an invaluable aspect of this study. This dedicated weekly time allowed participants to not only reflect on their own learning, but collaborate and brainstorm with their peers as well. If a participant faced a struggle in trying to create using VR, they were able to ask their peer group for advice and assistance. The participants also used this time to encourage each other in their progress. When designing sustained professional development, creating an environment that promotes a community of learners, such as the VR Mini Maker Faires in the current study, could be an important way to promote increased collaboration and problem solving.

Theoretical Implications

There are a number of theoretical implications provided by this study. The theoretical implications include the use of VR in creative ways, the role of VR in maker-centered learning contexts, and teachers learning new technologies through a maker-centered approach.

With VR still being a novel technology in K-12 education researchers and practitioners are still evaluating where this tool fits in this specific context. Using VR as a tool with which to create in K-12 environments directly addresses the reported limitation of VR not being an adaptable tool in K-12 contexts and applications not aligning to educators' curricular goals. Creating 3D models using VR opens the door for a wide range of curricular connections and increased utility of VR in K-12 contexts. In addition, using VR in this way allows educators to be less reliant on the development of VR experiences that can apply to their curricular goals.

Digital tools have proved invaluable in maker-centered learning contexts and VR could be the next digital tool to be used in maker-centered contexts. Because VR can allow for digital creation with a more hands-on approach this tool seems to have the potential to play a role in maker-centered learning contexts. There are many ways VR can be used and this is still being investigated by researchers and practitioners, but the way VR was used in the current study was well aligned with the ethos of maker-centered learning. More research is needed to investigate the full potential VR could have in maker-centered learning.

The participants learned how to use VR and the Gravity Sketch application through play and creation which is very much aligned with the idea of maker-centered learning. Though each participant found success in developing a lesson plan and example artifact using these tools, the participants expressed a need for more direct instruction with the tools. There was a brief introduction to the tools in a whole group setting, but following the introduction the participants learned through creating artifacts and sharing their experiences with the group. With the participants interested in a balance of more direct instruction with the tools and a maker-centered learning approach it could be beneficial to find a balance between these approaches when learning new technologies.

Limitations

The interpretation of the findings in this study are limited by numerous factors. The study is limited by the study design. In addition, when interpreting the findings of this study the researcher's role and biases must be considered.

Being the sole person designing and implementing the study in the school division in which I work was a limitation in the study design. This could have impacted the honesty and openness of the participants. Though through the duration of the study the participants and I were able to develop a sense of community where open, honest, and critical feedback was encouraged, my role as a central office employee could have impacted the participants' honesty. However, throughout the duration of the study the participants seemed open and willing to provide their honest thoughts and opinions. This comfort during the study could be due to established relationships.

The data collected in the study, as with all case studies, were based on description, opinion, and feeling (Suryani, 2008). Though these data provided insight and were able to address the research questions in the present study. Through triangulation methods, this inherent limitation was addressed (Maxwell, 2013; Stake, 2005; Yin, 2018).

Recommendations for Future Research

Though the implications and findings of this study contribute to both research and practice, there are many recommendations for future research in this field. This study focused on educators' thoughts and perceptions of using VR in a maker-centered context to address curricular goals. Future research could take the lessons developed by the participants of this study, or newly developed lessons using VR with a maker-centered approach, and carry them out in classrooms with students. Though the teachers participating in this study were able to create lessons and were enthusiastic about implementing their ideas, the implementation was outside the scope of this study.

The participants were interested in how they could use VR as a tool to create instructional materials for their classroom including videos for reviewing topics. Future research could investigate the possible affordances using VR in this way could bring to K-12 learning environments. In addition, future research could investigate the connection between teachers' motivation to create using digital tools and developing a maker mindset.

Future research on maker-centered learning could investigate the possible need for a balance of direct instruction of new tools for teachers and students and learning through play and creation. The current study was structured in a way where teachers learned to use the tools through play creating artifacts. However, the participants did express their belief that a more direct instruction of the tools could have been beneficial to the process.

This study specifically focused on the use of VR in maker-centered learning contexts to address the curricular goals of high school science courses. This focus was based on previous research in the field. However, even though the participants did not teach other contents they shared how approaching learning with a maker-centered lens with the use of VR could be used to address other content areas. When the participants shared their experiences at the end of the school year at the division-wide conference, teachers from other content areas and grade-levels were interested in learning how they could use these tools with their students. This could be a focus of future research.

The current study used a multiple-case case study design with six participants. This methodology and sample were appropriately aligned to the research questions presented in this study. However, other methodologies with a wider group of participants could be a direction for future research. The current study was exploratory in nature, but the findings and conclusions are promising and require future research in the field to expand on the ideas presented in this study.

Conclusion

Researchers and practitioners alike are still finding how or if VR fits into K-12 instruction. The current state of integrating this technology into K-12 education to date has focused on students consuming knowledge in VR environments. This study approached the use of VR as a tool for creation paired with a maker-centered learning context. The aim of this study was to explore the possibilities of using VR as a tool to create through the lens of maker-centered learning. The results of this study are promising in the fields of both VR in K-12 contexts as well as maker-centered learning. When used as a tool for students and teachers to create, VR could prove to be an important tool in maker-centered learning experiences. The findings of this study and the fact that the prices and technical knowledge of using VR equipment are both declining could lead to a promising future for VR in maker-centered learning experiences.

Through examining the experience of science educators learning to use VR as a tool for educational creation and developing learning activities aligned with their curriculum it is clear that more research is needed on the overlap of VR and maker-centered learning. This study addressed the gap in the research of using VR as a tool for creation that aligns with curricular goals. In this study the way high school science educators use VR to design maker-centered learning activities to address K-12 science content was analyzed. The participants of this study were able to craft maker-centered learning experiences using VR as a tool to create for various science content areas (i.e., biology, chemistry, physics, and physical science). This is a promising start for beginning to integrate VR into K-12 learning experiences that focus on students being producers rather than consumers of knowledge.

The participants of the study also shared the perceived benefits and limitations of using VR to facilitate maker-centered learning activities which address K-12 science content. Though there were many possible benefits to student learning—VR as a creative tool, new perspective on content, possibly engaging more students, and the ability to save models for continuous work—the participants also began to explore possible benefits for teachers as well. The participants identified teachers using VR as a creative tool, assessment, and differentiation as possible benefits for teachers. The fact that the participants saw VR as a way to assess student learning was a particularly interesting finding because previous research found lack of assessment ability as one of the limitations of VR in K-12 contexts. This discrepancy could be due to the pairing of VR and maker-centered learning. In addition, the main limitations the participants found were the learning curve and access to VR equipment. Though access to equipment may rely more on school budgets or grant availability, the learning curve limitation could be directly addressed with continuous professional development and the implementation of the lessons developed by the participants.

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Appendix A

Pre-PD Interview Question	Example Probing Sub Questions
Can you describe the experience you have had with VR in the past?	Was this experience related to your work as a teacher at all? Have you ever used VR as a tool to make something? If so, can you describe the experience?
How would you describe your interest-level in VR?	
Do you see VR as a tool that could be integrated into your classroom?	If so, how could VR be used as a tool in your classroom?
Do you ever incorporate students making things in your classroom?	If so, do you see any benefits to students making things in your classroom? If not, do you see any possible benefits to students making things in your classroom? Is this something that you could tie to the content you teach? Why or why not?
What are you hoping to get out of this professional development experience?	

Appendix B

Screen Recording Question	Example Probing Sub Questions
What did you make?	
Why did you make it?	
How does what you made align to the lesson plan you created?	How did it feel to show an example of learning through the creation of something in VR?
Did you have any struggles when you were working in VR?	Is there anything you learned from overcoming these struggles?
What was it like using VR to create something?	
Was there anything you would change in your design if you had more time?	

Appendix C

Lesson Title	
SOL (Number & Description)	
Background knowledge	
Describe what the students will be doing	
Describe what the you as the teacher will be doing	
Outcomes - what would you like the students to come out of this learning experience with?	
Additional Notes (if needed)	

Appendix D

Mini VR Maker Faire Question	Example Probing Sub Questions
Would anyone like to share what they made?	Could you describe what it was like to use VR to make your artifact? Why did you choose to make this?
What went well when you were working in VR?	
Was there anything that you wished you knew how to fix or accomplish using the app in VR?	Does anyone have any tips for this?
Did anyone learn anything that could help the group this week?	
How do you see this tool connecting to the content you teach in your classroom?	Would anything get in the way of you implementing it?
What benefits do you see VR bringing to learning?	
What limitations do you see with using VR in the classroom?	

Appendix E

Post-PD Interview Question	Example Probing Sub Questions
Can you describe the artifacts you made during the PD experience?	What inspired you to create these particular artifacts?
What was it like learning to use VR as a creative tool?	Did you get more comfortable using VR through this process? Why or why not?
How did it make you feel to create something in VR?	Did this PD experience inspire you to want to do this in your classroom?
What did you like about creating in VR?	
Did you face any struggles during the PD when you were trying to complete the tasks each week?	Do you think students would face any of these struggles if you were to implement this in your classroom? As a teacher how would you address these struggles?
Has making or creating an object using VR helped you understand something besides what you set out to create?	
Can you describe what it was like connecting VR to your content area?	
Was this experience beneficial to you? If so, how?	How would you compare this professional development experience to previous professional developments as a teacher? Did you feel a sense of community throughout the PD experience?
What did you learn through this professional development experience?	What was the most difficult aspect of the professional development? Why? Were you anxious about anything when learning about what the professional development entailed?
Do you see VR as a tool you could use in your classroom?	Why or why not? How would you like to use VR in your

	classroom?
	Is there anything standing in the way of you using VR in your classroom?
What could have improved your learning during this PD experience?	

Appendix F

Good afternoon,

My name is Matt Caratachea and I am looking for possible participants to take part in a qualitative research study focused on the experiences of high school science teachers when learning how to create 3D models aligning to science content using immersive virtual reality (VR). The study will be a professional development experience where you would get extended use of VR tools and will collaborate with a professional learning community at the school made up of the science team. At the conclusion of the professional development, you will have an improved understanding of how to create 3D models using VR and concrete ways to connect it to the content you teach in your classroom.

There will be five focus group meetings after school that will last 45-60 minutes. These meetings will be recorded for transcription purposes. At the conclusion of the professional development experience, I will conduct 45–60-minute one-on-one interviews with each participant which will also be recorded for transcription purposes. Though the focus group and individual interviews will be recorded for transcription purposes, your name, school, and other identifiable information will be anonymized to ensure complete privacy. Once the transcripts are completely anonymized, they will be analyzed for themes by a research team.

Throughout the professional development you will be provided with an Oculus Quest (belonging to the school) and an iPod Touch (provided by VCU) for audio recording purposes. During the professional development you will create three models using VR. While in VR you will share the models through a screen recording on the Oculus Quest. Because the Oculus Quest does not capture audio in screen recordings, the iPod Touch will be used for that. I will combine the screen recording and the audio from the iPod Touch deleting any identifiable information to ensure complete anonymity. Once the audio and video are combined, I will delete the audio recordings from the iPod Touch.

This experience is completely voluntary. If you are interested in participating in this study please reply to this email to let me know. We will then set up a schedule that works for everyone who is interested in participating. In addition, if you choose to take part in the study you are able to drop off at any point for any reason without any negative consequences. In a small percentage of people, Virtual Reality has the potential to lead to negative physical reactions (dizziness, headaches, or even nausea). If you experience any of these and would like to leave the study after it begins you will be able to do so without any negative consequences. If you have any questions or concerns please do not hesitate to reach out and ask.

CV

EDUCATION

2021 **Ph.D. in Education (Curriculum, Culture, and Change)**

- Virginia Commonwealth University - Richmond, Virginia
- Dissertation: Virtual Reality as a Tool to Make in K-12 Environments

2010 **Master of Teaching**

- Virginia Commonwealth University – Richmond, Virginia

2007 **Bachelor of Science in Psychology**

- Virginia Commonwealth University – Richmond, Virginia

RELEVANT WORK EXPERIENCE

2020 – Present Coordinator of Technology Integration & Innovation - Goochland County, Virginia

- Division-wide leader focused on the intersection of technology, teaching, and learning
- Work hand in hand with teacher, principals, and community partners to positively impact the student experience

2020 Adjunct Professor

- Virginia Commonwealth University - Richmond, Virginia
    - TEDU-510: Instructional Technology in K-12 Environments

2016 – 2020 12-month Elementary Innovative Learning Coach - Henrico County, Virginia

- Member of the 12-month Innovative Learning leadership team
- Collaborate with curriculum and professional learning specialists to support teachers and other coaches in the district
- Work in conjunction with educational directors to help support the Innovative Learning team and my school principals on district-level initiatives
- Engage community in learning experiences by acting as a lead for multiple Henrico County Innovative Learning sponsored events

Summer 2016 Henrico County Public Schools Summer Academy

- The 3 C's: Code, Create, and Think Critically
    - Summer enrichment course for rising 4th and 5th graders
    - This class focused on coding, 3D design, and 3D printing

2014 – 2016 11-month Elementary Innovative Learning Coach – Henrico County, Virginia

- Coach teachers in developing 21st Century teaching skills through implementation of the Henrico Learner Profile, as well as leveraging digital tools, incorporating computer science standards, and integrating STEAM into their classrooms
- Coach and collaborate with Kindergarten – 5th grade teachers and students
- Meet regularly with school administration to develop professional learning experiences for teachers to meet school-wide goals

- Work collaboratively with teachers and content specific coaches to inspire innovative teaching practices county-wide

2011 – 2014 Third Grade Teacher at Crestview Elementary School – Henrico County, Virginia

- Provided meaningful learning experiences within the third-grade classroom

Scholarship

2021 Jones, W. M., Caratachea, M., Schad, M., & Cohen, J. D. (2020). Examining K-12 teacher learning in a makerspace through the activity-identity-community framework. *Journal of Research on Technology in Education*.

2020 Caratachea, M. & Jones, W. M. (2020, April). Constructionism in maker-centered learning: A systematic literature review. Poster presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Jones, W. M., Caratachea, M., & Schad, M. (2020, April) Authentic maker experiences as teacher professional development. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

2019 Jones, W. M., Cohen, J. D., Schad, M., Caratachea, M., & Smith, S. (2019). Maker-Centered Teacher Professional Development: Examining K-12

Teachers' Learning Experiences in a Commercial Makerspace. *TechTrends*. https://doi.org/10.1007/s11528-019-00425-y

2018 Caratachea, M. (2018, March). Developing a Maker-Centered Professional Development Program for K-12 Teachers. Paper presented at the Society for Technology & Teacher Education International Conference, Washington D.C.

Jones, W. M., Schad, M., Caratachea, M., Cohen, C. & Smith, S. (2018, April). Maker-Based Teacher Professional Development: Examining K-12 Teachers' Learning Experiences in a Makerspace. Paper presented at the annual meeting of the American Educational Research Association, New York, NY.

OTHER RELATED WORK EXPERIENCE

2020 Swiss National Science Foundation

- External grant reviewer

2019 University Course Co-Developer

- Virginia Commonwealth University - Richmond, Virginia
    - TEDU-510 Instructional Technology in K-12 Environments

University Course Co-Instructor

- Virginia Commonwealth University - Richmond, Virginia
    - TEDU-510 Instructional Technology in K-12 Environments

RVA ScratchEd Meetup Co-Organizer (2019-Present)

- Peer-designed professional learning experiences inspired by the unconference model focusing on the web-based coding platform Scratch

Society for Information Technology & Education (SITE) Program Review Board Member

- Reviewed academic paper proposals focused on teaching and learning with emerging technologies for the SITE annual conference

PROFESSIONAL PRESENTATIONS

2021 EdTech RVA

- 3D Design and Printing Present & Beyond

SITE

- VR in Education – Panelist

2020 VCU College of Engineering Early Engineers Teacher Workshop

- 3D Design and Printing

American Educational Research Association (AERA)

- *Constructionism in maker-centered learning: A systematic literature review*
- *Authentic maker experiences as teacher professional development*

EdTech RVA (Virginia Commonwealth University)

- *Extend Your Love of Scratch*
- *Bring Coding to Life*

2019	Virginia Society for Technology in Education (VSTE) Conference • *ScratchEd Meetups* VCU Holmes Scholars Fall 2019 Research and Mentorship Summit • *Tell Me About Our Graduate Student Organizations - LaunchPAD* International Society for Technology in Education (ISTE) Conference • *Teed Up For Success: Using the Learner Profile to Map Growth* #LifeReady Henrico County Public Schools Conference • *Encourage Critical and Creative Thinking Through 3D Design and 3D Printing* Guest Lecturer - University of Richmond • *21st Century Teaching and Learning* Virginia Children's Engineering Council Convention • *Become a Coding Pro with Scratch 3.0* EdTech RVA (Virginia Commonwealth University) • *Digital Creations on a Dime* • *Surfin' with Google Sites*
2018	Virginia Society for Technology in Education (VSTE) Conference • *Be the Most Tubular Teacher with Tinkercad* VCU LaunchPAD at Reynolds Community College • *Show Me the Money!*

- Co-presented a session to community college students focusing on how to find and apply for scholarships when they are transferring to a four-year institution

Guest Lecturer - Virginia Commonwealth University

- *Integrating the arts into the Curriculum for Young Children*

Henrico County Public Schools Elementary Technology Conference: Dive into Deeper Learning

- *Getting Artsy with 3D Printing*
- *How and Why You Should Let Students Decide: Using Choice in the Classroom*
- *Flipping the Elementary Classroom*

American Educational Research Association (AERA)

- *Maker-Based Teacher Professional Development: Examining K-12 Teachers' Learning Experiences in a Makerspace*

Society for Technology & Teacher Education (SITE): International Conference

- *Developing a Maker-Centered Professional Development*

Virginia Children's Engineering Council Convention

- *Coding the Curriculum*
- *Soaring to New Dimensions with 3D Printing*

EdTech RVA (Virginia Commonwealth University)

- *Learning Takes Flight: Using Codable Drones in the Classroom*

2017 Guest Lecturer - Virginia Commonwealth University

- *Integrating the arts into the Curriculum for Young Children*

Virginia Society for Technology in Education (VSTE) Conference

- *Soaring to New Dimensions with 3D Printing*
- *Learning Takes Flight: Using Codable Drones in the Classroom*

Virginia Children's Engineering Council Convention

- *Tinker the Curriculum (3D printing and design in the elementary classroom)*

TeacherFEST (Henrico County Secondary Teacher Conference)

- *Digital Creations on a Dime: Free Creative Digital Resources for Teachers and Students*

Henrico County Public Schools Elementary Technology Conference: Field Day of the Future

- *Taking Children's Engineering from Analog to Digital*

2016 Virginia Society for Technology in Education (VSTE) Conference

- *Code, Create, and Think Critically*

Richmond Area Reading Council Conference

- *Literacy and Technology*

Henrico County Public Schools Elementary Technology Conference: Techapalooza

- *3D Printing and the Curriculum*

MathScience Innovation Center Conference: K-12 Educator Conference

- *Code, Create, and Think Critically*

Poster session: Teaching Literacy in a Digital World (Virginia Commonwealth University)

- *Digital Fabrication and Literacy*

EdTech RVA (Virginia Commonwealth University)

- *Coding, Creating, and Critical Thinking*

2015 Leading Edge

- *Innovative Leadership: How to utilize technology as a school administrator*

Henrico Elementary Technology Conference

- *Put Your Class on the Red Carpet with Adobe Premiere*

2014 Henrico Elementary Technology Conference

- *Students Creating Videos in the Classroom*

2012 EdTech RVA (Virginia State University)

- *Edmodo in the classroom*

Elementary Technology Conference, Connections: Content, Technology and 21st Century Skills

- *Edmodo in the classroom*

GRANTS

2018 Learning Taking Flight ($3,113.86)

- Received funds to purchase codable drones and 360 video cameras
- Acted as a member of the writing team for the grant

2017 Code, create, and think critically ($4,000)

- Providing opportunities to utilize emerging technologies and STEM based activities to deepen learning in the core content areas
- Acted as a member of the writing team for the grant

2016 Math on the Spot ($1,964.81)

- Received funds to produce an educational math web series promoting the real-world application of elementary math skills
- Acted as a member of the writing team for the grant

2015 Moving the Maker Movement into the 21st Century ($3,109.07)

- Received funds to purchase 3D printer, Makey Makeys, and materials for Henrico County Public Schools
- Acted as a member of the writing team for the grant

PROFESSIONAL MEMBERSHIPS AND CERTIFICATIONS

2019-Present

- Virginia Society for Technology in Education (VSTE) Board of Directors
- Certified Apple Teacher for iPad, Mac, and Swift Playgrounds
- President of LaunchPAD at VCU
    - LaunchPAD is a doctoral student organization focused on providing support to doctoral students, with faculty assistance, in writing for academic publication, reviewing research manuscripts, and an overall introduction to scholarly publication.

2018-2019	• Media Specialist for LaunchPAD at VCU ○ LaunchPAD is a doctoral student organization focused on providing support to doctoral students, with faculty assistance, in writing for academic publication, reviewing research manuscripts, and an overall introduction to scholarly publication.
2017-Present	• International Society for Technology in Education • Society for Information Technology and Teacher Education • American Educational Research Association
2015-Present	• Virginia Society for Technology in Education

HONORS AND RECOGNITION

2019	• Jose G. Alcaine award winner at VCU
2016	• VSTE Innovative Educator of the Year • Nominated for the VCU 10 Under 10 Award
2014	• Henrico 21 award winner • Received recognition from the Henrico County Division of Fire for writing a song and producing a video promoting fire safety with preschoolers at Kaechele Elementary School • Students chosen to share at Student 21
2013	• Two-time Henrico 21 award winner

2012

- Crestview first year teacher of the year winner
- Henrico County first year teacher of the year finalist
- Featured on GoAnimate for schools website