MARTIN, TEENA L. Ph.D. Learning in 3D: Creating Virtual Reality Environments. (2024)
Directed by Dr. Melody Zoch. 165 pp.

This study investigated the understudied area of virtual reality (VR) creation among elementary-aged youth, exploring their engagement in VR creation and the ways in which educators can facilitate this creative process. Using an embedded case study, the researcher examined how the youth visualize writing using the VR creation tool, CoSpaces. To answer the research questions, 13 youth in grades three to five and one instructor participated in observations, focus groups, and interviews. The findings show that a "community of learners" developed in which the youth and adults engaged in dynamic learning to create immersive, interactive VR scenes that effectively visually represent their writing and provided the youth with ideas to improve their writing. Furthermore, the youth were actively engaged and expressed pleasure in the activity. The findings of the study support the view that VR creation can be an effective tool for learning in the elementary classroom.

LEARNING IN 3D: CREATING VIRTUAL REALITY ENVIRONMENTS

by

Teena L. Martin

A Dissertation
Submitted to
the Faculty of The Graduate School at
The University of North Carolina at
Greensboro in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Greensboro

2024

Approved by

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Dr. Melody Zoch
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DEDICATION

To Aspen: Always remember to follow your dreams.

APPROVAL PAGE

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ACKNOWLEDGEMENTS

I couldn’t have completed this dissertation without the support of a great many people. First, I am deeply grateful to my committee chair, Dr. Melody Zoch, for your unwavering support and understanding. I am also grateful to my committee members, Dr. Wayne Journell, Dr. Heather Moorefield Lang, and Dr. Sara Porter for pushing my thinking and helping me grow as a researcher and scholar.

When I began this journey, I met so many new people who I now consider friends. Sarah and Dearing, you both helped me so much in my research. I cannot express enough how much easier it was to have you by my side. For everyone I met at UNCG in the doc program, your friendship has meant the world to me.

Two years ago, I started a new job, and they have been incredibly supportive of this journey. Ms. Mika Davis, I couldn’t ask for a better colleague. Your support, whether through your words of Zen or your understanding as I take a bit of time here and there to get this thing done, has been lifesaving. Dr. Joi Bulls, I couldn’t ask for a better, more understanding supervisor. I never once felt that I couldn’t get this done while working because you made sure I could. For my HHS family, thank you for asking how it’s going and reminding me that it can be done.

My family, both by blood and by choice, have been nothing short of extraordinary. You’ve all had to listen to me gripe about the process and lament at the time I didn’t have, but you did it with patience and understanding. Daddy, just to have you ask me what my dissertation is about and know that you’re telling other people about it makes me grateful; thank you for being proud of me. Carolyn, my bonus mom, you never failed to ask how it’s going and to tell me how proud you are of me, and I appreciate it so much. Jim, my bonus dad, thank you for always believing in and supporting me. Mama, you were my first mentor, my shero and one of

my primary sounding boards, even when you didn't know what I was talking about. I like to tell people how you tried to talk me out of teaching to go into computers instead. I'm happy to say that we were both right. Lynn and Rhonda, my sisters by choice, thank you for the girls' days, nights out, and the group chat where I know I can count on your support. To the rest of my family, thank you for your love.

Ethan, you were there at my first college graduation, even if you don't remember it, my inspiration. You were my whole life for so long, and now, still, I count you not just as my son, but my friend. And now, you've given me another reason to finish: for your daughter, and any more grandchildren I may have, to always know what's possible. Thank you for being in my life. I'm super proud of you!

And finally, thank you to my husband, Eddie, my best friend. You've been my rock. You're the first one I call whether good or bad. I cannot express enough how much I appreciate your support. You've listened to me complain, you've celebrated with me even when you weren't sure what we were celebrating, and you've told me I can do it over and over. Life is better with you in it. I love you.

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CHAPTER I: INTRODUCTION

Making, or the creation of some sort of product, has increased in educational settings with the incorporation of digital technologies and makerspaces. As digital technologies are becoming a standard in the classroom rather than an extravagance, new opportunities for learning and teaching unfold. For instance, one type of digital technology, virtual reality (VR), has benefits for learners. However, the literature contains limited information on the educational outcomes of students engaging in virtual reality creation activities. This study aims to address the gap by exploring how youth engage in creating VR and how teachers can support them. This chapter will provide an overview of the conceptual framework and background information which shaped this study, the research problem, and the questions this study addresses, and the significance of the research.

The Changing Landscape of Educational Technology

In Mid-March 2020, schools across the US began preparing for an inevitable shut-down because of the Covid-19 pandemic. In districts without 1:1 access to technology, teachers prepared work packets. However, those with enough devices for every student began preparing to switch from face-to-face instruction to online instruction. Instructional technologists had been preparing for this moment for forty years, since recommendations to include computer science in graduation requirements had been introduced (Culp et al., 2005). Despite calls for implementing educational technology in the classroom, including the 2017 *National Educational Technology Plan* (NETP), many teachers felt unprepared for that role when the pandemic necessitated the switch to online schooling (OECD, 2019).

Still, the pandemic led to changes in how technology is used in education. Pandemic funding led to gains in school-to-home communication, quality of instructional materials, student engagement, and technology skills within learning (McEwen & Foss, 2022; Project Tomorrow &

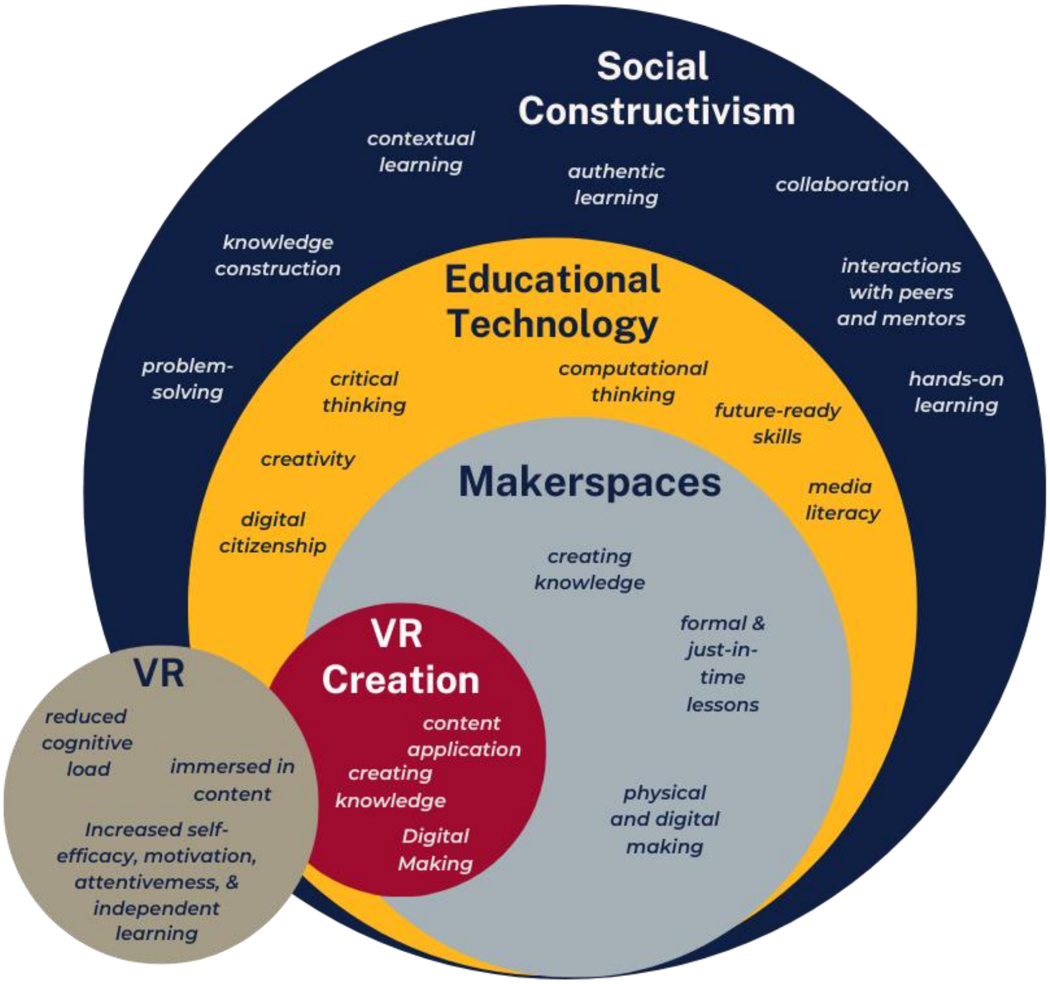
Spectrum Enterprises, 2022). EdWeek Market Brief (Molnar, 2020) reported in July 2020 that access to educational technology tools averaged 90% more per month in the 2019-2020 school year than the previous school year (Molnar, 2020). Much of this increase occurred after the pandemic-related school closures due to the switch to completely online learning. The abrupt switch to online made clear that despite the slow adoption, when necessary, schools can make the changes necessary to utilize educational technology. In fact, many are touting this as a new age in education, in which technology is an extension of the classroom (McEwen & Foss, 2022; Project Tomorrow & Spectrum Enterprises, 2022). With this in mind, this study sought to explore how to harness the power of educational technology for learning in the classroom.

Exploring the Intersection of Social Constructivism, Educational Technologies, Makerspaces, and VR Creation

Figure 1 shows the conceptual framework from which I approach this research study. Using a nested Venn diagram demonstrates the related nature of each component (social constructivism, educational technology, makerspaces, VR in education, and VR creation). I believe they intersect in a way that makes them inseparable from one another.

Overarching this study, and shown as the largest circle of the diagram, is the belief that learning is more than just the intake of knowledge. Social constructivism posits that the learner's active engagement with information results in the construction of new knowledge and understanding (Applefield et al., 2001; Damico, 2019). Authentic learning activities add to the context of previous experiences.

Figure 1. Intersection of Social Constructivism, Educational Technology, Makerspaces, VR, and VR Creation



Thus, the knowledge is specific to each individual learner. In addition, through collaboration and interaction with peers and more experienced mentors (i.e., teachers), the learner gains further context, new ideas, and different perspectives of knowledge. Social constructivism encapsulates all the other parts of this conceptual framework.

Educational technology can help teachers and students put social constructivism into practice. One of the first uses of digital technologies has been communication; technology in schools allows students to communicate and interact not only with their peers and mentors in the classroom or school, but with global peers and mentors. This communication can lead to global collaboration and problem-solving. When used effectively, educational technology can lead to enhanced critical thinking and creativity through problem-solving. To be prepared for the future, students need to apply skills like computational thinking. They can achieve this through activities like coding and robotics. Regardless of how educational technology is used, it's important to ensure that students are learning media literacy, or the ability to access, analyze, evaluate, create, and act using all forms of communication, and to think critically about media and how it shapes our thoughts and actions. Similarly, it's important for students to understand how to be good digital citizens while using digital and online materials and tools.

Many schools are using educational technology to address these skills in makerspaces. Some school makerspaces allow students to work on chosen products, but many are associated with curricular goals (Buchholz et al., 2014; Hsu et al., 2019; Kafai et al., 2014; K. M. Sheridan et al., 2013). Teachers or leaders in makerspaces provide formal lessons and respond to needs as they arise.

Students may work with both physical and digital tools to solve problems or create products (Marsh et al., 2019). Digital making is a form of making in which the maker uses digital technologies to create. Rather than creating a physical product, digital makers create a product that resides in the digital world. Some examples of digital making include stop motion animation, green screen videos, and digital art.

Digital making can be combined with physical making to create a physical product with a digital output. One example of this would be the creation of a three-dimensional poster, which, when a trigger is touched, would signal an attached computer to play an explanation of the poster. In makerspaces, students are literally creating representations of the knowledge they are building.

The smallest circle of this framework is VR creation. VR creation is just one way to use digital tools to create a product. I chose VR because of the benefits of VR in education. Research on VR has shown that VR in the classroom can increase self-efficacy (K.-T. Huang et al., 2019; Shu & Huang, 2021), motivation and attentiveness (Alfadil, 2020; Chang et al., 2020; K.-T. Huang et al., 2019), and independent learning (Alfadil, 2020; Bujak et al., 2013). It also can reduce cognitive load as students are immersed in the content (Bujak et al., 2013; Innocenti et al., 2019).

I relate VR to social constructivism and educational technology as it provides access to experiences that would not otherwise be available. For example, I have used VR to take students on a field trip to the Auschwitz concentration camp. Traveling to see the site was not possible, but students could view, through 360° images, the deplorable conditions of the camp. In addition, the use of VR in the classroom provides opportunities for students to interact with technologies and imagine the possibilities that VR can provide in the future. It also encourages interest in STEM careers.

In this framework, simply having students experience VR is not a makerspace activity, as it does not involve making. Creating VR is, however, an activity associated with makerspaces, as it is a form of digital making. VR creation immerses students in the content, ensuring that they include the concepts being learned in their designs.

This conceptual framework demonstrates the relationship between social constructivist theory, educational technology, makerspaces in education, VR in education, and the creation of VR in the classroom. Rather than separate concepts, they are interrelated. VR creation in this view is not possible without an understanding of all the other components.

Problem Statement and Research Questions

VR is becoming readily available for marketing, education, and game play. (Greener, 2022). Furthermore, tools for creating VR are becoming accessible, including for youth. The next logical step in the evolution of VR in education is to have students create VR. By creating VR, students are engaging in 'digital making', or making with digital mediums. This study examined how VR creation can assist young writers in visualizing stories they write as part of a summer writing camp.

Visualization is a skill that helps writers to improve their writing by focusing on and expanding details, generating new ideas, or clarifying ideas (Bomer et al., 2010; Jurand, 2008; Zeigler et al., 2007). VR creation brings several benefits to visualization. First, the creation of VR, as opposed to drawing for visualization, makes revisions easier, as they rarely require starting all over, as a sketch might (Blikstein, 2013). Second, VR creation allows writers to be immersed in the scenes in their stories, taking visualization to a new level. Third, working with three-dimensional modeling software has been found to improve students' spatial skills (Smith, 2018; Yrjönsuuri et al., 2019). The three-dimensional environment enables writers to visualize shapes and dimensions more effectively than one- or two-dimensional drawings, enhancing their spatial perception. Finally, VR creation provides students opportunities to use skills, such as coding, which can be helpful for future careers.

There is a large gap in the literature regarding youth creation of VR in educational settings. Only a handful of studies address VR creation as a classroom activity, and they are all at the university level (Frydenberg & Andone, 2021; Paatela-Nieminen, 2021; Stone et al., 2022; Warrick & Woodward, 2021). This lack of research is a missed opportunity for innovation in VR creation as a learning tool.

Given the lack of research on VR creation by elementary-aged youth, this study aimed to address this gap by examining how elementary-aged youth engage in creating VR and how teachers can support them. Using a qualitative embedded case study design, this study examined how a group of elementary-aged youth worked through the process of creating a VR environment based on stories they had written. Specifically, I focused on the collaborative nature of knowledge-building and the hands-on approach to learning.

Teachers play an important role in how and what students learn. To that end, a second objective was how teachers support students in this endeavor. The youth used a tool unfamiliar to them, CoSpaces, and teachers provided lessons, both formal, whole-group lessons and small-group or individual just-in-time lessons. Teachers also provided individual guidance as the youth navigated this new tool and other digital resources. As the youth were creating an environment based on their writing, the teacher provided pedagogical guidance on setting when needed.

With these objectives in mind, my research questions are:

> RQ1: How do elementary-aged youth engage with a virtual reality tool to create a virtual reality environment?
>
> RQ2: What technological and pedagogical supports do teachers provide to guide elementary-aged youths in the creation of a VR environment?

This study contributes to the body of knowledge on digital makerspace activities by exploring a new, innovative activity, which has yet to be explored at the elementary level. It builds on existing knowledge about the positive impacts on engagement when engaging in makerspace activities and using VR.

Overview of Key Terms

To ensure clarity, this section provides definitions for key terms, as I have used them throughout this study.

Virtual Reality (VR)

Virtual reality refers to an altered sense of reality, using tools, such as VR viewers or cell phones. VR environments are three dimensional, allowing the viewer to be fully immersed in the image (Stanković, 2015). Turning around or moving within the environment changes what you see and hear. VR environments can range from 360° images to computer-generated simulations. Using digital technology allows creators to include interactions with objects and other users in the environment. In educational settings, VR can be used to explore a city across the globe, visit the moon, or to provide a simulation of a roller coaster. For this study, youth created computer-generated VR environments to correspond to a story they have created.

Makerspace

Although makerspaces can serve many purposes, this study focuses on the purpose of creating. The type of products that are made in makerspaces vary depending on the purpose of the makerspace and the intentions of the makers (Hira & Hynes, 2018).

This study focuses on educational makerspaces-those that are intended to be used in a formal or informal educational setting. You can find educational makerspaces in school libraries, classrooms established for making, in a small section of a classroom, or as a mobile station that moves from one class to another. In these settings, making can happen as part of the curriculum as part of the school day, or as extracurricular activities.

Makerspaces employ a variety of tools, which also vary depending on the purpose. Tools vary from high-tech 3D printers to low-tech scissors (Hira & Hynes, 2018; Marsh et al., 2019). Most makerspaces provide a continuum of low- to high-tech tools to meet the needs of a variety of products.

Digital Making

Digital making is when a product created is completely on a computer or mobile device or combines digital technology with physical resources. An example of a product that combines the physical world and digital technologies would be the use of a microcontroller, a small computer on a single circuit (Noyce & Hoff, 1981) connected to both a poster and a computer via copper tape, such that when a viewer touches an area of the poster, it signals a computer program to play a recorded speech. Purely digital products may be videos, video game creation, or graphic design. In this study, youth will engage in digital making to create an immersive virtual reality environment.

Chapter Summary

VR is already being recognized as a valuable tool in educational settings. Research has not yet fully explored the creation of VR as a way for elementary-aged youth to engage in learning activities. VR creation can be an innovative pedagogical tool for learning, and thus this study aims to address this gap in the literature by exploring how youth engage in creating VR. This chapter has reviewed how the intersection of social constructivist theory, educational technology, and makerspaces support VR creation. The next chapter will review the relevant literature and theoretical framework of the study. Chapter III describes the methodology of the case study.

CHAPTER II: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

The world is changing quickly, and with it, so is education. One of the more recent innovations in education is the use of virtual reality (VR) to engage learners. VR uses headsets to create the impression of being inside a new, often computer-generated environment by focusing the vision on the new environment and blocking out all other visual stimulation.

VR allows students to visit the moon, interact with non-English language speakers, and do science experiments that cannot be done in the classroom, just to name a few. While researchers have begun to do extensive research on how educators are using VR to *teach* content, they have not researched students *creating* virtual reality. New applications are making it easier for students to create their own virtual reality environments, but little research has been done examining the effects of such activities. We can trace the potential of this new area of research to inform teaching back to educational makerspaces, where students create to learn. This research study seeks to add to this limited research.

This chapter begins with a brief review of the conceptual framework for the study. Next, I will discuss the theoretical framework that shapes this research study, social constructivism. I will then provide a review of literature on what makes an educational makerspace, who is a maker, and what learning occurs in an educational makerspace. And finally, I will review the literature on virtual reality in the classroom. I will use this grounding in the literature to make the argument that virtual reality environments, created through the principles of social constructivism and as a form of digital making activity, can be a valuable tool for learning for elementary-aged students.

Conceptual Framework

The aim of this study is examining how elementary classrooms can apply VR creation. Social constructivism envelopes all aspects of this study. It provides the basis from which VR creation, at the center, is based. VR creation is a digital making activity. VR viewing is not a makerspace activity, as it does not involve creation. However, the inclusion of VR is necessary to understand the purpose of creating VR environments. VR in education is an example of educational technology and social constructivism. I represent this framework in Figure 1 as a nested Venn diagram.

Social Constructivism

Constructivism is a theory that puts the learner at the center of learning. According to the American Psychological Association (n.d.), constructivism is a theoretical perspective in which a person actively builds their understanding of the world, based on prior understandings and the context of the current event. As a learning theory, this means that students actively construct knowledge through engagement in learning activities. This knowledge is personal for the student, as it depends on what the student has previously learned about the phenomena in question, as well as other contextual factors.

Though many attribute the beginnings of constructivist theory to Jean Piaget, it has much deeper roots. Greek philosophers as far back as Plato and Aristotle believed that knowledge was constructed through the senses (Damico, 2019). Throughout history, there have been others who posited similar thoughts. The most recent antecedents were John Dewey in the early 1900s, Lev Vygotsky in the 1920s, and Jean Piaget in the 1950s. While the three likely did not communicate with one another, they shared some common ideas about learning. All three theorists believed that learning is an interactive process rather than separate steps and that it involves talking with others to make sense of new information (Mayer, 2009). Where those beliefs diverge, leads us to the different varieties of constructivist theories.

We often sort constructivist approaches to learning into three types: radical, cognitive, and social. Radical constructivists believe the learner invents knowledge, rather than discovering it (Damico, 2019; Siegel, 2004). In this view, reality is subjective and personal to the individual. Knowledge is not transferable from one learner to another.

Cognitive constructivism is closely aligned with Piaget. To cognitive constructivists, learning is an active cognitive process in which a learner presented with new information must either assimilate the knowledge into pre-existing knowledge or make accommodations to previously learned information (Applefield et al., 2001; Damico, 2019; Hoadley, 2011). Cognitive constructivists are less concerned with how culture can influence learning (McLeod, 2018).

Social constructivism, which is rooted in the works of Vygotsky's sociocultural theory of learning, places an emphasis on the interactions between the learner, their peers, and mentors (Damico, 2019; Hoadley, 2011). In this collaborative environment, engagement becomes a pivotal force, as learners actively participate in shared activities, discussions, and problem-solving with their peers and mentors. Vygotsky's Zone of Proximal Development (ZPD) highlights the significance of these engagements by illustrating the contrast between what a learner can do without assistance and what they could do through collaborative assistance (Applefield et al., 2001; Schunk, 2020). Across the different types of constructivist learning theories, we can see that learners construct their knowledge based on their own experiences (including prior knowledge or conceptions), the context of the knowledge, and social interactions with peers, teachers, and other experts.

I conducted this research study through the lens of social constructivism. Proponents of social constructivism believe that knowledge is not acquired but is *constructed* (Applefield et al., 2001; Damico, 2019). This construction is not just the taking in of new information, but the active engagement in the learning process, through learning and applying new skills and collaborating with others. It is comparing this new information, acquired through interactions with peers, mentors and learning activities, against previous knowledge.

When this new information fits with their current mental models or schema, they assimilate the information into this schema (Coghlan & Brydon-Miller, 2014; Damico, 2019; Schunk, 2020). If this new information does not fit with the existing knowledge, the learner experiences cognitive disequilibrium and must accommodate this new information into the current schema. They facilitate assimilation and accommodation through authentic activities and social interactions.

Authentic learning activities include real-world problem-solving, and when that is not possible, are contextually relevant. These types of activities are crucial in facilitating assimilation and accommodation through social interactions with individuals, culture and society (Applefield et al., 2001; Lave, 1996; Lave & Gomes, 2019; Schunk, 2020). As a member of the society in which they live, society teaches how to be a member of that society.

Learners come to the classroom holding the knowledge they have learned from previous experiences. These experiences come from a variety of sources, such as previous schooling, their home, and the society in which they live. What they learn depends on these previous experiences. The knowledge they construct depends on the ideas expressed by others, whether explicit or implicit.

In a social constructivist classroom, the role of the learner is to actively take the sum of experiences, past and present, and mold them into knowledge. The role of the teacher is to guide the learner to new experiences, whether through social or cultural exchanges or through activities, to understand new information in context. With guidance from the teacher, the learner can move from a less-experienced point of view to one with more experience, and, eventually, on to an expert level. In the next section, I will explore the common characteristics of a social constructivist classroom.

The Social-Constructivist Classroom

Learning is an active process in a constructivist classroom (Confrey, 1990; Damico, 2019; Hausfather, 2001). The teacher provides experiences that lead to knowledge construction using various tools and methods, such as KWL charts (what we know, what we want to know, what we learned), concept mapping, tutorials, and discussion boards. The learning experience is not confined to individuals but is situated within the learner's interactions with peers and mentors. Learning is collaborative, allowing learners to gather information from peers and share their own knowledge. The learner must take the knowledge that they have previously acquired and weigh it against the information that is being presented to them. They must decide if this information fits with what they previously learned, thus adding to the body of knowledge, or if it contradicts what they previously learned. If this new information does not fit with previous knowledge, the learner must decide if there is enough evidence to put aside previous knowledge, or if they can shape it to fit.

Take, for example, an elementary science lesson on insects. The teacher asks the students to tell what they know about insects. A student responds that all insects have wings. As part of the lesson, the student reads about an insect that does not have wings. This may lead the student to ask the teacher what other insects do not have wings. This reshapes the mental model of insects for the student. Later, while talking with a peer, the student can share their newfound knowledge of wingless insects. As this example illustrates, knowledge construction is an ongoing process, and involves not only the taking in of information, but the sharing of knowledge.

The role of the teacher is to act as a facilitator of knowledge, rather than imparters of knowledge. They should provide time for reflective thinking and implement hands-on projects for applying knowledge (Landis, 2008). The teacher also encourages students to ask questions and debate with both the teacher and with peers. As the facilitator, the teacher is not seen as one who has all the knowledge, but as a more advanced learner (Lave & Gomes, 2019). The teacher facilitates authentic learning experiences in which students construct their knowledge through exploration and collaboration. In doing so, they must understand the needs of the learner to provide the right amount of support for each learner.

Social constructivism situates the learning experience within the learner. Knowledge and experiences come not just from those the teacher facilitates, but from peers and those outside the classroom. Inside the classroom, the experiences for learning are collaborative in nature, allowing learners to gather information from peers and to share their own knowledge with peers. Engagement is a continuous process in the social-constructivist classroom, where learners actively engage with peers, mentors, and information.

Educational Technology

Educational policy has increasingly focused on the use of educational technologies in the classroom over the last forty years. Culp et al.'s *Retrospective on Twenty Years of Education Technology Policy* (2005) examined education technology policies beginning with the 1983 federal report from the National Commission on Excellence in Education, *A Nation at Risk*, which included a recommendation that high school graduation requirements should include computer science. The authors of the report felt that graduates should have basic skills in using computers as communication tools. Communication skills in education were primarily using word processing programs.

By the time Every *Student Succeeds Act (ESSA)* of 2015 was enacted, technology was an important educational tool (US Department of Education, 2017). The 2017 *National Educational Technology Plan* (NETP) was developed to align with the ESSA. The plan begins:

> Technology can be a powerful tool for transforming learning. It can help affirm and advance relationships between educators and students, reinvent our approaches to learning and collaboration, shrink long-standing equity and accessibility gaps, and adapt learning experiences to meet the needs of all learners. (p. 7)

This goes far beyond the idea of computers as mere tools for communication. However, many classrooms failed to meet the ideals in the statement above. A majority of district and school administrators feel that effective technology use in schools is essential and 65% of teachers felt that technology creates interactive experiences for students in which to participate (Project Tomorrow & Spectrum Enterprises, 2022). However, the same survey showed it was not always happening. As few as 44% of 6-8 grade students reported using the internet for research for class assignments, and as few as 56% of 9-12 students reported the same. Reports of using technology for collaboration were even less, with as few as 26% of middle school students and 45% of high school students collaborating on documents with classmates and teachers. The question, then, is why effective technology use remains out of bounds for so many classrooms.

Barriers

In the not-so-distant past, the "digital divide" referred to the lack of available resources (Culp et al., 2005; National Commission on Excellence in Education, 1983). Schools had to build the infrastructure to support online devices. Now, 96% of US schools have internet access (Baruffati, 2023). This is beneficial for using devices at school, but it is also important that students have Wi-Fi access at home as well. While the number of households with reliable internet access is increasing, one in five U.S. households do not have reliable internet. (National Telecommunications and Information Administration, 2022). This presented a problem during the pandemic. Schools that sent devices home then had to find ways to help students get connected. Some districts resorted to parking their now un-used school buses in neighborhoods and broadcasting Wi-Fi from them (McEwen & Foss, 2022).

Another aspect of the previous definition of the digital divide was the actual devices, whether they be laptops or tablets, to provide access to every student. While some schools already had a device for every student, many more did not have that when the pandemic hit. Pandemic funding provided many schools and districts the opportunity to fund these devices (McEwen & Foss, 2022). Devices are not one-and-done, however, so schools will need to find a way to repair and replace devices in the coming years. In addition to the devices, schools need a place to store and charge them when left at school. These solutions for storage and charging will also eventually need to be repaired and/or replaced.

1:1 initiatives invite other barriers, as well. Classrooms must be re-imagined allowing for flexibility. The storage and charging solutions mentioned will need to find a home in the classroom, the library, or some other location within the school. Charging stations in the classroom are essential for ensuring that students whose devices are not charged before class do not miss out on educational opportunities. What may have been a narrowing of the digital divide may yet widen again.

The new digital divide refers to not only the availability of infrastructure for technology use in the classroom, but also the equity of practice (Project Tomorrow & Spectrum Enterprises, 2022; US Department of Education, 2017). Project Tomorrow's Speak Up survey (Project Tomorrow & Spectrum Enterprises, 2022) found inequitable technology usage in schools during the 2020-2021 school year, with mostly students of color compared with schools with mostly white students (Project Tomorrow & Spectrum Enterprises, 2022). Students in schools with primarily white students were more likely to use digital tools for collaboration and research. To use technology effectively, however, teachers need support to do so. They reported that to do so, they need time to plan for the use of technology, student access to the internet outside of school, and professional development on how to use new tools. What, then, would effective technology use in classrooms look like?

Effective Educational Technology Use

When asked about the benefits of using educational technology, many students understand it can help them understand what they are learning, apply their learning, collaborate, and develop creativity, critical thinking, and problem-solving skills (Project Tomorrow & Spectrum Enterprises, 2022). Similarly, teachers believe that effective use of technology in learning activities can create experiences that are more interactive, develop lifelong learning, and develop skills necessary for college and work. The skills that students will need in future careers can be hard to imagine, since many of those jobs may not even exist yet (World Economic Forum, 2016).

The *Framework for 21st Century Learning* (Battelle for Kids, 2019) attempts to address this shifting of priorities with three sub-sections of 21st century skills: life and career; information, media, and technology; and learning and innovation. Life and career skills are those that enable students to prepare for working in a global, collaborative world. Information, media, and technology skills prepare students for interactions in those domains. Information and media literacy ensure that students know how to access the multitude of information available today and to analyze it critically. ICT (Information, Communications, and Technology) literacy ensures that students can use a variety of technologies effectively to acquire and communicate information. Learning and innovation skills are collectively known as the 4Cs: Creativity and innovation, Critical thinking and problem solving, Communication, and Collaboration.

Effective use of educational technology has less to do with the tools themselves, but more with how they can apply these skills to learning tasks. The ISTE (International Society for

Technology in Education) Standards for Students provide a guide for implementing these skills in the classroom (International Society for Technology in Education, 2017). These standards state students should be advocates of their own learning; use multiple resources to construct knowledge; design solutions to problems using computational thinking; be able to communicate those solutions; collaborate with others around the world; and be a good digital citizen. Educators are encouraged to design activities, with or without educational technologies, that help students to apply these skills. Therefore, effective use of educational technology is when teachers select, or guide students to select, technologies that will enable them to meet these goals.

Educational Technology and Social Constructivism

Educational technology and social constructivism are closely connected and can mutually reinforce each other in the context of learning and instruction. Many educational technology tools facilitate collaboration, through students and teachers working together, sharing ideas, and constructing knowledge collectively. For example, virtual simulations, online labs, and interactive multimedia sources enable learners to explore, experiment, and construct knowledge through hands-on experiences. This provides learners with active, contextually meaningful learning. Educational technology tools can also help teachers to provide personalized and adaptive learning experiences based on the needs and preferences of learners. This promotes learner autonomy and self-regulation by allowing learners to make choices and take ownership of their learning (Makhno et al., 2022).

Technology tools can also provide opportunities for students to collaborate not just in their classroom, but with peers or mentors across the world. Students can access a vast amount of information and resources from diverse perspectives with technology tools, such as online databases, digital libraries, and educational websites. This aligns with social constructivism by providing learners with multiple viewpoints and opportunities to engage in critical thinking and knowledge construction.

When used together, educational technology and social constructivism can create a powerful learning environment that allows learners to actively construct their own knowledge through interaction with others and with the world around them.

Makerspaces

The educational maker movement has grown largely from this idea that students can acquire knowledge through *doing* (Halverson & Sheridan, 2014; Harron & Hughes, 2018; Marsh et al., 2019; Sheridan et al., 2014). Rather than passively acquiring knowledge and then shooting it back in a similarly passive fashion, makerspaces provide students with the tools to acquire the knowledge in a variety of ways, and to showcase this knowledge in ways that are personal to each individual. We know that knowledge is created and then dispersed through connections (Schunk, 2020). It makes sense, then, that we teach students to not only be consumers of knowledge but also creators of knowledge.

What constitutes a “makerspace”? A makerspace, in its simplest terms, is a space in which “making” occurs. Merriam-Webster (n.d.) defines making as “the act or process of forming, causing, doing, or coming into being”. By this simple definition, forming castles in the sand could be considered making, thus making the beach a makerspace. In practice, however, the notion of a makerspace has a much more specific meaning, often including multiple purposes. As stated in Chapter 1, this study focuses on the conception of makerspace as a place to create. In the following sections, I will describe this specific meaning of a makerspace, what makes one a maker, and what it means to “make” in an educational context.

What's In a Name?

Since designated spaces for making began appearing in the literature, they have taken on many different names - hackspace, FabLab, makerspace (Hira & Hynes, 2018). Each can have a slightly different definition, but they all have in common several factors. They are not just places for individuals to create, but places for communities of creators to come together.

Collaboration, learning from peers, and sharing ideas are all hallmarks of these spaces (Calabrese Barton & Tan, 2018; Halverson & Sheridan, 2014; Hira & Hynes, 2018; Sheridan et al., 2014). They often combine low tech and high-tech tools and materials (Hira & Hynes, 2018; Marsh et al., 2019). It is not unusual to find cardboard, markers, and scissors being used alongside scroll saws, electrical circuits, and 3D printers.

Finally, while we can presume the main purpose of an educational makerspace to be learning, all makerspaces, regardless of the name, contain some measure of learning (Buchholz et al., 2014; Halverson & Sheridan, 2014; Harron & Hughes, 2018; Hatzigianni et al., 2021; Hira & Hynes, 2018; Marsh et al., 2019; K. M. Sheridan et al., 2013; Stornaiuolo & Nichols, 2018), whether it is learning to use tools or learning the dynamics of physics. For this study, I refer to these spaces as makerspaces.

Hira and Hynes (2018) explored a variety of makerspaces to create their conceptual framework of makerspaces. They refer to the people, means (tools, materials, and skills), and the activities of a makerspace. The people are those participating. This can vary from adults to children. It can even supersede those who are physically in the makerspace. Calabrese Barton and Tan (2018) worked in a makerspace for youth who also got input from their community, thus making these communities part of the making process. The means refer to the tools, materials, and skills used in the makerspace. Tools range from larger equipment, like laser-cutting machines, to hammers and screwdrivers. Makers may use specially purchased material, such as filament for 3D printers or items to be upcycled. The makerspace may purchase material, individuals may donate materials, or makers may use they can find whatever. The skills are related to the various tools to be used in the makerspace. Participants often learn new skills while participating in a makerspace. The activities are things that happen in a makerspace. Makers may work on individual or collaborative projects that have meaning for the makers. Often, participants will prototype multiple versions before getting to their final product.

These three aspects are all dependent on the purpose of the makerspace. For example, an educational makerspace serves the purpose of educating, therefore, the people involved are mostly teachers and students. The means are the tools and materials acquired by the educational setting and are dependent on the educational activities that take place.

The Making of a Maker

We often refer to participants in a makerspace as makers, as they participate in the activities of making. Many proponents of makerspaces believe anyone can be a maker. While in a technical sense, this is true, there are characteristics of makers that set them apart.

Marsh et al. (2019) examined youth aged three to eight through a socio-cultural lens. They identified three principles for makers: maker agency, maker funds of knowledge, and maker postdigital play. We can see maker agency in makerspaces when participants make choices about what and how they make. Harron and Hughes (2018) found that the educational makerspaces they studied provided opportunities for students to have freedom in what and how they learned, unlike the rigorous testing environment of traditional school classrooms.

Marsh, et al.'s (2019) maker funds of knowledge relate to the cultural knowledge which youth bring to the makerspace. Sometimes this cultural knowledge is related to the community and family of youth (Calabrese Barton & Tan, 2018), but it can also include the knowledge of skills that youth bring with them to the makerspace (Harron & Hughes, 2018; Marsh et al., 2019;

Sheridan et al., 2014). Today's youth are familiar with digital tools, like smartphones and tablets, from an early age, for example. Makerspace leaders should leverage this knowledge as makers explore the options available to them.

Maker postdigital play is based on the notion that making is not an either/or endeavor but includes both digital and nondigital methods and low- and high-tech materials for making (Jayemanne et al., 2016; Marsh et al., 2019). One example of maker postdigital play was a project I assisted with in which Kindergarten students created a Lego representation of an ecosystem, wrote a story (with the help of the adults) describing their ecosystem, and then created a stop-motion movie of the story and their Lego representation. This portrait creates a more comprehensive view of a maker.

Makerspaces have the potential to open doors to anyone who wishes to be a part of the maker community. In reality, that is not always the case (Buchholz et al., 2014; Calabrese Barton & Tan, 2018; Halverson & Sheridan, 2014; Harron & Hughes, 2018; Seo, 2019). The activities and materials available in a makerspace can attribute to who participates, such as makerspaces that focus on robotics and other STEM activities (Buchholz et al., 2014). Opportunities for participation may also be limited by the location and/or fees (Barton & Tan, 2018).

Some makerspaces actively work to be inclusive with activities geared towards girls, such as sewing circuits into clothing to make them light up (Buchholz et al., 2014; Kafai et al., 2014; Norris, 2014). Makerspaces in the communities of minority youth provide opportunities that may not otherwise be available (Buchholz et al., 2014; Calabrese Barton & Tan, 2018; Harron & Hughes, 2018; Kitzie & Moorefield-Lang, 2018). Educational makerspaces can provide opportunities for all students, but schools offer them during the school day; after school makerspaces are reserved only for those who have the transportation, often.

Another area in which makerspaces fall short in equity is for persons with disabilities. Persons with vision impairments may have an especially hard time accessing most makerspaces, as few tools offer alternatives to written instructions and buttons with recognizable symbols (Seo, 2019).

Likewise, persons with hearing impairments may need assistance with tools which require hearing to understand if they are working. Moorefield-Lang and Dubnjakovic (2020) provided suggestions for increasing accessibility in makerspaces, such as paying attention to layout and design, and getting community feedback on the layout.

Learning in the Makerspace

Learning in the makerspace is primarily about hands-on activities. This type of learning has its roots in constructivist theories of learning, which posit that learning is not imparted to the learner, but a process by which the learner constructs meaning from experiences (Confrey, 1990; Damico, 2019; Hausfather, 2001; Krahenbuhl, 2016). Makers bring with them previous knowledge and then add to that knowledge through the act of making and through working with others.

Learning in makerspaces is about more than products that are made, although products often drive the activities of the makerspace. Some are based on a set of criteria or projects to complete (Buchholz et al., 2014; Hsu et al., 2019; Kafai et al., 2014; Sheridan et al., 2013). Others offer flexibility in choosing what to work on (Calabrese Barton & Tan, 2018; Kajamaa & Kumpulainen, 2019; Martin et al., 2018; Stornaiuolo & Nichols, 2018). Regardless of the flexibility of the makerspace, they often combine formal, structured learning with just-in-time learning. In order to create, students must know how to use the tools and materials. Some tools, like power tools (when allowed) require specific training. Other items may be available for tinkering and play to learn how to use (Halverson & Sheridan, 2014; Harron & Hughes, 2018; Hira & Hynes, 2018; Marsh et al., 2019; Sheridan et al., 2014).

Learning is not always teacher-directed but can be from other makers or from the community. Makers get help from their peers in a variety of ways. They can show how to use specific tools in the makerspace (Buchholz et al., 2014; Frydenberg & Andone, 2021; Halverson & Sheridan, 2014; Hira & Hynes, 2018; Kajamaa et al., 2020; Marsh et al., 2019; Martin et al., 2018; Sheridan et al., 2013; Sheridan et al., 2014). Sometimes, part of the iterative design cycle includes getting feedback from peers (Hira & Hynes, 2018; Kajamaa et al., 2020; Martin et al., 2018; Sheridan et al., 2014; Sheridan et al., 2013; Stornaiuolo & Nichols, 2018).

Makers also sometimes get assistance from outside the makerspace. Calabrese Barton and Tan (2018) reported on makerspaces at community youth centers in Michigan and North Carolina in which some makers consulted with community members to learn new skills, learn about the problem at hand, or to see what changes needed to be made to their designs. The social aspect of makerspaces situates them firmly within constructivism.

The content taught in educational makerspaces can vary depending on the purpose of the makerspace. Some makerspaces focus solely on the creation of products. These makerspaces often have little or no concrete ties to curriculum. They encourage students to come up with their own projects and to implement them. In doing so, they learn how to use various tools, the engineering design process, and problem solving.

Curriculum-based makerspaces, on the other hand, include activities that relate directly to specific curriculum objectives. For example, I worked with students in a middle school science class to create musical instruments as part of a unit on sound. While teachers gave students some freedom in determining the type of musical instrument, there were specific aspects of their project that were mandated to fit the criteria of the learning objectives. These two examples make up the ends of a spectrum of makerspace learning activities. Most makerspaces, however, fall somewhere in-between.

The location of the makerspace in a school may also impact the activities that happen there. Many educational makerspaces first found life in libraries. Libraries are open to all, and therefore provide an opportunity for creating (H. Moorefield-Lang, 2015). Many school libraries still house their school's makerspace as either a drop-in space for students when they have downtime or are working on special projects. At other times, these makerspaces serve as a secondary classroom for teachers to bring whole classes to work on projects. A growing number of schools are dedicating a classroom, and sometimes a special teacher, to making activities.

A few classroom teachers are dedicating classroom space for making activities and tools. However, many classrooms lack space. This also limits the availability of tools for others in the school. One solution to this may be a mobile makerspace, in which the making comes to the students (H. M. Moorefield-Lang, 2015).

Digital Making

The use of educational technology can push making activities to a new level. Students can create a diorama of a scene from a book with only some cardboard and found objects. However, if they add electronics and coding to the same diorama, they can create an interactive presentation in which viewers can touch various points in the diorama and hear a recording of the creator explaining why the scene is important.

There are conflicting definitions of digital making. Some definitions require that making is only considered digital making if it leads to an understanding of how technologies, like electronics or coding, work. Other definitions rely only on the use of digital technologies to create a product. For this study, I use the broader definition. I define digital making as the creation of a product either partially or wholly created online or using digital tools. Within this definition, there is a lot of variation in how technology is blended with creativity (Quinlan, 2017). Quinlan (2016, 2017) describes crossed axes of high-to-low technology and high-to-low creativity to describe this variation. An activity may fall in any of the resulting quadrants. The degree of technology and creativity does not determine whether it is a making activity.

There are many advantages to digital making. Digital making provides students opportunities to work with tools and applications that can prepare them for future skills (Edwards et al., 2021; Kervin & Comber, 2021; Niiranen, 2021; Peppler & Kafai, 2007). This encourages students to go beyond just consumers, but creators as well (Peppler & Kafai, 2007). It also teaches students valuable digital literacy skills. Edwards et al., (2021) found that digital making led to risk-taking when students were designing products. This is often because the use of digital tools makes it easy to reiterate and improve on designs. This easy reiteration also contributes to students being able to focus their time on creating polished products using tools such as a 3D printer as opposed to having to manually manipulate physical materials, leading to increased self-esteem (Blikstein, 2013). A plethora of digital tools are available today; many of these tools make tasks that used to be reserved for experts in their respective fields easy for students of all ages to use.

The advances in technology are changing how educators teach. The students of today are the users of these technologies tomorrow. Many teachers look to these new technologies as ways to innovate their teaching. One such technology that is disrupting the idea of teaching is virtual reality (VR). The viewing of VR is not a making activity, but the creation of VR environments is a digital making activity. In the next section, I will explain what VR is, how teachers are using it in their classrooms, and how the creation of VR is being used in education.

Virtual Reality (VR)

In October 2021, when the Facebook parent company changed its name to Meta, it likely had many people wondering what the big deal about this new “metaverse” was all about (“Facebook Changes Ticker To META – Forbes Advisor,” 2021). Popularized in science fiction books, films, and video games, the metaverse describes a shared virtual space in which users interact with each other and the computer-generated environment in real time. Facebook saw the potential of building and hosting such worlds, allowing users to interact through gaming, socializing, and even working in this virtual reality. Virtual reality (VR) was not a new concept, but Facebook executives recognized the growing popularity. XR Today, an extended reality (XR) e-zine, states that 78% of Americans know what virtual reality is and that it is anticipated that there will be a 16-fold surge in the demand for devices in 2023 (Greener, 2022).

Stanislav Stanković (2015, p. 13) states, “Virtual reality aims to create the impression of presence in a virtual environment, i.e., an environment different from the user’s actual physical surrounding.” S.C. Chang et al. (2020) go further to explain VR as computer-generated and interactive. Many different models of VR headsets, with varied price tags, are available to help achieve an immersive experience. However, there are a growing number of websites and applications that support VR without the use of a headset. Today’s smartphones and tablets can view 360° videos and images. Viewers can also view VR right on a computer screen through websites dedicated to VR, like YouTube’s Virtual Reality channel (*Virtual Reality*, n.d.). Viewing VR through a phone, tablet, or computer doesn’t produce the same immersive feeling, but it allows the user to interact with the virtual world. These versions of VR worlds also don’t cause the side effects that VR headsets do, such as dizziness, eyestrain, and headaches (Dolgunsöz et al., 2018; Kavanagh et al., 2017).

VR is already being used in training engineers, medical professionals, pilots, and more (*Virtual Reality Market Size & Share Report*, *2022-2030*, 2022). Educators are taking notice of VR uses in the classroom to enhance learning outcomes. They can take students on virtual field trips around the globe, simulate science demonstrations, and reenact historical events, just to name a few.

Researchers have seen positive impacts on the brain, self-efficacy, and motivation when learners use VR. Many educators are examining the use of VR in classrooms, such as games to teach foreign language vocabulary (Alfadil, 2020), studying anatomy in a medical class (Kolla et al., 2020), and examining musical genres (Innocenti et al., 2019). It can lead to increased self-efficacy (Chang et al., 2020; K.-T. Huang et al., 2019; Makransky et al., 2019; Shu & Huang, 2021), increased motivation and attentiveness (Alfadil, 2020; Chang et al., 2020; K.-T. Huang et al., 2019; Innocenti et al., 2019), and independent learning (Alfadil, 2020; Bujak et al., 2013).

Rather than learning by seeing or hearing, learners are immersed in the content (Bujak et al., 2013; Chiang et al., 2014; Innocenti et al., 2019), or as Alfadil (2020, p.9) points out, "learning by living it." VR for educational purposes can have positive effects on the brain, as well, making learning easier. Learning through VR may reduce cognitive load since the interactions within the immersive environment are more natural (Bujak et al., 2013; Innocenti et al., 2019).

A few educators are examining how the creation of VR can impact learning, though the research is still sparse and involves university students. Some projects use 360° images as a base for students to annotate with information about the image. This usually involves students using a 360° camera to take the image, then uploading the image to a VR creator, where they add interactivity (Bonner & Reinders, 2018; Frydenberg & Andone, 2021; Stone et al., 2022; Warrick & Woodward, 2021). Other projects require students to create the VR environment using materials within the VR creation application (Al-Gindy et al., 2020; Paatela-Nieminen, 2021). Regardless of the method of creation, the creation of VR in the classroom has implications for STEM and makerspace learning.

As mentioned previously, social constructivist activities should be authentic, meaningful, hands-on, collaborative, and involve higher-order thinking. Stone et al. (2022) described a making activity in which graduate students created a 360° VR tour of the Austin Cary Research Forest, complete with interactive elements for viewers to learn about the forest. They then shared their tours in three different public settings. This assignment helped students to not only share their knowledge of the forest but also to understand what more information they needed to learn.

Frydenberg and Andone (2021) had university students work in teams of four - two in the US and two in Romania - to create VR representations of well-known businesses in their respective countries. The students used 360° images, avatars, and interactive objects to share information about the businesses. The assignment was especially important for the students who were studying to do business internationally.

While the act of creating a VR environment is inherently hands-on, Paatela-Nieminen (2021) took it a step further by having art student teachers create immersive art. Using Google Tilt Brush, the students created 360° art exhibits, allowing viewers of the exhibition to be surrounded by the art.

Teachers can encourage collaboration in VR creation by having students work in groups, as Frydenberg and Andone (2021), Paatela-Nieminen (2021), and Stone et al. (2022) did when having students create their VR environments, but collaboration can also come more naturally, as it did when Warrick and Woodward (2021) asked first-year university students to create 360° interactive posters. They found that, even though students were working individually, they collaborated by seeking help from one another.

Higher-order thinking skills are needed when creating many VR environments, such as coding animations of characters in the environment (Frydenberg & Andone, 2021). Al-Gindy et al. (2020) proposed that students can create VR environments which show experiments and physics concepts that are harder to show in real life. Also, as Paatela-Nieminen (2021) showed in her study of the VR art, spatial reasoning is much more difficult in a 3D environment than creating a two-dimensional piece of art.

VR creation has been, until recently, relegated to technology classes dedicated to digital media creation. As technology becomes more sophisticated and more affordable, educators are seeing the possibilities of using VR creation in their classrooms. When students create VR, they can learn about concepts that are hard to see and conceptualize in the real world or connect concepts with the real world. They can also create new worlds or envision those that they haven't seen.

There is a large gap in the literature about the creation of VR as a learning experience. There are few studies that address VR creation at all, and they are all with university students thus far. New applications are being developed that allow even elementary-aged students to create VR. Researchers studying VR creation in education can gain insights into how these activities can enhance students' understanding and engagement with content.

Chapter Summary

This literature review has shown the connection between makerspaces, educational technology, and social constructivism. Makerspaces emphasize the constructivist tenets of authentic, hands-on, collaborative learning experiences. Making is not only confined to making physical artifacts. Digital products, such as websites, online games, and graphic design, often include the same processes and qualities of physical products made in a makerspace. The creation of these digital products relies on the availability and use of educational technology. The creation of digital products prepares learners for careers in game development, digital marketing, data science and analytics, and much more.

The creation of VR in educational makerspaces is one way to prepare learners for future careers in a growing market. VR in advertising, games, and even education is expected to steadily increase. These industries will need people capable of creating VR products. Until recently, VR creation was relegated to advanced coders and programmers. With the introduction of tools available for even beginning coders, this is now an activity that can be done with learners as young as elementary aged. However, because the technology is so new, there are few studies examining the usefulness of creating VR in educational making activities, and none are in K-12 schools.

VR creation can benefit students by increasing spatial skills by providing an immersive experience for students while visualizing their writing. This study addresses this gap in the literature by guiding elementary-aged learners to use a creation app with included world-building elements and drag-and-drop coding to create their own VR environments. This study shows how the creation of VR world-building for their own stories helps learners to have a fuller understanding of setting in a story.

CHAPTER III: METHODOLOGY

In this study, 13 learners aged 7 to 11 participated in a summer camp workshop to create a virtual reality environment that coincided with the setting of a story they wrote in a summer writing camp. The youth used an iterative design process to plan, design, test, and refine their environment. They participated in daily reflections and group discussions on their learning challenges and successes. I was a participant researcher and co-teacher along with another teacher to assist and guide the youth as needed. I also encouraged them to seek help and share their designs with their peers for feedback and assistance.

As the creation of VR has received little attention in education research, this study will seek to address this gap, specifically by helping to identify the challenges associated with student creation of VR, as well as the driving forces of learning as students construct their knowledge and present it as a tangible, though digital, product. In addition, it is important to understand the role of the teacher in helping students to navigate this new technology along with the educational goals. My research questions are:

RQ1: How do elementary-aged youth engage with a virtual reality tool to create a virtual reality environment?

RQ2: What technological and pedagogical supports do teachers provide to guide elementary-aged youths in the creation of a VR environment?

To examine this question, students created virtual reality environments with a digital tool called CoSpaces to visualize their written composition. I used a qualitative embedded case study to examine the experiences of the youth and teacher. I used a variety of data collection methods, including observations, interviews, and focus groups to understand the perspective of the learners and the teacher. I also examined the virtual reality creations of the youth for evidence of learning. I used thematic analysis to analyze the data collected. I addressed quality measures through triangulation of the multiple sources of data, member checks, and detailed descriptions of processes. The next section will explain why I chose qualitative case study to examine the research questions.

Research Design

I approach this research from an epistemological and ontological perspective of constructivism. As an ontology, constructivism suggests reality is subjective (Guba & Lincoln, 1994). Constructivist ontology purports that individuals construct reality through the experiences of the individual or the shared experience of a group. From a constructivist epistemological perspective, we can only know knowledge through the interaction of the researcher and the participants, thus the nature of the knowledge is subjective (Creswell & Plano Clark, 2018; Guba & Lincoln, 1994).

These philosophical perspectives undergird the decisions made developing this study. I can only achieve the nature of understanding how students learn through examining how learners construct the knowledge individually and socially. Qualitative research allows the researcher to understand from the perspective of one or of a group of people. There is no starting point for this understanding; it must be realized inductively.

Guba and Lincoln (1994) describe the methodologies connected to constructivist ontology and epistemology as being "hermeneutical and dialectical" (p.111). This corresponds with Merriam and Tisdell's (2016) definition of qualitative research as seeking to understand participants' interpretations of experiences. This approach situates the researcher "as the primary instrument for data collection and analysis" (p.16). Data collection methods such as observations, interviews and focus groups put the interviewer in a position to acquire more than just what a respondent offers by expounding on answers. I sought to have a deep understanding of a small group of learners' experiences with creating virtual reality as a learning activity. This dynamic environment required methods which corresponded to getting a variety of data to have a holistic examination of the youths' experiences. A qualitative, embedded case study was determined to be the best design based on the research questions and the bounded context of the study.

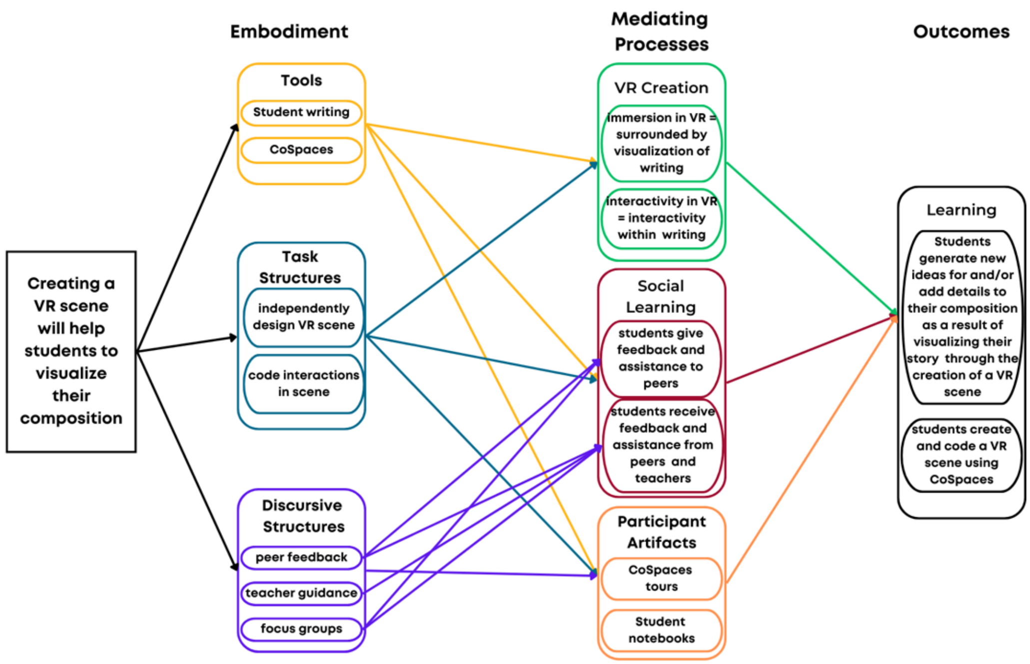
Mills et al. (2010) define three characteristics of a qualitative case study: research that takes place in a natural setting, investigation of complex social processes, and a multifaceted approach to data. The current study fits with this definition. It occurred in a nontraditional classroom, as it occurred as part of a summer camp. The structure of the setting was close to that of a traditional classroom, having structured activities and lessons, and learning was a natural part of the workshop. The research question addressed the complex dynamics associated with learning, teacher and peer supports, and interactions. To understand these interdependent behaviors, I employed a variety of data collection measures to provide different perspectives.

In addition to these criteria, the *case*, or bounded system, comprised the two week-long camp in which I conducted the study (Merriam & Tisdell, 2016; Mills et al., 2010; Tight, 2017). The participants were embedded sub-units of the case, in order to examine a sample of individuals (Yin, 2018). An embedded case study enabled me to observe the dynamics of collaborative learning and social interaction within the camp session, and explore how campers engaged with each other, instructors, and CoSpaces to construct their VR scenes. The case study design also allowed me to give an in-depth examination of the integration of CoSpaces as an educational technology, investigating the challenges, affordances, and impact on the learning process. By embedding the study within the camp, I observed the students' engagement with CoSpaces and explored its role in supporting learning through the iterative processes of digital making. An embedded case study facilitated a comprehensive understanding of how social constructivism was enacted, educational technology was integrated, and digital making activities were facilitated within the summer camp context.

VR Creation for Visualization of Compositions

Figure 2 represents the design for student VR creation shown as a conjecture map. The box to the left details the high-level conjecture, specifically that the creation of a VR scene would help students to visualize their composition. The Tools and Materials, namely the student compositions and the CoSpaces web application, provided for the creation of an immersive scene to visualize their writing.

Figure 2. VR Creation for Visualization Conjecture Map



The conjecture map suggested that the three-dimensionality and animations would contribute to the immersive and interactive qualities of VR and would help students to visualize their composition. As students worked on their individual scenes, interactions with peers provided feedback and technical assistance in creating their CoSpaces. The close proximity of students in the computer lab would naturally foster frequent interactions between peers. Teachers would also offer feedback and assistance as they reviewed students' work.

At the end of each day, focus groups would provide a dedicated time for students to share challenges and triumphs, serving as a valuable platform for students to gather new ideas for overcoming challenges and receive specific assistance as needed. To facilitate this process, the co-teachers encouraged students to write ideas, challenges, solutions, and feedback in their notebooks each day. These daily notes could then be used to incorporate into their designs or shared with others. Teachers would also encourage the youth to explore their peers' CoSpaces periodically, to gain ideas, share challenges, and provide feedback or assistance. I believed this collaborative approach would foster a supportive learning environment.

The role of the teachers in the design was also important. To introduce visualization, my co-teacher and I would provide a formal whole-class lesson on visualization, provide students with feedback on their CoSpaces visualizations, and provide instruction on using CoSpaces, including coding scenes. All instruction was mediated by whole-group instruction to get students started, and small group and one-to-one instruction for students as problems arose.

The intended learning outcomes focused on the visualization of their compositions and the use of the technology. By creating a VR scene representing their visualization of their compositions, students would be able to generate new ideas for their compositions. They would also be able to add more details to their compositions as they would be able to see their writing from an immersive perspective.

Using VR creation for their visualization, students are immersed in the writing in a way that is not possible in traditional visualization techniques, like drawing, seeing things from multiple perspectives. Interactivity brings the composition to life, allowing the writer to experience what characters in their composition would experience. I believed this immersion and interactivity would help students to improve their compositions.

Reflexivity Statement

My interests in pursuing this research relate to both my personal and professional interests. As a former K-12 educator, I witnessed many students whose full potential was not realized largely because teachers expected them to sit and listen to lectures. Most of these students had a diagnosis of behavioral disorders, and that style of teaching was not the best for them.

In my classes, I adopted a constructivist approach to teaching and frequently saw students make great strides. I have always had an interest in all kinds of technology, and that has influenced my career path. I currently work as an instructional technology specialist, helping university faculty to utilize technology in the classroom. When I see something innovative, I must try it.

On a personal level, I love the ability to create, whether it is physical or digital. I have embraced educational makerspaces because I feel they are a great way to get hands-on experience. Although I love the idea of VR, it is the thought of creating VR which really interests me. Joining education, technology, and creativity is a driving force. I see much potential for the future of innovation in education.

Context

The study occurred as part of a two-week summer writing camp for elementary youth in a mid-sized city in the southeastern United States. The camp occurred Monday-Friday for the two weeks and was divided into two sessions – a three-hour morning session that everyone attended and an optional three-hour afternoon session. In the morning sessions, youth worked with instructors to write stories of their choosing. Instructors helped guide the youth to think about age-appropriate elements of story writing. In the afternoon sessions, youth could choose from a variety of classes, including the class that serves as the context for this study. The title of this class was “Making in 3D” and the description of the class stated that youth would create a virtual reality environment to accompany their writing from the morning session. The camp organizers advertised this class for youth entering grades three through five in the fall. The enrollment for the class was capped at fifteen to ensure the instructors could meet the needs of all participants, which included having enough subscriptions to CoSpaces, the virtual reality tool.

In this afternoon class, there was one instructor, Stacy, a former elementary teacher. I also served as a co-instructor for the first week. Due to time constraints, I was only able to attend the first week of camp and part of the second week. During this first week, I focused on teaching the youth to use CoSpaces, as this is an area of my expertise, and Stacy had little experience with it. In the second week, I came to camp on the second to last day to conduct interviews with individuals.

The Tool: CoSpaces

CoSpaces is an online tool for creating three-dimensional scenes that can be viewed both online and with virtual reality goggles, for an immersive experience. Each scene is a page in the whole CoSpaces creation. Creators start with an empty scene, then decide on an environment, a 360° background, for the scene. CoSpaces only offers sixteen different environments, but they vary from sunny daytime scenes in the mountains to space scenes. They then add elements to their scene from the CoSpaces library: characters, animals, buildings, objects, and other items. Most items are customizable to some extent, such as changing skin tones, hair, and clothes colors on people, or changing the color and texture of a wall. Items can also be re-sized, either larger or smaller, moved around the canvas, and turned around. Characters can be animated to appear to be doing different activities or reacting to their environment. Some items can also be animated where appropriate.

Creators can code, or write instructions for the computer to follow, scenes to make these actions triggered by specific events. CoSpaces uses a "visual, block-based programming language" called CoBlocks (CoSpaces.edu, 2023). CoBlocks provides an accessible way to create custom code, allowing students to add animations, movement, and interactivity to their scenes. It includes various categories, each with a set of blocks, that when dragged to the CoBlocks workspace, and specifying parameters, tells the program what you want it to do. You can further customize by nesting blocks, to make certain things happen together, for example.

The Case

The youth spent the entire day at the site, eating lunch before being brought to this session. Most days, once the youth were in the meeting room, we immediately left to go to the computer lab to work in CoSpaces. Students logged in to the site and worked until snack time, about halfway through the three-hour session.

I created student accounts before the camp and created an assignment in CoSpaces to assign to each student. Assignments have specific parameters, such as the type of scene (3D environment, 360° image, tour, or student choice) and whether the assignment allows templates. Playgrounds, on the other hand, allow students to create as they wish. Although I expected students to create in their assignments, I did not allow the use of templates. After realizing that some students were creating in playgrounds because they could use templates there, I attempted to change the assignment but was unable. Therefore, some students' final scenes were in playgrounds. This sometimes made it difficult to know which area they had been working in.

We encouraged students to interact with one another, and even to walk around the room to explore their peers' work. This never became an issue, possibly because they were so engaged.

They appeared very focused on creating in CoSpaces. Sometimes students appeared to be playing, but everything they did in CoSpaces helped them to learn new things they could do.

Daily Procedures

On the first day of the study, students were introduced to the aims of the camp: to create a VR representation of a scene from a story as a visualization to help improve their writing. To introduce the students to CoSpaces, I shared an example of a created CoSpace that included animations, coding, and multiple scenes. They were then provided with a brief lesson on visualization, after which they used their notebooks to draw and/or write details to begin thinking about their compositions. Using whole-group and partner discussions, students were encouraged to make connections between the VR scenes and visualization. With teacher guidance, they noted that the VR visualizations were more immersive and interactive than their drawings and writings, thus giving the feeling of being in the story.

Students began creating in CoSpaces on the second day. After getting logged in to their accounts, we gave them free reign to explore, either by looking at the gallery of pre-created scenes, creating in a playground (a CoSpace not tied to an assignment), or beginning their writing visualizations. At the end of the second day, the youth began requesting information about coding, so I provided lesson on coding. To further emphasize the connection between creating in CoSpaces and visualizing, Stacy led a whole-class lesson. Together, they wrote a short story. Then, working in groups, they created a visualization of the story. As a whole group, we examined each groups' creations and discussed the similarities and differences.

Aside from these whole-group lessons, we focused on providing just-in-time lessons to individuals or small groups as needed. Students also received help from their peers. Select students were also video recorded for observational artifacts. These ten students were chosen because they agreed to be videotaped; the others preferred not to be recorded. I attempted to do video observations of all students who would allow it at least once throughout the camp, though most were recorded multiple times. The student or students recorded at any time was/were chosen based on active creation at the time and whether or not they had been recorded that day, so as to get perspectives from as many different students as possible.

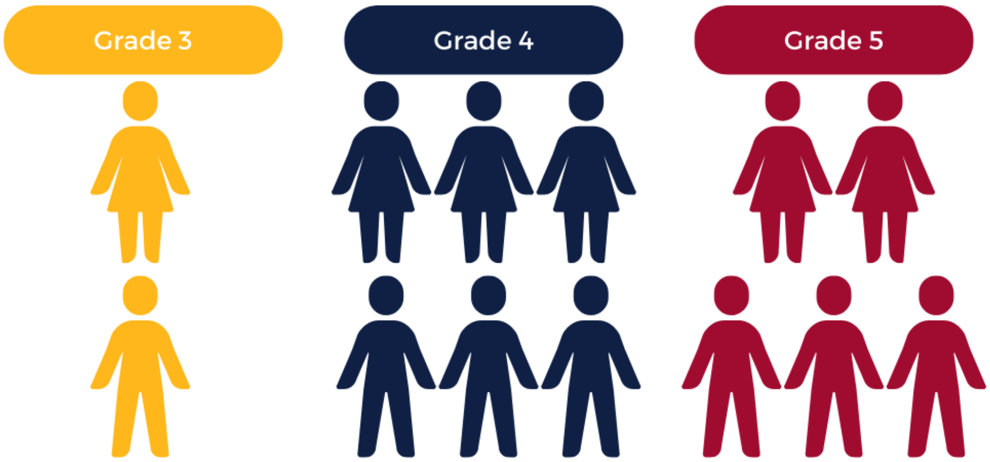
At the end of the day, we had a group debrief. The discussion was videotaped, taking care not to record those students without permission for inclusion. In the guided focus group discussion, students were asked to describe their challenges and successes in creating their CoSpace. Students were encouraged to write anything they learned from the discussion in their notebooks for use the next day after each focus group. They were also instructed to write any changes to their morning compositions they wanted to make based on their VR visualizations.

By the end of the first week, all students were still working on their CoSpaces. Stacy continued to assist them as needed the next week until their CoSpaces were complete. By the time I returned to interview students on the next to the last day of the camp, the students were finished with their assignment.

Participants

There were 15 youth in the class and 13 had parents/guardians who consented for them to participate in this study. Figure 3 shows the grade and gender of the youth participants.

Figure 3. Participants by Grade and Gender



Ethical Considerations

At the beginning of the camp, I provided an introductory letter about the research to guardians and requested signatures of informed consent to allow their youth to participate in the research study. All guardians also signed a permission form for the use of CoSpaces, which included links to CoSpaces' data security and privacy policies. On the second day of camp, I collected consent forms from all youth participants whose parents had given consent to participate and provided information to the youth about the research study and its purpose. I then provided assent forms for them to sign.

Before each recorded session, I ensured that participants still consented to being recorded. I positioned cameras to avoid recording any youth who did not wish to be recorded.

I informed the other instructor of the research study being conducted before she agreed to be part of the camp. She provided a signed assent to participate in the study before camp began.

To preserve confidentiality, I have changed the names of all participants. I stored all physical data in a locked cabinet in my office. I stored all digital data in a password-protected, secure drive. Before the study began, I secured institutional Review Board approval.

Participant Demographics

The 13 youth participants ranged from 7 to 11 years of age, in grades three to five. Detailed profiles of each participants' experiences can be found in Chapter IV. The names of all participants have been changed.

Alex

Alex, a fifth grader, was a quiet, ten-year-old boy. He created three scenes for his assignment. Alex was fairly modest about his work but expressed pride in his creations when asked. He was quiet during focus groups but did occasionally share about his progress.

Benjamin

Benjamin, a fourth grader, worked quietly, but steadily. He created five scenes in CoSpaces, which created a cohesive story and mostly aligned with his writing. He interacted with peers and teachers infrequently, and also spoke only occasionally in focus groups.

Caleb

Caleb is a fourth grade student. His five story scenes complemented his written story. Caleb worked steadily and quietly, rarely interacting with others. He remained quiet during most focus groups, only answering one question.

Charlotte

Fourth-grader Charlotte created three loosely-connected scenes. The scenes did not match her writing, as she felt that CoSpaces did not have the necessary items. She occasionally looked at the other girls' screens, either from her seat, or by getting up, and sometimes looked around the room at others' creations. She was very vocal in focus groups.

Harper

Harper, a fifth grade girl, finished with only one scene, though others were created throughout the camp. This scene demonstrated the setting of her writing. She worked alone but walked around looking at others' work a few times. Harper rarely requested any assistance, but when approached by the instructors would answer questions. She did not answer any questions during focus groups.

Liam

Liam, a third grader, created five scenes which loosely matched his written story. Liam worked steadily on his CoSpaces. He stopped occasionally to look at others' work and to offer assistance when needed. He received significant help from Stacy in finding problems in his code. He talked frequently in focus groups.

Mason

Mason, fourth grader, finished three scenes during his one week in camp. His final writing was not available since he was not at camp the last week. Mason was very animated during his creation and enjoyed showing it to others. He occasionally requested help from instructors and peers. He also frequently got up to look at others' work, but would go back to his own computer quickly. He was vocal during focus groups, sharing his successes and challenges.

Morgan

Morgan was a fifth grade girl. She created a total of five scenes which largely matched her writing. Morgan seldom left her seat, preferring to focus on her scenes. She did occasionally look at others' work but was focused on her own. She provided some help to her peers and received some help from both peers and instructors. She participated in all focus groups, talking at length about her successes and her challenges. Although her scenes were not what she had hoped to make, she was proud of her accomplishments.

Oliver

Another fifth grader, Oliver created two final scenes., which were mostly similar to his writing. He sat by himself, but behind others, and frequently watched what they were doing.

During focus groups, he contributed, but was a little hard on himself at the beginning stating he did not think he had gotten much done. By the end of the two weeks, he was quite proud of his accomplishments.

Olivia

Olivia, a fourth-grade girl, was another youth who sat alone. She got up and looked at her peers' work from time to time, though. Olivia did not request help from peers or instructors very often. She also did not talk during focus groups. She had only one final scene, which demonstrated the vivid characters of her written work.

Quinn

Third grader Quinn had two final scenes. Only one of the scenes seemed to relate to her final writing. She also sat alone. She did not talk to peers often. She requested help from Stacy and me a few times. She was mostly quiet in focus groups, but occasionally talked, sharing what went well and what she had trouble with. She expressed pride in her work and enjoyment of the process.

Samuel

Samuel, a fifth grader, created three scenes. He stated that they were to help him in writing his story, but was not a direct visualization. He took on the role of mentor for anyone willing to let him teach them. Samuel was also very vocal in focus groups.

Sophia

Sophia was an outgoing fourth grader who loved to share her successes and struggles with CoSpaces in focus groups, as well as providing feedback and assistance to her peers. She completed eleven scenes, which told a complete story, but was only one chapter of her written work.

Instructor Demographics

Stacy

Stacy previously taught at the elementary level and was currently a PhD candidate in teacher education. She describes her teaching style as not the "gatekeeper of all knowledge" but as part of a community "where we can learn and grow and push one another." Stacy's expertise in elementary education was essential in guiding learners' knowledge of world-building for their stories. Including Stacy in the study was important to provide an understanding of how a teacher in a classroom can support student learning through the creation of VR.

Procedures

Data Sources

A variety of sources help with triangulation to ensure credibility and consistency in a case study (Merriam & Tisdell, 2016; Tight, 2017). This study included data sources of observational field notes, focus groups, individual interviews, and documents and artifacts. Observations, focus groups, and field notes were completed during the first week of the study. Interviews were completed on the next to last day of the study, except for one youth who would not be present the second week. His interview was completed on the last day of the first week. Figure 4 shows how each data source aligns with the research questions and when each type of data was collected during the two weeks.

Figure 4. Alignment of Research Question to Data Sources and When Data Collection Occurred

Data Sources	RQ1: Youth Engagement	RQ2: Teacher Support	When data collection occurred
Observational Field Notes	✓	✓	Week 1
Focus Groups	✓	✓	Week 1
Youth Interviews	✓	✓	End of week 1 & End of week 2
Notebooks	✓		End of week 2
CoSpaces	✓		End of week 2
Teacher Interview	✓	✓	After camp completion
Youth Writing	✓		After camp completion

Piloting Data Sources

I conducted a pilot study in July 2022 to test the individual interview protocols for learners and instructor, focus group protocol, and the observation protocol. Seven girls and four boys participated in a summer camp workshop over two weeks to create a virtual reality environment. The procedures were similar to the current study.

Testing of the youth interview protocol (see Appendix F) revealed a need to alter the language of the questions to be more specific and direct. I removed a question about the camp, which received answers about the whole camp experience rather than just the afternoon workshop. In the focus group protocol (see Appendix G), I changed the language to be clearer for the participants and made sure I would ask about specific learning goals.

Upon reviewing the CoSpaces created in the pilot study, it became evident that I needed an observation protocol for viewing them. Additionally, several learners finished early in the two weeks, and it was determined that one week may be sufficient for the full study. For this reason, I was present only for the first week of the camp (plus one day at the end of the camp for interviews), expecting that students would complete their CoSpaces by the end of the week.

Observational Field Notes

An important aspect of understanding how students navigate learning is observing them as they do it (Merriam & Tisdell, 2016). In this study, it was important to observe learners as they interacted with CoSpaces and other resources, such as internet searches, to gain insights into their learning processes. Equally important were the interactions between the students, their teacher, and their peers. As a co-teacher of the camp class, it was difficult to capture all the details of the class. To address this, I set up a video camera daily during the first week to observe select participants who had consented to being video recorded. In total, I had nine recordings that lasted an average of 15 minutes, with no more than three per day, so that multiple viewpoints of the classroom and different students could be observed. The classroom was noisy, so an iPad was set behind groups of students to capture student interactions both with CoSpaces and with others. Observations were limited to three per day to balance my dual role as researcher and co-teacher.

These observations provided data on how the youths proceeded through the design process, tackled challenges, navigated the CoSpaces platform, conducted research for their VR scenes, collaborated with peers, and constructed knowledge as demonstrated through their CoSpaces creations. These recorded observations also captured important insights into the teacher’s role in supporting the learners. To review the recorded observations, an observation protocol was used (see Appendix A) for systematic analysis and interpretation.

I compiled field notes daily after each session. Saldaña and Omasta (2022) state that the goals of observation and reflections are to:

- Analyze what people want or want others to do;
- Analyze how people react to their *own* actions, their given circumstances, or to what is said and done to them; and
- Analyze strings of action and reaction that compose significant interaction moments. (p. 44)

My daily field notes focused on capturing participants' interactions with CoSpaces, other youth and teachers; participant reactions to their experiences; and the dynamics of their interactions. My reflections went beyond descriptions, offering interpretations and connecting observations to the goals outlined by Saldaña and Omasta to provide a rich understanding of participants experiences and interactions.

Focus Groups and Individual Interviews

Interviews are a way for the researcher to discern a participant's thoughts and feelings about an experience or concept (Merriam & Tisdell, 2016). The interviews in this study were semi-structured, with open-ended questions, to understand youths' thoughts about how their work is progressing, any challenges or successes they were having, and what they felt they had learned as a result of the activities. I utilized both focus groups and individual interviews.

Focus groups allow the acquired data to be socially constructed (Merriam & Tisdell, 2016). A daily debrief for all youths and teachers at the end of each day served as focus groups (see Appendix B). I conducted a total of five focus groups, lasting an average of 18 minutes. The focus groups were used to find opportunities for collaboration and to provide data. For example, as participants reflected on their challenges of the day, others who had discovered solutions could share those solutions. The focus groups were video recorded for later analysis. I wrote reflection memos after each focus group to add any additional information that may not have translated to the recording or any immediate reflections.

From the focus groups, I selected six youths for individual, recorded interviews. The interviews were to elaborate on the discussions in the focus groups. Interviews happened at the end of the project, to collect the summative thoughts of learners after they completed their environments. Interview questions built upon the discussions in the focus groups. See Appendix C for the learner interview protocol.

Due to time constraints of the study, only six youth participants were interviewed. The participants interviewed were purposively sampled because they were the most vocal in focus groups and thus, I believed they would have the most to contribute to individual interviews. These six youth had also already completed their CoSpaces by the time I interviewed them, while others were still working. Though interviews with all students would have been preferred, this purposive sampling provided a representative cohort of the youth participants, given the time constraints. Interviews were completed with five of the youth on the next to last day of the camp. The other youth was interviewed at the end of the first week, as he would not be present the following week.

In addition, I interviewed the other teacher on her perceptions of learning and the support needed during the study (see Appendix D). I wrote memos after each interview to add any additional information that may not have translated to the recording or any immediate reflections.

Documents and Artifacts

Merriam and Tisdell (2016) suggest that documents can be an excellent source of objective data. As part of the design process, learners were encouraged to journal in notebooks questions they had while creating their environments. They also created their plan for their

CoSpaces environment before they began creating. This type of personal document is useful for understanding the participant's thinking about the project and to see some of their thought processes. I took daily screenshots of each students' work and added each to a memo documenting the student's participation and progress. Field notes, including screenshots of each students' work, occurred only during the first week of the study.

After the completion of the camp, I collected the students' written works to compare to their VR visualization. I also screen-recorded each youth's final CoSpaces and analyzed them using the CoSpaces observation protocol (see Appendix E). These video documents offered further insight into the learners' thought processes and provided additional evidence of their learning through the CoSpaces platform.

Data Analysis

Data collected, whether it be observations, artifacts, or the words of a participant, are just pieces of information. The role of the researcher in analyzing the data is to organize the information in such a way as to ascribe meaning to it (Lester et al., 2020).

I used thematic analysis to analyze the data across and between sources. I sought to understand the subjective experience of the participants. The flexibility of thematic analysis makes it a good fit with an interpretive qualitative method (Braun & Clarke, 2006; Lester et al., 2020). Using thematic analysis can result in findings that are based *in* the data. This is consistent with the inductive nature of qualitative research (Merriam & Tisdell, 2016).

Lester et al. (2020) also note that researchers can use thematic analysis with a variety of data and sizes of data sets. I used the software program Atlas.ti Mac (version 23.2.1) to organize the data, apply codes and themes, and create memos. Using this software helped manage the large amount of data and allowed me to synthesize across multiple sources of data.

I followed Lester et al.'s (Lester et al., 2020) seven phases of thematic analysis. Though the authors give the phases sequential names, the analysis is not linear, but recursive.

In the first phase, the researcher organizes the data using a specified naming protocol and enters it into a master catalog. Next, the researcher transcribes all recordings. The researcher then does an initial analysis, making notes of ideas and reactions.

In the fourth phase, the researcher creates memos with initial ideas about the data. The next phase is coding the data to assign meaning. Lester et al. recommend at least three phases of coding, starting with a descriptive, low-level inferencing, then a higher-level inference in which the research applies additional codes, and finally the highest-level coding, in which they make explicit connections.

In phase six, the researcher organizes the codes into categories, which are then organized into themes. In the last phase, they create an audit trail throughout the process to make the process transparent. Figure 5 shows Lester et al.'s steps for thematic analysis.

Figure 5. Thematic Analysis Steps

Following Lester et al.'s steps, I began my analysis by organizing all the data. I used a standard naming format for each type of data (focus groups, observations, notebooks, daily CoSpaces screenshots, and interviews) and created folders to organize the data. I did this daily as I collected the data.

Next, I transcribed recorded focus groups, interviews, and observations. Though the recording methods provided automatic transcripts, I reviewed them for accuracy. As I became familiar with the data through transcription, I began to see some possible initial codes, which I noted in memos. Once all transcripts were complete, I uploaded all data to Atlas.ti qualitative data analysis software. Atlas.ti made it easy to code and recode, group codes, see codes across data.

Examining through the lens of social constructivism as the conceptual framework, I approached the coding process as a way to understand students' incorporation of VR as a form of digital making mediated by the educational technology tool CoSpaces. Specifically, I looked for evidence of student critical thinking and problem-solving; collaboration; application of creation techniques in CoSpaces; and students' visualization of their writing, beginning with focus group transcripts as the primary source material.

I began with focus groups because they involved all the participants in interactive conversations. While I initially posed questions, dialogue frequently expanded as multiple students responded to each other and built upon other's contributions. I applied codes using descriptive coding (to summarize the passage topic), in vivo coding (words and phrases spoken by the participant), and process coding (using gerunds to describe actions) by examining each line of the transcript or field note, as described by Miles, Huberman, and Saldaña (2020) for evidence of students discussing or describing the ways that they solved problems, specific procedures and tools they used to create, and why they made those decisions as it related to the visualization of their writing. I then wrote a memo describing my process and initial thoughts. This initial coding provided broad codes that encompassed general ideas.

Next, using the codes already developed, I examined interview transcripts using the same process and codes in mind. I added new codes as necessary. I repeated the process with observational transcripts, then field notes and student notebooks. I wrote an analytic memo after each round of coding, examining the emerging categories and themes.

Once I had applied initial codes to all transcripts, I examined screenshots of each student's CoSpaces throughout the week and their final CoSpaces, applying descriptive and process coding to capture nuances in their creative processes, once again using codes previously ascribed and adding new codes where necessary. I looked for evidence of what students included in their scenes, such as objects and characters. In addition, I looked to see if the student included coding or animation to make the scene interactive. I also looked across their scene iterations and noted changes in scenes to understand the processes used in creation. Finally, I used descriptive coding to compare the final CoSpaces to the written works of each participant to identify the connections between student visualization and the creation process, i.e., what decisions students made to visualize their writing. I wrote analytic memos to document the process. At the end of this initial coding, I had identified 49 broad initial codes.

I conducted another round of examination of each data source to review codes and compare across other sources of the same type (e.g., I compared different participant interviews) and across different types (e.g., I compared participant interviews with their interactions in focus groups). During this round of examination, I added details to codes to provide precise coding, splitting up codes as needed. For example, the initial code "animation" referred to animation present in a CoSpace scene; this round of analysis split the code into "animation: present" and "animation: not present". An additional examination of the codes further refined the codes to provide further distinction among codes. For example, “animation: present” was extended to include the kind of animation, such as “animation: present: speech”. At the end of this round of coding, I had a total of 165 codes.

Next, I assigned colors to categorize the codes, grouping them into small, related sets of codes by examining for similarities and differences (Miles et al., 2020; Ryan & Bernard, 2003). In looking for these categories, I considered how the codes represented how students used the CoSpaces tool, how their creations represented their writing (or not), and overall engagement in the process of creating (actions and speech which demonstrated feelings about their creation of VR) and independent and collaborative learning (actions and speech which demonstrated learning). I was then able to combine sets into larger groups until I had four over-arching categories.

“Story Elements” referred to the setting, characters, and action in the CoSpace environment that the youths included to represent their writing, relating to the visualization of their writing. These codes came from reviews of each student’s CoSpaces, youth interviews, observational field notes, notebooks, the youths’ writing, and the teacher interview.

Exploring through the lens of digital making and VR creation, “CoSpace Creation Techniques” were actions taken within CoSpaces to build their scenes. It included adding and removing objects; solving creation problems, like making uploaded pictures blend into the scene; and coding their scenes. These data came from observational field notes, focus groups, youth interviews, and the teacher interview.

Student expressions of frustrations, enthusiasm, and pride in their work served as the basis for the category “Feelings about VR in CoSpaces.” This category represented the problem solving and critical thinking that students used as they learned to use CoSpaces. These data came primarily from focus group discussions and interviews, but some also from observations.

The final category, “Community of Learners” showcased the ways in which learning happened independently, with peers, and with teachers. It also included the ways that learning was not limited to just teacher to student, but flowed from student to teacher, as well as teachers and students working collaboratively to solve problems. The data for this category came from observational field notes, focus groups, youth interviews, and the teacher interview. The name of this category came from a statement in which Stacy, in her interview, called the class a “community of learners”.

As I progressed with the refinement of categories, I continually grounded my analysis within the conceptual framework, which encompasses VR creation as a form of digital making mediated by educational technology and underpinned by social constructivist principles. My iterative process of refinement aimed to capture the nuanced interactions and learning experiences of students using CoSpaces and within the classroom. I refined these categories by splitting and combining codes once again to ensure that the categories accurately reflected the multifaceted nature of student engagement and learning processes in VR creation. This iterative refinement not only allowed me to discern patterns and trends but also enabled a deeper exploration of the ways in which students collaboratively construct knowledge and meaning using the digital making tool CoSpaces. Analytic memos helped to provide the audit trail of thinking.

In examining the categories, codes, and my analytic memos, I split some of the codes about teacher learning into a fifth category. “Teaching CoSpaces,” which addressed the things that teachers may need to know about before teaching and facilitating CoSpaces in their classroom. The data from this category came from the teacher interview. Each category contained many sub-categories. I once again examined the sub-categories and compared across and within data sources and participants, adjusting as needed.

In examination of the codes within each category, I realized that the fifth category, Teaching CoSpaces, was also an extension of the Community of Learners, as a community of learners would include all kinds of learning and combined them. As I began thinking about how students visualized their writing, I found that much of the creation techniques fit within their own category, which I first categorized as Visualization. These creation techniques, while a process used to visualize, were processes of using the CoSpaces tool to create VR environments. As a result, I split the category CoSpace Creation Techniques. Codes that referred to how students incorporated their story, whether through the items included or ways that the CoSpace showed action, were grouped together as Visualization. This also included similarities and differences between their morning writing and their CoSpaces. Codes that were more generally about the CoSpaces creation, such as the number of scenes created, how students used cameras, and the included objects and characters, remained in Story Elements or CoSpace Creation Techniques.

I also combined the remaining Story Elements, CoSpace Creation Techniques, and Feelings about CoSpaces categories, as they seemed to be synergetic. The creation of their CoSpaces, including choosing what and how to include characters, settings, and actions, was a source of the feelings they experienced, and thus connected. These processes and feelings created an authentic and contextual learning experience.

With this combination, I felt that Morgan's words in her interview would perfectly describe the encapsulation of this theme. She stated, "I would maybe like explore more of what I could do in CoSpaces. So, like reach the max of like adventure in it. Like find all these things out about it that I haven't messed with." Morgan was expressing her desire to learn and do as much as she could with CoSpaces. With that in mind, I renamed the theme to "Max of Adventure" to represent the adventure that the students felt in creating their CoSpaces scenes. This was a theme that was seen across all students as they worked in CoSpaces, adding characters and objects, and making them interactive. As seen through the conceptual framework, the students were working on the authentic learning experience of both using a new digital creation tool and visualizing their writing by creating VR scenes.

This led me to three themes: Community of Learners, Max of Adventure, and Transforming Writing with CoSpaces, which better described the category of visualization. Table 1 provides examples of the progression of codes and categories.

Throughout this process, analytic memos helped to further analyze the data and keep track of the decisions made, providing an understanding of patterns, trends, and key insights. Additionally, they served as valuable documentation, providing a reference for future analyses.

Table 1. Code and Category Development Data Examples

Example of Coded Data	Initial Code	Initial Category	Final Theme/Category
"This one has a blank environment, with a barn, and several buildings." (Olivia CoSpace Screenshot Observation July 12, 2023)	Blank environment	Story Elements: setting: not appropriate to the scene	Max of Adventure: Key Elements: Environments
"Quinn looks through her CoSpace, a house. She adds a door and continues looking through items." (Observation, July 12, 2023)	Building	CoSpace Creation: techniques for creation	Max of Adventure: Key Processes: Building Their World
"I would maybe like explore more of what I could do in CoSpaces. So, like reach the max of like adventure in it. Like find all these things out about it that I haven't messed with. (Morgan, Interview, July 20, 2023)	Do it again	Feelings about creating VR in CoSpaces	Max of Adventure: Exploring Student Engagement: Student Satisfaction in VR Environment Creation
"Mason asks to find a grape. Teena says that there are no grapes in the CoSpaces items. He searches through items until he finds a rock that he thinks will work and changes the color to purple." (Observation, July 11, 2023)	Characters	Story Elements: characters	Transforming Writing with CoSpaces: Enacting Visualization: Enhanced Creativity

"Chapter 4 of Sophia's story is almost exactly like the CoSpace story. The only differences are that there were two girls, and they killed the dragon using ice." (CoSpace Observation)	Visualization	VIS: Morning story: same	Transforming Writing with CoSpaces: Analyzing CoSpaces-Enhanced Visualization and its Impact on Writing: Enacting Visualization
"Liam and Samuel discuss using physics. Liam explains he is trying to code his characters to get hit five times and then fall down. Samuel explains that he needs to use physics coding to do that." (Observation, 7.11.03.26)	Receiving help	Peer to Peer: receiving help	Community of Learners: Student Learning: Learning from Peers
"Liam was trying to get his soldiers to like move at a certain time. But he had like 86 codes. And there was this one that went, it was in line with everything because I helped him line it up. But it kept going further. And we're like what the heck is this doing because it's literally, they're all on the same…. What happened was it was all the way up in the initial coding that took place. He was like, point five of a centimeter further than the other ones. We had to go back and figure that out." (Stacy, Interview, September 8, 2023)	Help from teachers	Community of Learners: help from teachers	Community of Learners: Teacher-Student Learning Dynamics

Quality Checks

Qualitative research is by definition subjective and inductive (Creswell & Plano Clark, 2018). The goal is to understand from the perspective of the participants, and how they interpret experiences (Merriam & Tisdell, 2016). This may leave some, especially those more familiar with an objective quantitative approach, wondering just how accurate qualitative research can be.

Quantitative research uses the methods of validity and reliability, but those don't quite fit with qualitative research. Qualitative researchers have suggested various other names and conditions for validity and reliability, but I will refer to them as Merriam and Tisdell (Merriam & Tisdell, 2016) suggests, based on the work of Lincoln and Guba (Lincoln & Guba, 1985): credibility, consistency, and transferability (p.242).

Credibility

The researcher establishes credibility by showing that they have made accurate interpretations of the data (Creswell & Miller, 2000; Merriam & Tisdell, 2016). To establish credibility for the current study, I used triangulation of the data, member checks, and peer review.

By using multiple methods of collecting data, I could compare across the different methods. Having multiple interviews, focus groups, and observations provided a way to cross-check from each type of data.

Another method for credibility mentioned by Creswell and Miller and Merriam and Tisdell is that of reflexivity. It is important for the researcher to disclose their "assumptions, beliefs, and biases" (Creswell & Miller, 2000), as I did at the beginning of this chapter.

Consistency

The other area related to the quality of the research is consistency. In a quantitative study, the researcher seeks to establish reliability so that others can replicate the results (Creswell & Miller, 2000; Merriam & Tisdell, 2016). Qualitative research, on the other hand, is not easily replicated, as it involves the study of human nature, which is always in flux. Qualitative researchers instead seek to establish consistency by ensuring that the results and the data are consistent. Triangulation, peer reviews, and reflexivity are three ways to address consistency. Another way I ensure consistency is to include an audit trail. An audit trail provides detailed information about all aspects of the research (Creswell & Miller, 2000; Merriam & Tisdell, 2016).

Transferability

A third measure of quality is that of transferability (Merriam & Tisdell, 2016). Transferability involves the ability of the research to be generalized to other settings. To ensure that readers can extrapolate how they can apply this study to other settings, I have provided details of the setting and participants. The setting and participants are similar enough to a typical classroom that they can make generalizations. The next chapter will describe the findings in detail. I also use "thick, rich descriptions" (p. 256) in the next chapter to help readers and researchers determine the generalizations that can be made and to aid in extending this research with the details needed to apply to similar situations.

Chapter Summary

This qualitative case study used a social constructivist approach to understanding how elementary youth navigate the process of creating a virtual reality environment. Learning in a social constructivist classroom is a complex endeavor, and understanding how the learning happens requires a complex system. In this study, I utilized multiple sources of data, including observations, interviews and focus groups, and physical and digital documents, to compare across the data and across participants. The week-long summer camp also provided an opportunity to analyze the role of the instructor. I undertook a multi-step thematic analysis to make meaning of the data. I attended to credibility and validity through triangulation of data, member checks, and peer review.

CHAPTER IV: FINDINGS

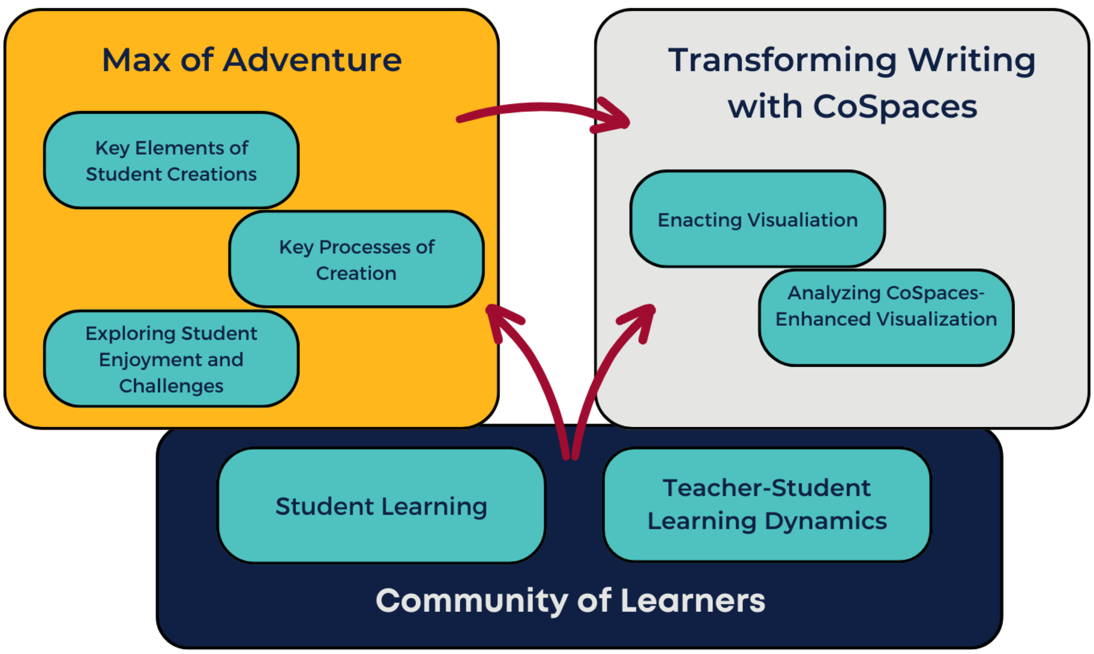
This study sought to understand how creating a VR scene can help students to visualize their writing. Visualization helps writers to improve their writing by expanding details, generating new ideas, and clarifying ideas (Bomer et al., 2010; Jurand, 2008; Zeigler et al., 2007). VR visualization improves upon this process with easier revision by not requiring students to completely start over when deleting and adding to their visualization (Blikstein, 2013) and immersion in the story (Alfadil, 2020; Bujak et al., 2013; Chang et al., 2020; Innocenti et al., 2019; Li et al., 2020). Furthermore, another benefit of creating VR scenes is to prepare students for future-ready skills, such as coding, which provides an opportunity for students to begin to learn how to code.

Looking through a lens of social constructivism, my approach to the study emphasized cooperative knowledge-building and hands-on learning. Students used CoSpaces, an educational technology web application, as the platform for this VR creation. Student-created 3D scenes in CoSpaces could later be viewed through VR goggles, which students kept in mind as they digitally visualized their writing. Further, as most students would not be familiar with the tool or with visualization through VR, I needed to know how they needed to be supported in order to use CoSpaces. Therefore, my research questions were:

> RQ1: How do elementary-aged youth engage with a virtual reality tool to create a virtual reality environment?
>
> RQ2: What technological and pedagogical supports do teachers provide to guide elementary-aged youths in the creation of a VR environment?

Figure 6 shows the interconnected dynamics of learning, creating, and technology demonstrated by the themes from this analysis. The community of learners, both student learning and the teacher-student learning dynamics, provided a foundation for the other two themes, for without learning, the others would not have been possible. The Max of Adventure theme explores the act of creation through the key elements and processes of creation and student reactions to creating with CoSpaces. This theme enabled students to transform their writing by enacting their visualizations in CoSpaces.

Figure 6. Interconnected Dynamics of Learning and Technology



The following sections will explore each of the three themes, beginning with the Max of Adventure, followed by Transforming Writing with CoSpaces, and finally, Community of Learners.

Theme 1: Max of Adventure

> I would maybe like explore more of what I could do in CoSpaces. So, like reach the max of like adventure in it. Like find all these things out about it that I haven't messed with. (Morgan, interview, 07/20/23)

Morgan's quote captures the essence of the experiences of youth in the session who sought to explore the limits of what they can create with a VR tool like CoSpaces. The virtual landscape provided a unique environment for digital creation in which students navigated and engaged with CoSpaces in multifaceted ways.

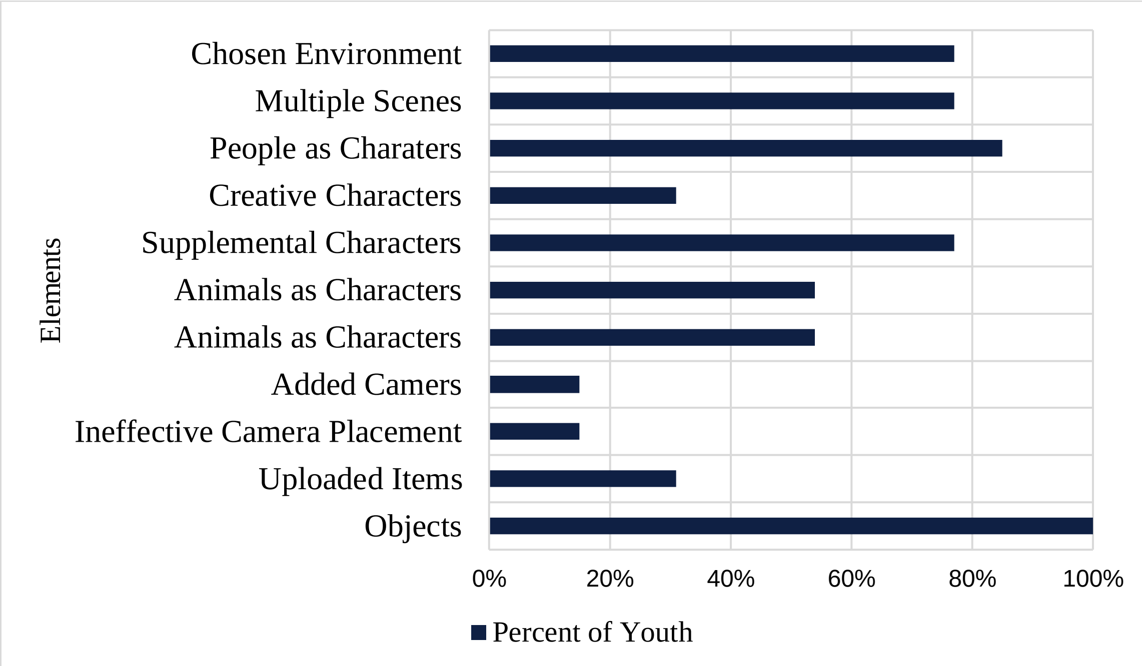
This theme explores the intricate interplay between the elementary-aged youth, their digital creations, and the dynamic processes involved in constructing VR environments in this unique educational tool. I seek to explore the nuanced and profound ways in which students manipulated the items in the scene and the intricate steps involved in creative building and storytelling. I further aim to explore the emotional dimensions of using this tool and of creating VR.

This theme responds to the first research question of how the youth engaged with the VR creation tool from the perspective of creating. I will first discuss the key elements incorporated in student CoSpaces, including environments, characters, cameras, and objects. Next, I will explore the key processes experienced by students in building their VR world and bringing it to life. Finally, I will discuss student enjoyment and frustrations in creating in CoSpaces.

Key Elements of Student CoSpaces

Students created their VR scenes using varied elements and processes in CoSpaces (for a more detailed description of the elements and processes available in CoSpaces, see Chapter III). While students were limited, mostly, to what CoSpaces offered, they were observed utilizing these elements and customizing them for their scenes frequently. Figure 7 shows the percentage of students using each element.

Figure 7. Key Elements of Student CoSpaces



Environments

Across all the final CoSpace scenes, students used all but two of the available scenes. Most of the time, scenes were chosen deliberately. Caleb wanted to show his character walking a great distance, so his scenes included a jungle and two different snowy scenes. Liam's story included a scene in which a king is threatened by a pirate in his throne room; he used the house environment to represent the dark throne room. Morgan used the same house environment in her scene of an old school classroom. However, Oliver's first scene (see Figure 8), is a blank environment, with only his two characters and a building. He provided no explanation for not choosing an environment that showed the setting. Figure 9 shows his second scene, in which he did choose an environment. Choosing the scene environment, for most students, added depth and context to the story being told by situating the action within a set space.

Figure 8. Oliver's First Scene

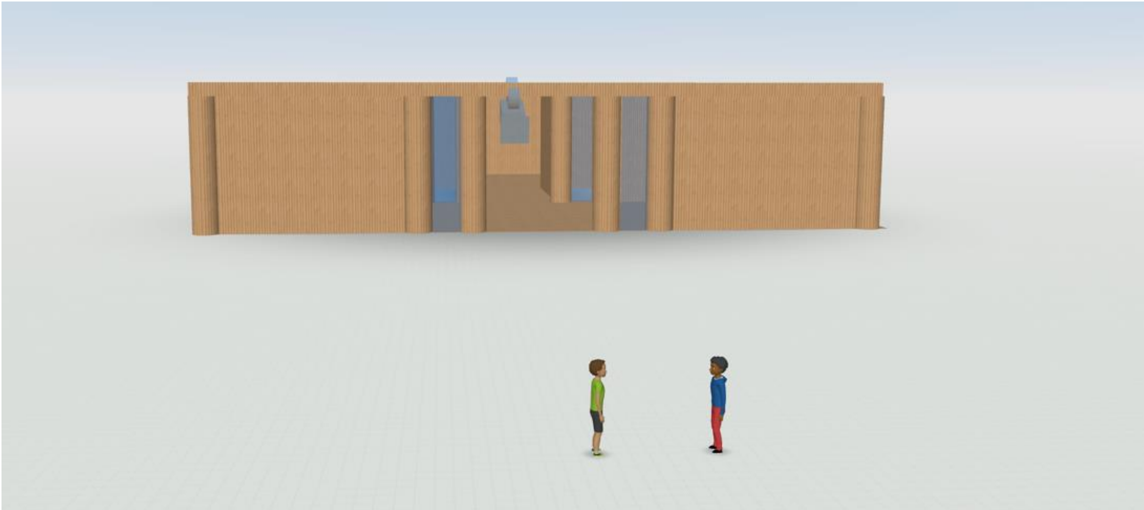


Figure 9. Oliver's Second Scene

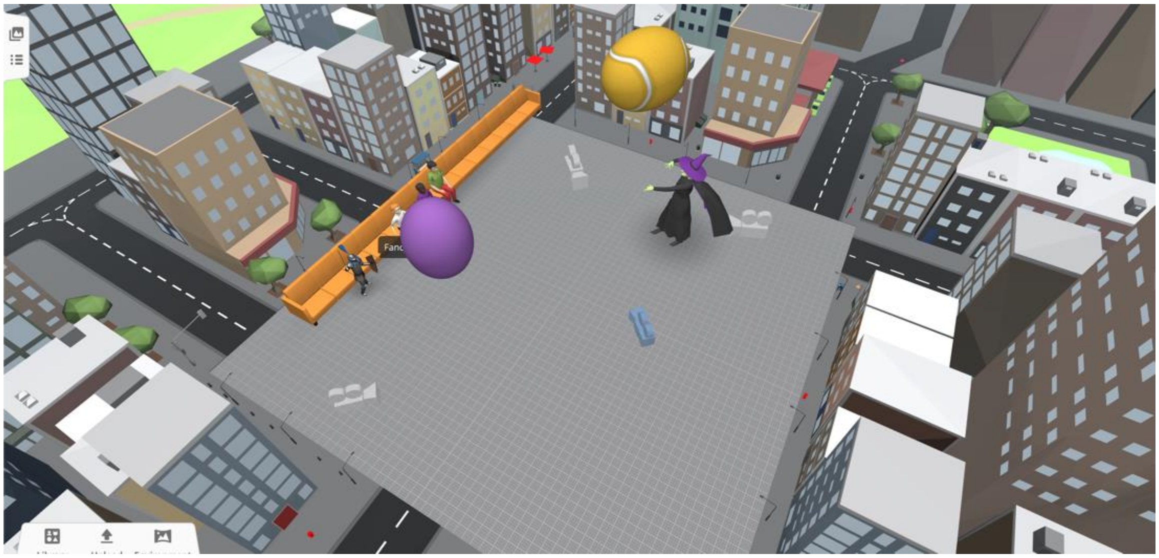
Most students created multiple scenes as part of their final stories, with an average of four scenes per CoSpace. Only two students had only one final scene, although both had worked on multiple scenes. The largest CoSpace had eleven scenes. The amount of detail in the scenes, i.e., items and coding applied to the scenes, varied among the students, as well as among the scenes. Students' inclination to create multiple scenes reflects their commitment to building intricate and engaging narratives. Those students who had only one scene in their final scene may have been influenced by their storytelling choices, the complexity of their projects, or a desire to work in other, non-assigned, spaces.

Characters

Students used a variety of characters in their scenes, from those that represented real people to animals to completely made-up beings. Each student included at least one character, and one student included nearly 85 characters in his scene. Not all characters played a major role in students' stories. Many also included characters that did not move the story forward but added to it.

Most students were creating non-fiction stories based on characters that they imagined, so they changed little of the appearance of their characters. Morgan, on the other hand, created a story about starting middle school with her friends. She took care to select the characters that would best represent them. Olivia's writing contained only colorful animals. She changed the colors of her animal characters in her CoSpaces to match: cotton candy sheep were blue and pink, the banana horse was yellow, and the marshmallow bull was white. Meanwhile, Mason created a character from a shape: Garry the Grape. He made Garry very large and changed his color to purple. Figure 10 shows the scene including Garry. For these students, it was important to get their characters to look a certain way, to match the characters in their writing.

Figure 10. Mason's Scene 3 with Garry the Grape



Besides selecting and customized their characters, students also incorporated objects and animation that enriched the storytelling experience. They included objects that were appropriate to the characters, such as a cutlass for a pirate, or a backpack for a student. Almost every character included some kind of animation, whether it was the posture of the character, an action, or a reaction. Animals were shown eating other animals, people moved their hands while they talked, and characters spoke with speech bubbles.

The characters in students' CoSpaces were not just things to include. They were important parts of the story that each student wanted to tell with their CoSpaces scenes. Regardless of the number of characters, the type of characters, or what the character was doing, students took care to find the right characters to make their scenes complete.

Cameras

The camera angle determines what is seen when a scene is played. It can be moved within the scene, both while creating and while the scene is played, through coding. As students in the study were creating a story, the view that was seen was an essential part of the story. Many students worked with the camera, or added cameras, to show the story that they intended.

Strategic Placement. Students strategically positioned cameras within their scenes to control the viewer's perspective. For instance, in Alex's scenes, the camera was directed at a man on a sports field providing facts about the sport. The point of view provided the opportunity to not only see the man, but the field, providing additional facts. Similarly, Sophia placed her camera inside a house, allowing her to capture the moment the door opened, and a girl entered.

The placement of the camera had a significant impact on the narrative. Consider Liam's scene, in which a pirate ship is attacked by an island kingdom. The camera's position could alter the story substantially. Placing the camera behind the king, knights, and canons positioned the viewer as a member of the kingdom defending their land. This careful camera placement allowed students to convey a point of view in their virtual scenes, akin to how a written story conveys perspective through words.

Camera angles were also used to hide parts of an environment that the creator wished to hide. In particular, Benjamin used camera angles to focus attention to a specific part of a scene, and nothing else. In one of his scenes, three soldiers on horseback and the deer they are chasing stand outside a house. When played, the camera angle shows only the deer and one soldier on horseback entering. All the action happens right in front of the camera, so that you never see the characters outside the house. Figures 11 and 12 shows the contrast of those two views.

Figure 11. Benjamin's Final Scene Creation View

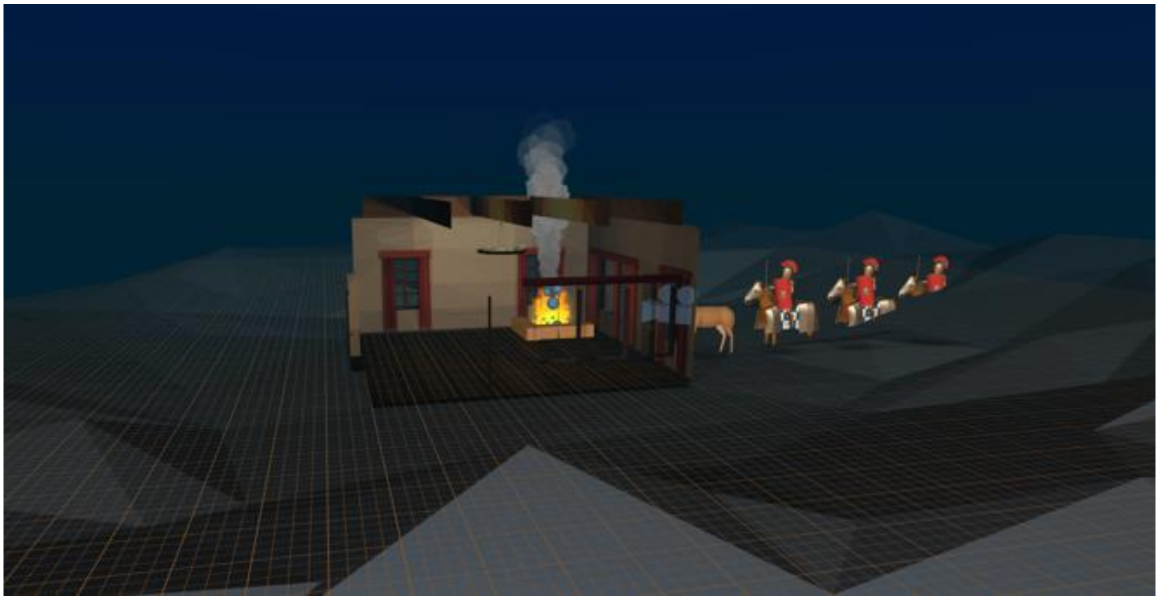
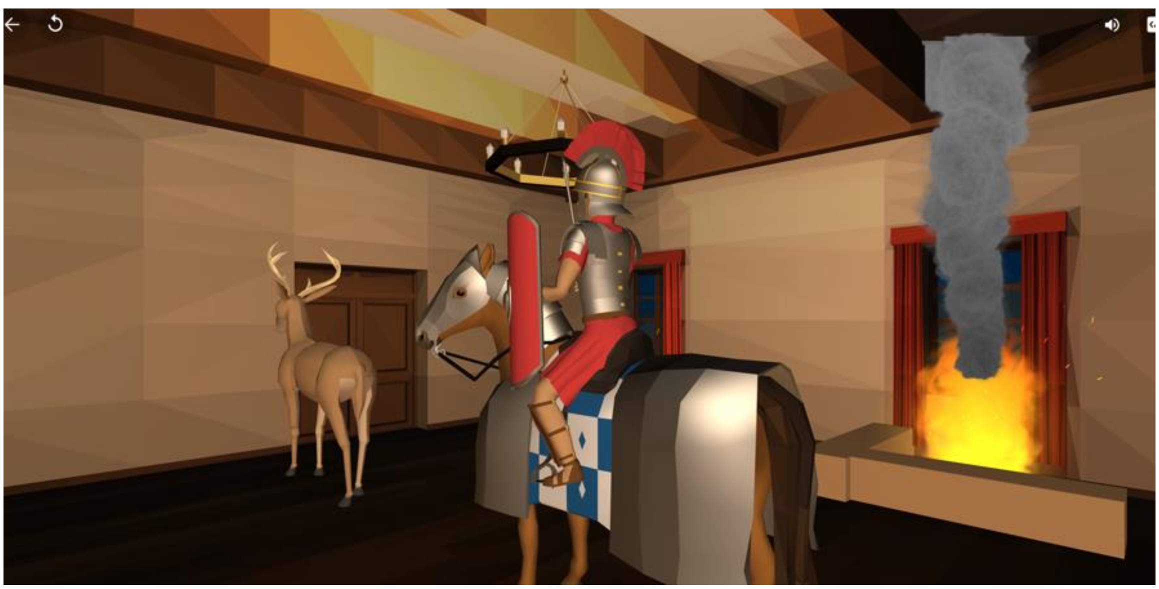


Figure 12. Benjamin's Final Scene Camera View



Morgan similarly used the camera angle, and an uploaded picture to remove any view of the house environment, other than the floor, to show her characters walking down a school hallway. These students effectively limited the perspectives of viewers, creating a close-up of the action.

Added Cameras. Students were not restricted to one camera. Using an additional camera allowed students to show different views. For example, Charlotte wanted viewers to explore her scene, and then when they were ready, to click a character. When the character was clicked, the camera changed to one pointed at her character so that you could see her walk away.

Likewise, Oliver used an extra camera to enhance storytelling. He added an extra camera to transition from the perspective of his character entering the VR scene in his story to what the character would be seeing. This multi-camera approach added depth to their stories, providing viewers with a richer and more dynamic narrative compared to what a single camera could offer.

Ineffective Camera Placement. Not all camera placements were effective, though. Mason added three cameras to one of his scenes, but since he did not provide a way to change which camera is being used, they were useless. Oliver added an additional camera that was pointing where it needed to be, and included coding to switch to that camera, but the main camera was pointed away from what needed to be seen when starting the scene. As a result, you miss the character's speech unless you move around the scene. Although it's possible to add cameras to a scene, students need to try to see the scene from the perspective of these cameras to ensure that they are effective.

Using cameras in a CoSpaces scene can focus the story on the parts that the creator finds the most important. Many students used the cameras effectively for that purpose. For some, though, more examination was needed to create a scene that used the camera to its full advantage.

Objects

Students added other objects to their scenes, as well. Some objects were necessary to their stories, while others just provided extra details. On the first day of working on her CoSpace, Quinn had a number of animals, including a pink kangaroo and a purple giraffe. She decided her scene needed a rainbow to go with them. She explained to the instructor that the rainbows in her first scene were an afterthought, but one which she felt made her scene, and her story, better. Her other scene included a treasure chest, and the key to open it, which was held by a girl in the scene. The chest opens when the girl walks to it and unlocks it with the key. The chest is present in her final shared writing from the morning, and it was necessary to add it to her CoSpace to show the story adequately. Including these objects not only added context to the story but added extra visuals for the viewer.

Several students demonstrated creative and resourceful approaches to using in their scenes. Sophia and Charlotte both used text panels, rectangles with text on them, to provide information to viewers. Sophia's text panels showed the passage of time during the story, while Charlotte wanted to inform viewers they could look around the house.

Morgan and Alex uploaded pictures into their scenes since they could not find suitable objects in the CoSpaces library. Morgan added pictures of her middle school to make it more like real-life (see Figure 13), while Alex needed pictures of soccer and basketball goals.

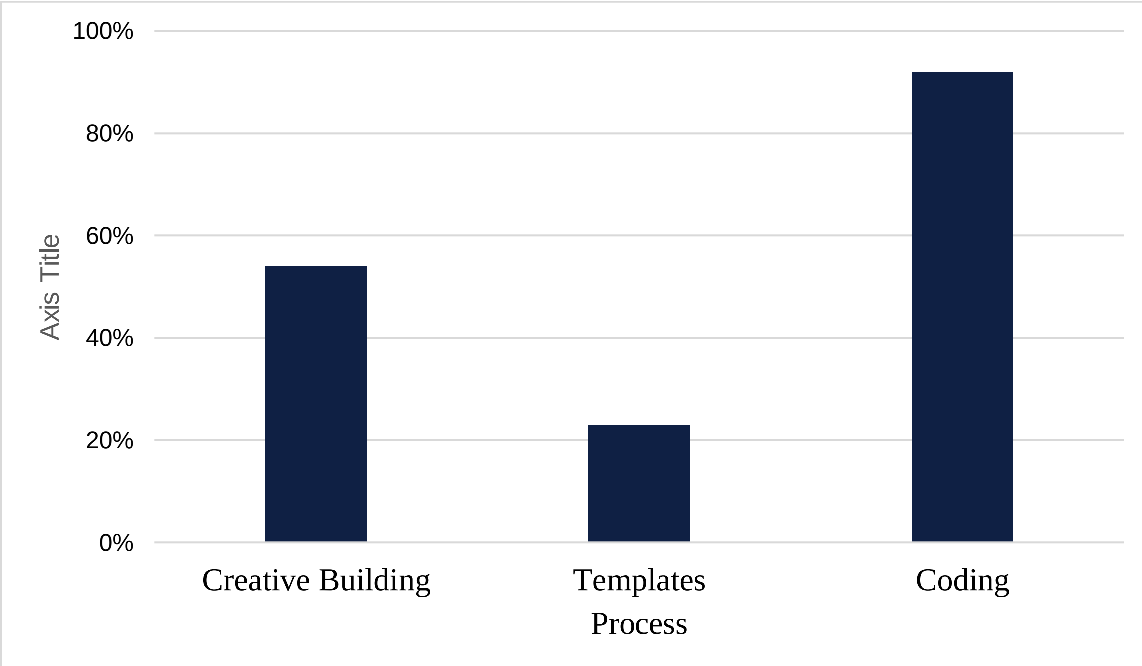
Figure 13. Morgan's Uploaded School Picture

In contrast, Caleb needed a portal for his scene, and he improvised by using a rock arch, which creatively served his purpose. These examples highlight the students' ingenuity and resourcefulness in adding unique elements to their projects.

Key Processes of Creation

CoSpaces scenes provide a sense of immersion, as the scene can be created so that the viewer can look around the entire space. Creating an immersive virtual reality scene requires adding enough to the scene to make it worth looking around. It also requires an understanding that when looking at the scene from different angles, you will see different things, and see things differently. In creating their VR scenes, students in the study worked with the items they added to find the best placement and sizes. Many students found that the items they wanted were not available in their CoSpaces library, so they had to make them with the materials available. Coding their scenes added to the immersion, when characters talked or moved around, and reacted to the events of the scene. Using cameras and changing scenes created a true digital storytelling experience. Figure 14 shows the percentage of students using each key process. Next, I will explore some ways in which students created their VR scenes in CoSpaces.

Figure 14. Key Processes of Youth CoSpaces



Building Their World

Much as a carpenter must carefully size, place, and attach materials, the students used the tools within CoSpaces to do the same. In observations, students were seen consistently adding in objects and sizing them to the correct size. They would move them and turn them around to be in a specific position. In one observation, Charlotte, while attempting to build a house, decided she needed a door:

> She duplicates a wall with a door and puts it in another location. However, she can’t see it because the other wall is covering it. She moves the original wall out of the way, then places the new wall. She then puts the old wall back in, shortening it to fit. (Observational Field Notes, 07/12/23)

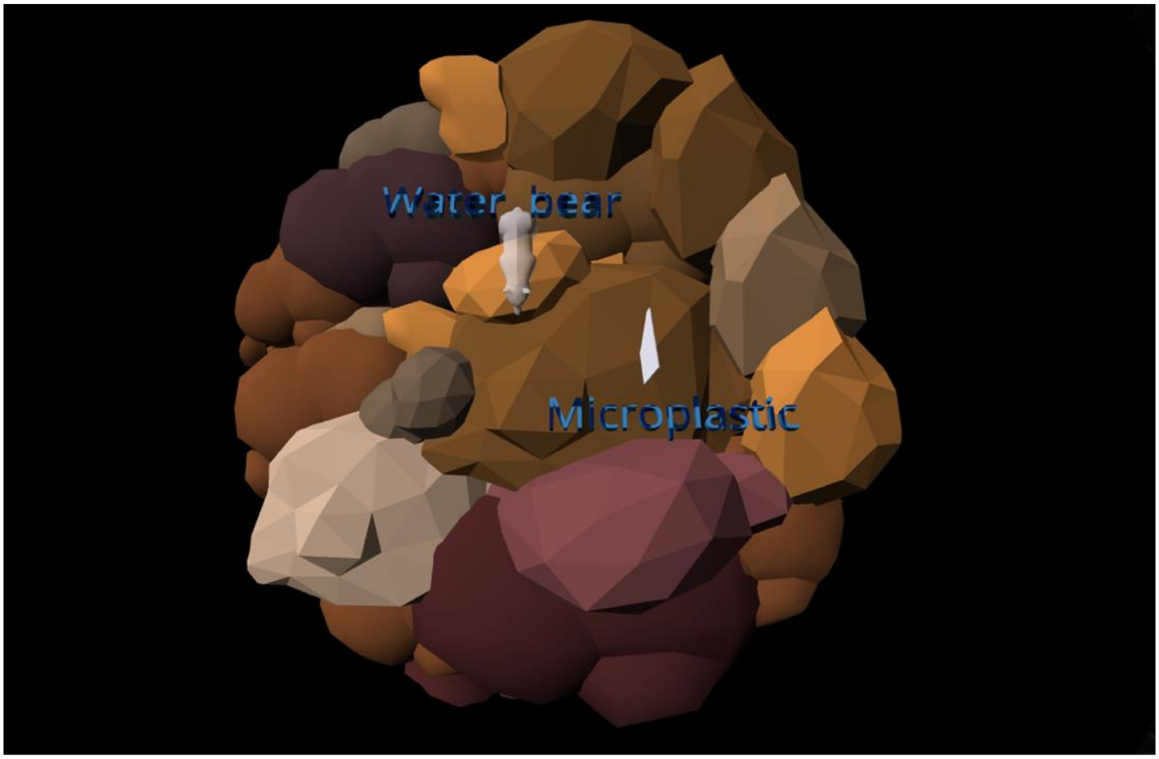
Sophia wanted the floor in one room of her house to be two separate pieces. She shortened the piece to the size she needed, duplicated it, and placed it in the now empty space. She then changed the color each floor piece to a different color. Throughout the observations, students were seen making similar adjustments to their scenes. These adjustments empowered students to refine their scenes, crafting the exact view they desired for their audience.

Some found that what they wanted was not available and devised creative solutions to fulfill their needs. Several students created a lake in their scenes using a flat circle that they enlarged to the desired size and changed the color to blue. Olivia used a similar process to create a brown mud puddle for one of her pigs to lie in. Alex used building materials to create his sports fields. A few students tried to build their own houses using the walls, windows, and doors found in the CoSpaces library, but found the process to be too time-consuming and gave it up. Oliver, however, built his museum using cylinders and cuboids which he sized, placed, and colored to look like brown marble. His museum can be seen in Figure 8. The act of building in CoSpaces enabled students to enact their visions of their stories.

Creative Building. Several students creatively built items for scenes. Part of a group assignment on visualization included a fireplace in the story. There is no fireplace in the CoSpaces library, so each group used different objects to build their fireplace: a brown ring, bricks, a stack of boards, or boards arranged in a square. The use of a variety of building materials not only showcases the creativity of students but also demonstrates the ability to work with a range of available materials to create new objects.

Perhaps the most creative illustration of building was Harper's atom (see Figure 15). Harper's story was about a man who is shrunk down to the sub-atomic level. She tried to build a scene using a desert environment and rocks, and another with a man surrounded by tall grass, but finally built an atom. She used rocks and clouds from the library, colored various shades of brown and orange on a black backdrop to represent her atom. She added a white bear, set to be semi-transparent, to represent a tardigrade and a white cuboid to represent a piece of micro-plastic. To help with identification, she added the labels for the tardigrade (water bear) and microplastic. Harper had struggled with the most effective way to create her story visualization, but through creative building, she created a scene which clearly illustrated it.

Figure 15. Harper's Atom



Skipping Steps with Templates. Charlotte and Sophia both used templates to create their scenes. They both wanted to show the inside of a house as part of their stories but found that building a house from scratch would take a great deal of time and effort. Instead of focusing on the building of the house, they each found a template of a house that they could copy into their scenes. They did each do some personalization, like adding items to decorate their houses. As mentioned above, Sophia especially spent time changing up her house to meet her needs.

Using the templates enabled them to focus their time on their stories, rather than the building. For these students, templates allowed them to represent their vision for the scenes efficiently.

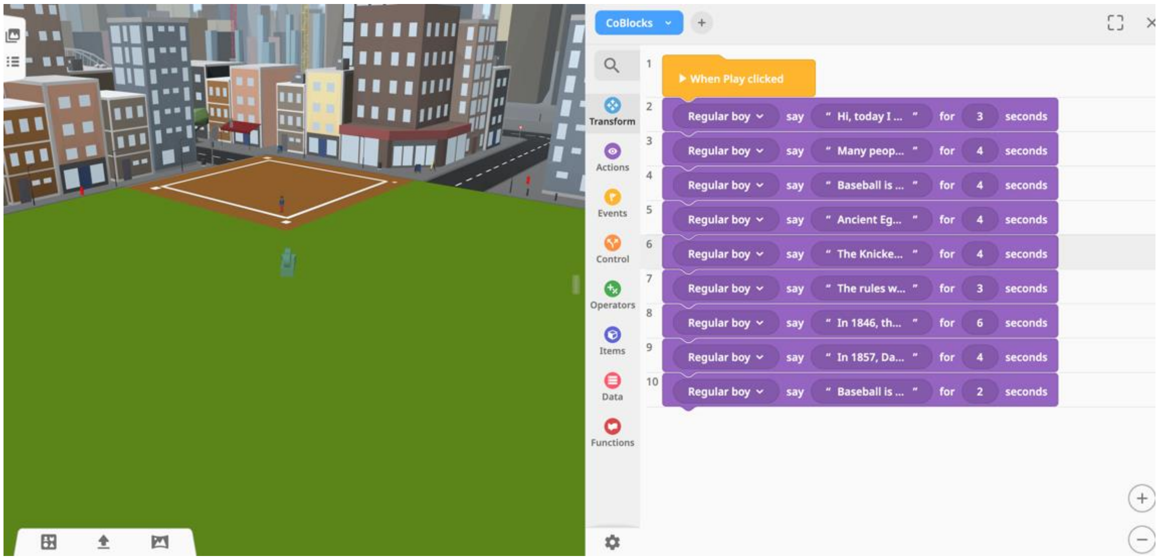
Bringing the Story to Life

To make their stories truly come to life, students had to make things happen. They could add animation to their scenes to have characters, and even some objects, behave in certain ways, like exhibiting speech bubbles. However, adding animation kept it like that for the entirety of the scene being viewed. All but one student decided it would be much more interesting if they made things happen throughout the scene. They did this by coding their scenes using the included coding program, CoBlocks, described in Chapter III.

Students' use of CoBlocks varied from simple to complex, even from individual students. Simple coding was usually only a few lines or lacked variety in the types of CoBlocks used. Complex coding contained several different types of CoBlocks or complex combinations of CoBlocks. A combination might include a code to apply animation to a character to appear to talk excitedly while a speech bubble appears. More complex combinations included more than two events happening at the same time, or things that happened as a result of something else happening.

Simple coding usually included animations. Though students could set animation for a character by clicking on the character and selecting an animation, when coding, you can make animations come and go. One of the most common animations used was to make the character speak. In CoBlocks, students enabled speech of their characters for a specified amount of time, then it went away. Figure 16 shows an example of this type of coding. This allowed students to create more nuance to their stories but required little coordination of codes.

Figure 16. Alex's Baseball Scene Coding



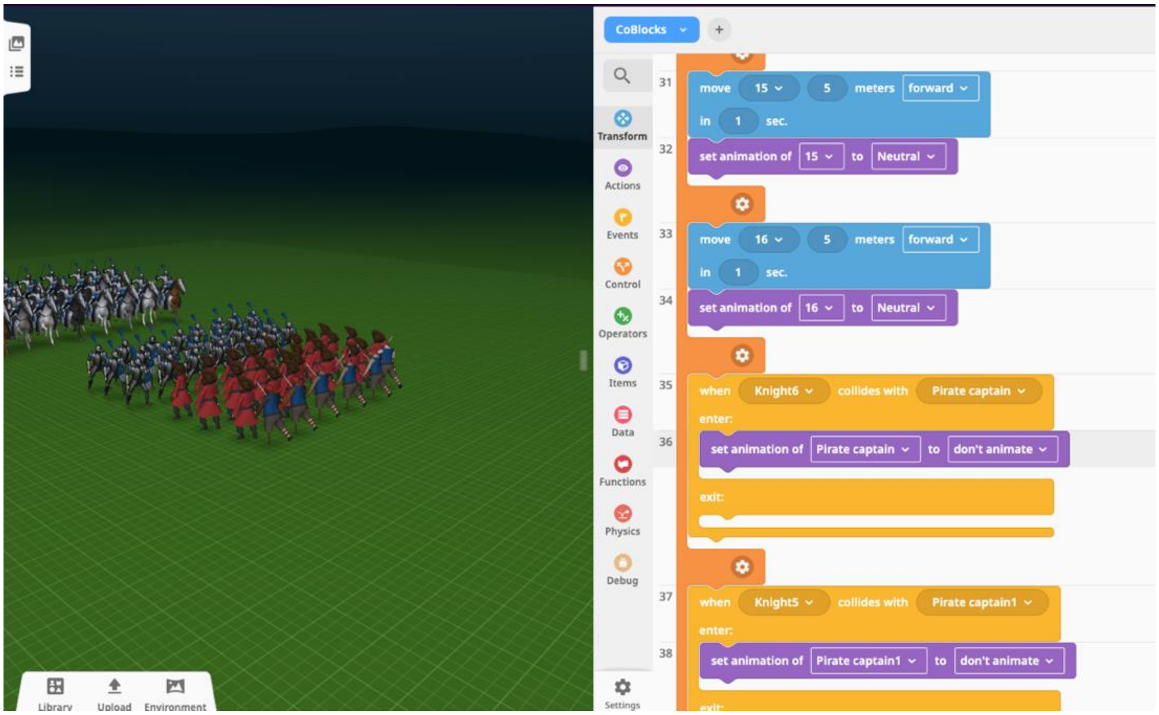
Students frequently animated their characters to walk and move at the same time. This was just one way that they enhanced the immersive experience. In her interview, Charlotte explained her process for making her character walk:

> ... when I first did like the go forward 9 meters, she just slid through the door like this [she gets up and shows sliding] and I was like wait, why is she not working? And so, I tried to find the animation of walking. And I found it. (Interview, 7/20/23)

As Charlotte found, without using the animation code, the character appears to be floating. Students applied these complex combinations to create realistic animations.

Complex coding often included “control” blocks that paused the coding for a specified amount of time, repeated codes, or moved the next scene. Some students even mastered having separate events happening concurrently, like walking and moving, using the parallel block. Using these codes often made the coding long and complex. Liam created a fight scene between rows of knights and pirates, all happening simultaneously. As the first row of soldiers moved forward, they collided with the first row of pirates, who fell down. Figure 17 shows only a portion of the 60 lines of code required for making this scene come to life. Creating these codes was quite time consuming, which is why he did not code the whole battle. However, the coding that he used was effective in creating the appearance of a battle.

Figure 17. Snippet of Liam's Land Battle Scene Coding



Students also used coding to perform other advanced actions in their scenes. Liam, in another battle scene, used physics to make pirates fly off their ship into the ocean when cannons, shot from the island shore, hit the ship. Oliver used the “switch camera” CoBlock to change from the main camera, at the back of his scene, to another camera further in to watch a bear get attacked by a lion. Sophia’s use of the “scene change” CoBlock progressed her story without the viewer having to navigate. This created a seamless story and limited the viewer to watch what she wanted them to see. Samuel, one of only two students with previous experience with CoSpaces, used a text panel and buttons to take players to his other creations. These advanced actions created dynamic scenes.

Exploring Student Enjoyment and Challenges in CoSpaces and VR Creation

Student engagement in the learning process is a key goal of using educational technologies and social constructivism. As a new tool, CoSpaces offers a novel experience for students. It is crucial to understand how students perceive the tool as a learning technology. This sub-theme explores the multifaceted reactions of students to VR creation in CoSpaces and the ways that their engagement, collaboration, and expressions of learning were shaped by their interactions with peers and instructors.

This section begins with an exploration of how the youth immerse themselves in their projects, expressed their excitement, and eagerly anticipated the opportunity to continue their work. Next, I will share some challenges that students faced while working on their scenes. Finally, I will discuss students' anticipation of and reactions to seeing their scenes in VR.

Student Engagement and Enthusiasm

On the first day the students worked in CoSpaces, most of them did not want to stop to go outside for a break and snack. The engagement in the computer lab as they worked on their CoSpaces was evident in every observation. Some students blocked out all distractions and worked without interactions with others for long periods of time. Others stopped to look at their peers' work near them or got up to go look around the room, engaging in social learning, through peer collaboration and interaction. This was a behavior that was encouraged by the instructors and did not result in having to tell students to go back to their work, usually. Social interaction is a vital part of social constructivism but has the potential to be distracting if students are not completely invested in their own work as well. This was not the case in the study. They would spend a few minutes looking, then go back to their own work without prompts.

Students frequently expressed their pleasure in their work through exclamations and gestures. Charlotte excitedly told me during one observation, "Guess what! I figured out how I can get this [points to her scene] in my story!" (7/12/23). She was proud that she had copied a template into her assignment. Other students were more subdued in their exclamations, like Quinn:

> [Quinn] opens the menu for one of the new walls but doesn't seem to see what she wants. After looking at something else, she goes back in and finds the setting to change the texture and color of the wall. "Perfect!" she says. She then changes the other walls. (Observational Field Note, 7/12/23)

Students also frequently used gestures to show their satisfaction with their work. Sophia imitated playing a trombone to show her triumph at completing a task in her space. After trying several times to get his coding right, Benjamin clapped quietly to himself when it succeeded. These expressions, whether loud or quiet, were frequent while students created. Regardless of the manner of expression, students frequently made known that they were excited about their work in CoSpaces.

During focus groups and interviews, they also frequently talked proudly about what they had done. This sharing proved invaluable as it offered peers crucial insights into what success might entail, enabling them to draw connections to their own work. Several students throughout the week expressed they liked what they had created. The other instructor of the session, Stacy, stated during her interview, "... the kids were engaged. They were excited." (9/8/23).

During one focus group, Morgan discussed her efforts to have a realistic setting for her story:

> Morgan: I think setting up like that picture and, like, actually, like making an accurate, like, setting like that went very good.
>
> Teena: Yeah. So, you worked really hard to get that picture, it's just a flat picture, to not look flat, didn't you?

Morgan: Yeah. I finally got it up against the back. (7/12/23)

Students' eagerness to discuss their positive feelings about their scenes each day represents the enjoyment they found in working in CoSpaces.

Students not only expressed pride in what they were doing in the session but also that they wanted to do more. All five students interviewed stated that they would like to create in CoSpaces again. Some stated they wanted to show their siblings how to do it. Many students expressed interest in using CoSpaces after the session. During an observation on the first day of working on their CoSpaces, Stacy asked who wanted to write their usernames and passwords to use at home; more than half of the students got them. The students desire to use CoSpaces outside of the camp further exemplifies their fondness of it.

Their desire to use CoSpaces outside of camp was not just for pure enjoyment; they wanted to work on their projects. During a focus group at the end of the first week, Sophia stated she wanted to try out physics over the weekend so that she could apply them the next week. I asked who else planned to work on it over the weekend and five students raised their hands. While reviewing what students had done one afternoon after camp, I noticed Caleb was working in his CoSpace, actively moving items. I later went back to his scene and confirmed that he had indeed changed his scene. Although not all students followed through with working on their scenes at home, they enjoyed it enough for it to be a free-time activity.

Students also responded that they thought CoSpaces would be a good tool for learning in school. In her interview, Morgan described the advantage, in her opinion, of CoSpaces:

> Yes, I like it a lot because it's just helpful in general to help write and it's a lot more fun than just sitting down and like in class. Like I'm always in school just sitting down and they're like, do this yellow sheet of paper and it's just not as fun.

Several students had ideas for using CoSpaces in school, including in math, science, and writing. Stacy said she wished she had known about CoSpaces when she was in the classroom and said that she could not think of a subject where it could not be used. CoSpaces is a tool that both teachers and students find useful for learning.

Hurdles and Displeasure in CoSpaces

Despite the overwhelmingly positive experiences students had with CoSpaces, their creative journey was not without its challenges. Some students expressed frustrations at not getting as much done as they would have liked. Quinn and Mason both stated they did not know how to do things in CoSpaces initially, and that frustrated them. Several felt that they did not do enough for their scenes. Alex responded to a peer looking at his scene that "*it's kinda boring*" (Observational Field Note, 7/12/23). While overall students seemed to enjoy working in CoSpaces, their experiences were multifaceted.

The limitations of CoSpaces were a recurring irritation for students. They frequently discussed the lack of items available in the library. Charlotte stated she had was writing a horror story, but that there were no horror items available. As a result, her scene was about her writing her story, rather than the story itself. The CoSpaces library contains hundreds of customizable items, but it does lack items in varied genres, which resulted in some students altering their stories.

Caleb lamented the ability to have his character have multiple animations at the same time. He said in his interview that he could not do what he wanted with the alligators in his lake:

> Caleb: I didn't know how to do some stuff for my alligator ones. I didn't… It looked like they were walking on water. When you make them swim, it makes them go underwater, but then I want them to attack the fish. So then, I don't know how to attack the fish when doing swimming, too.

Teena: So, you were trying to make the alligator actually attack the fish, but instead it just made it look like it was walking on water.

Caleb: Walking on water because it didn't swim. (Interview, 7/14/23)

Caleb's frustration with the mutually exclusive animations meant he had to make a creative choice in his scene to have his alligator either swim or attack.

Time was a final limitation for many students. The session was a three-hour session, but for many of them, the time went by quickly. This is a testament to the enjoyment they were having, but it also caused frustrations for those who felt that they could not do all they wanted. Liam's land fight scene between knights and pirates was remarkable in the amount of coding added to make the first row of pirates fall. He decided not to code all the pirates falling, though, because of the time it would take.

Sophia had a similar problem, as she explained during a focus group:

> So, like, I was in the house. I was trying to make, like, the second floor. So, I put the stairs, and I had the window. But when I got, like, the second floor, I can't go up, like, cause it's like, it stuck. So, I, like, make it. And I use the other wall and I like, try it. But then that's the class ended. So, I just needed to like use the other walls that, that is like has a hole, so I can like go upstairs. (07/12/23)

Sophia and Liam both had to decide what was possible for their CoSpaces due to the time available. Creation in CoSpaces provides many outlets for creativity, but the time needed to enact that creativity can be difficult for students, especially those first learning to use CoSpaces.

Though there were some negative aspects to creating with CoSpaces, students were still happy with their creations and with CoSpaces. They repeatedly demonstrated their ability to adapt their creations to the constraints of the tool. These limitations and struggles did not stop students from creating, nor, according to them, would it stop them from doing it in the future.

Student Satisfaction in VR Environment Creation

The scenes created by the students could best be described as 3D. Though the idea of immersion was present for the students, the scenes that they created could not be fully realized until seen through VR goggles. VR goggles were not available until the end of the camp due to a technical problem with the borrowed goggles, so students were not able to view their scenes through the goggles until then. All students reacted positively to seeing their scenes in VR. Morgan stated, "It's so cool in here! ... Like you're in it" (Interview, 7/20/23). In seeing their scenes in VR, the youth could view them as they were intended to be seen, fully immersed. This provided a new perspective on their writing, as well.

When asked in interviews if it would have helped them to see their scenes in VR while they were making them, there were mixed responses. Liam responded, "Not really" (Interview, 7/20/23) to the question. Morgan stated, "Maybe, I'm not sure" (Interview, 7/20/23). Charlotte, on the other hand, said that it would have helped her to see her scenes while she was making them. She had never seen a VR scene through VR goggles, and therefore felt that she would have had a clearer idea of what is possible. Experience with VR could be a predictor of the need to have access to VR goggles while creating. Those students who had previous experience in viewing VR through VR goggles may have a better understanding of how the scenes they created would look.

However, the actions of some students showed they understood the immersive aspect of a VR. Morgan made efforts to ensure that her flat pictures did not appear like one-dimensional objects through strategic camera placement. Liam added pirates down on the bottom parts of the ship in his scene in which the pirate captain is preparing to attack. He clearly understood that viewers would be able to move around and see the other pirates. Although seeing their scenes in

VR may have helped some students, others clearly understood that their 3D scenes were meant for VR.

Theme 1 Summary

The first research question asks how students engaged in creating CoSpaces scenes. This theme shows that students in the study exhibited a thoughtful and diverse approach to choosing and creating scenes within their CoSpaces projects. The variety of scene detail across all participants, both in terms of the items included, and the processes used to create the scenes, highlights the uniqueness of each student's creative process and the extent to which they employed the capabilities of CoSpaces. In utilizing the various elements available in CoSpaces, students learned through hands-on creation. Through each iteration of creation, they added to their knowledge of the tool and VR. Interactions with peers and teachers shaped the way that they approached their projects.

Students showed and expressed confidence and enjoyment in creating their CoSpaces scenes, despite some challenges. Though each student experienced unique challenges while creating, they all applied critical thinking to solve these challenges with innovative elements within, or added to, CoSpaces. The social interaction between students and teachers provided opportunities to learn from others as they applied critical thinking to find solutions to challenges.

Numerous students exhibited an understanding of how to create an immersive scene and were excited by the immersion into the VR version of their scenes. Students in this study iteratively created scenes which helped them to be immersed in the world of their writing. Students could add further immersion by adding interactivity through coding and animations. CoSpaces, as a digital tool, made iterations easy, as items and coding could be easily added or deleted as needed without starting over. The processes used in creating their CoSpaces combined to create a more complete visualization of their writing, allowing students to "see" the writing and explore new ideas.

Theme 2: Transforming Writing with CoSpaces

Elizabeth Dinkins, in "They Have to See It to Write It: Visualization and the Reading-Writing Connection", shared with her students, "... when I read a book I love, it's like seeing a movie in my mind..." (2007, p. 2). Dinkins beautifully captures the essence of how reading can evoke vivid mental imagery. CoSpaces provided a way for students to create a tangible image in their minds. It gave them a canvas for enacting the scenes as they saw them.

In focus groups, even from the first day of creating in CoSpaces, youth reported that they would change their story based on what they had created. This question was repeated each day, and each day, students affirmed that their writing was changing. When asked specifically how CoSpaces helped them to visualize, several of them stated it helped them to "see the story." Alex said that the sports facts he inserted in his CoSpaces helped him to know what to put into his writing. Similarly, Morgan said that as she created her scenes and saw the story, it helped her to think through what to write. They were creating their own version of a movie in their minds.

This theme explores the dynamic relationship between CoSpaces and the writing process of the youth in answer to the first research question. It delves into how CoSpaces facilitated the act of visualization, transforming abstract ideas into tangible and immersive experiences. I will first discuss how CoSpaces impacted their writing through creation of CoSpaces. Then, I will examine how their CoSpaces scenes compared with their writing.

Enacting Visualization

CoSpaces affords many advantages for visualizing when writing. Often, writers are asked to visualize by drawing it out. This creates a flat, one-dimensional visualization, limited to the space on the paper. Students who have difficulty drawing may feel intimidated and unable to create a more detailed picture. They are also limited to creating actions and interactions that can be drawn. Alternatively, students could create digital visualizations, which would allow for easier iteration, but remains a static image.

On the other hand, CoSpaces creates a three-dimensional image in which characters interact with each other and with the objects in the scene by animating and coding them. They can easily add details. They can make changes quickly and easily without worry of messing up their creation. The ability to use materials in various ways provides an opportunity for students to express their creativity in new ways. Finally, CoSpaces allows students engage in true world-building within a scene or a series of scenes.

The following sections will examine the ways in which students engaged in visualizing their writing in CoSpaces through interactive storytelling, world-building, and enhanced creativity. Further, I will examine how CoSpaces allowed students to iterate on their scenes.

Interactive Storytelling

As the viewer explores a CoSpaces scene, interactive elements engage the viewer in the immersive environment. Students creating their CoSpaces in the camp could visualize actions and dialogue in their story by creating interactive elements with animation and coding. This helped them to literally see either what they had already written or what they wanted to write, much like a movie.

When creating their CoSpaces, students added interactivity and played them to see it in action. Quinn had a scene in which she coded a character to use a key to open a chest. This helped her to visualize a possible ending to the story she was writing in the morning.

Some students added interactivity between the viewer and items in the scene. Samuel also had a chest in his scene, but his opened when it was clicked. Charlotte added doors to her house template that, when clicked, opened, allowing the viewer to see into the area beyond. Figure 18 shows the view in Charlotte's scene when a door to the outside was opened. By inducing the viewer to interact with the scene, the creators were able to see the interactions of their writing.

Dialogue was an important interaction of many students' CoSpaces. Mason used a pirate talking in a scene to let viewers know the story was going in a new direction. On the other hand, Morgan coded dialogue to tell her story of three friends on the first day of school. The dialogue for both students was an essential part of creating a cohesive story.

By using these interactive elements in CoSpaces, students could gauge how these interactions would work in their stories. This provided an additional layer to traditional visualization techniques.

Figure 18. Charlotte's Doors Opening to the Outside

World-Building

Several students commented on the role of CoSpaces to help them visualize the settings for their stories. Sophia said that she could not imagine the setting, but CoSpaces helped her to "try what it can look like" (Focus Group, 7/13/23). Morgan also said that she did not have a clear image of her setting but creating it in CoSpaces helped her make it more concrete. Visualizing in CoSpaces helped them to "see the story."

Co-Spaces provides a three-dimensional, 360° space for creating a rich, immersive world in which writers can imagine a higher-level of realism for their stories. Students used CoSpaces to help them visualize the worlds they were creating in their writing.

For example, Morgan wished to recreate the feeling of her middle school, an older building. In the classroom scene, she used an environment that represented an older room to her. She then added the student and teacher desks to further provide the feeling of a classroom. She stated that even though the candelabra in the middle of the ceiling led to the classroom "kinda looking like Hogwarts," (Interview, 7/20/23) referring to the setting of much of J.K. Rowling's *Harry Potter* series (1997), it helped her to visualize the scene more fully.

One the other hand, one of Liam's scenes shows the view from the island nation as they attack a pirate ship at sea near the island. There were no environments like that, so he literally *built his world* by creating an island in the sea environment. In the environment he created, the viewer can look around to see not only the king and his knights on the island, but the pirate ship as it is hit and sinks. Had he not done that, he would not have been able to see the entirety of the world in his story.

Similarly, Alex had to build the sports fields for his story, as there were no sports-related environments available. In building the field for each sport, he could better center the facts about each sport in his mind than without the fields.

CoSpaces provided opportunities for youth to feel as if they were in the world they were writing about. They could take in more than just a single point of view, but to see the world from multiple perspectives. This helped them to add depth to their writing.

Enhanced Creativity

Visualizing in CoSpaces stretched students' imaginations. They created characters that previously only lived in their minds. They came up with new ideas for their writing after creating their scenes. Sometimes, the limitations of CoSpaces forced them to be creative, which influenced their stories.

Several students' stories included characters that are not found in the real world. Sophia's antagonist was a dragon that could shapeshift into a woman. She coded her scenes in a way that the dragon appeared to shift between the two forms. This created a dynamic approach to visualizing her scene.

Meanwhile, Olivia stretched her imagination to include animals that do not look the same as they do in the real world. She changed the colors of her animals to match the animals she wrote about. For example, she changed the color of the horse to yellow to represent the banana horse. This provided Olivia an outlet for recreating her ideas before writing about them.

Mason, on the other hand, imagined Garry the Grape. There were no grapes available as an object in CoSpaces, but Mason could use a different item, an ellipsoid, to create a grape shape and to color it purple. This allowed him to use the character to create his scene in which Garry attacks a very large witch. Drawing a large grape would have been possible, but CoSpaces made it possible to use the character to interact with other characters.

As students created their CoSpaces scenes, they sometimes found new ideas to add to their writing. Quinn, for example, added rainbows to her scene because she felt they went with her purple giraffe and pink kangaroo. Morgan shared she thought of new scenes to add to her story because of the scenes she created in CoSpaces. Their writing evolved because they could see the story in CoSpaces.

CoSpaces provided a vehicle for students to express their creativity, and then to apply that creativity to their writing. Some of the creativity is possible through drawing, but the ease of creating in CoSpaces made it easier for youth to tap into their imaginations.

Ease of Iteration

During the drafting and revision stages of the writing process, a young writer may need to change their visualizations. Often, that means re-drawing what they have done. However, students using CoSpaces found that making changes was quicker and more intuitive than drawing. Every student made numerous changes to their scenes throughout the day while in camp. Many of these changes later influenced their writing.

One example of this is the changes students made each day to their scenes. The changes they made included adding new scenes or deleting scenes that had previously created and changing how a current scene looked or operated. In one observation, Mason deleted an object from his scene, stating that it didn't make sense. In seeing it in his scene, he could quickly determine that it did not fit with the rest of the scene and could quickly remove it, without it affecting anything else in his scene.

In another observation, Charlotte triumphantly exclaimed that she had figured out how to copy a template of a house into her scene. Previously she had been attempting to create a house using only building materials in CoSpaces, which was a laborious task. By copying the pre-created house, she could adapt it quickly to her needs, thus freeing up time to concentrate on the story.

Several students used CoSpaces as a form of drafting. For example, Caleb's first three scenes (see Figures 19 - 21) were all to help him decide the setting for the story he was writing.

In his interview, he said about his first scene, “So in scene one, this is not about my story, but it's good. It helps me because it has something to do with my story, like it's in the ice age like dinosaurs” (Interview, 7/14/23). Creating the scene helped him to visualize the scene in his story, even if it was not directly in his story.

Figure 19. Caleb's Scene 1

Figure 20. Caleb's Scene 2

Figure 21. Caleb's Scene 3

Likewise, Sophia used CoSpaces to test new ideas. In a focus group she stated, “When I go home and, like, explore, ... I can like [apply] physics or something. So, like tomorrow I can really use them, so I can like explain more better the story...” (7/14/23). For her, taking the time to try out physics would benefit her story in both her CoSpace and her writing. The CoSpaces platform made it easy to test some things to see if they would work. In the end, she did not use any physics in her scenes. The ease of making changes to scenes provided her an opportunity to try something that she may not have otherwise.

Many students created scenes that were seen in their work daily but did not make it to their final CoSpaces. Olivia and Harper both began creating scenes that they eventually deleted. Olivia began with a scene in which she was using blocks to make what she called a temple. She also had a priestess and animals in the scene. Although she worked on it for a few days, in the end, she deleted it and began creating what became her only scene with colorful animals, which aligned with her shared story. It’s unclear if she started over because she decided on a different story or if the issues, she was having resulted in her changing her story. Regardless, because of the ease of starting over, she could still create a new scene. Alternatively, Harper created at least two other scenes before deciding on her final scene. She was having trouble using the items available in CoSpaces to visualize her story, so she kept making new scenes until she found one that worked for her. Though she had to take the time to make those other scenes, it was very easy for her to start new scenes.

CoSpaces as a creation tool makes it easy to not only add, but delete items in the scene, to make changes to items or to the environment, or to start completely over when needed. This ability to make changes quickly and easily helped students to visualize efficiently.

Analyzing CoSpaces-Enhanced Visualization and its Impact on Writing

The youth were doing their writing in the mornings before our session. They were spread out among three different classes, and each class did things a little differently. They had notebooks for writing ideas down, but they were also writing online, either in Google Docs or in a story creation application. For this reason, we had limited access to their writing. We trusted the youth to use CoSpaces as intended: to visualize their writing.

At the end of the camp, the youth shared their writing with an audience of their peers and families. The writings that they shared were obtained to analyze how they used CoSpaces as a visualization tool. I also included in the analysis statements made by youth in focus groups, interviews, and observations about the use of CoSpaces to visualize their writing. This section explores the results of that analysis.

Deviations Between CoSpaces and Written Narratives

Youths' CoSpaces were not exact replicas of their writing. Many of them took liberties with their CoSpaces that they did not with their writing. For example, Morgan's CoSpace contains a scene in which she stands beside a brick wall holding her schedule. Her writing does not contain the details of her schedule, but it is discussed in her story.

Quinn and Liam both have scenes in their CoSpaces that are not in their writing. Quinn's first scene seems completely unrelated to her second scene, which is depicted to some degree in her writing. She may have had another story that her first scene represented, but that was not shared. Liam's first scene, on the other hand, was added to his CoSpaces after creating his second scene to explain why the knights and pirates are battling. He said in his interview that he did not include the first scene in his writing because it was not detailed enough. Though both youths omitted scenes from CoSpaces in their writing, the creation of these scenes helped them to think about where and how to add details to their writing.

Comparing Details in CoSpaces and Writing

Though there are some CoSpaces scenes that contain more detail than the youth's writing, most of the writing was more detailed. Though it is easy for youth to create, and re-create in CoSpaces, they seem to have used it as a springboard for adding depth to their writing. For example, in Caleb's writing, he details his character's journey after accidentally going through a portal to the past. His five CoSpaces scenes (ignoring the first three which were just to help him imagine the setting) show only the main ideas of the story. His writing, however, includes details about interactions with other people and animals. For example, in his notebook he wrote:

> he climbed up and ran he saw a portal but the wooly mamuth was bloking it it chaged it missd and whent strate into the watter [he] said by two the cave men and into the portal he apeard at the jungle and ran to his home

This scene is the final scene of his CoSpaces (see Figure 22). It shows only the man running towards the portal, which sits at the base of a snowy mountain area. CoSpaces seemed to merely help him to get an idea of the settings, and not to tell the whole story.

Figure 22. Caleb's Final Scene (Scene 8)

Similarly, Morgan’s scene in which she is in class is less detailed than her writing. In her writing, the teacher introduces himself, then calls on each student to introduce themselves. She writes about several students’ introductions. In her CoSpaces scene, however, only the teacher talks (see Figure 23). In her interview, Morgan explained that there are fewer students in her writing than in her CoSpaces scene. The creation of the classroom scene provided her with an idea of what it could look like, which she then translated into her writing adding and deleting details that fit her story.

Figure 23. Morgan's Classroom Scene

Alex was the only youth whose writing was non-fiction. It was entirely facts about sports. In CoSpaces, he created scenes for two of the five sports that he wrote about. He created scenes to showcase the playing field of each sport, and the sole character provided the facts about the sport. His writing of the three represented sports, however, included more information than his CoSpace. The creation of the CoSpaces helped him to picture the sport, and perhaps think of things to add to his writing, but he put much more details into his writing.

In comparing the created CoSpaces scenes and the corresponding writing, creating in CoSpaces helped the youth to see their stories differently but did not take away from their writing.

Theme 2 Summary

CoSpaces empowered students to visualize, create, and interact with their narratives in unique ways. It provided a platform for youth to engage in rich, immersive storytelling and world-building that breathed authenticity into the writing through coding and animations. Students saw their writing as if they were a part of it, allowing them to see it from multiple perspectives.

Additionally, it served as a catalyst for greater creativity, bringing life to characters and concepts that transcend the limitations of pen and paper. Digital visualization allowed students to see creative choices in their writing, without being locked into them. CoSpaces allowed for easy iterations, whether they were adding or deleting items, or adding new scenes. Students made quick and easy adjustments, experimented with new ideas, and ultimately refined their creative works with remarkable efficiency.

In examining the relationship between CoSpaces and students' writing, I discovered a fascinating dynamic. While CoSpaces offered students a versatile platform for visualization, it did not take the place of their written work. Instead, it complemented it, serving as a springboard for ideas and inspiration. Students saw not only the characters, objects, and scenes of the worlds they were building but also the dialogue and action of the scenes, creating an authentic learning experience.

Theme 3: Community of Learners

The youth strove for the "max of adventure" in creating their CoSpaces as visualizations of their writing. To get there, they had to learn how to use CoSpaces. This theme will explore how this community of learners worked together to learn and create, answering both research questions. It will detail how the youth engaged with learning in the class and how the instructors supported them. Additionally, the application of social constructivism in the session will be examined.

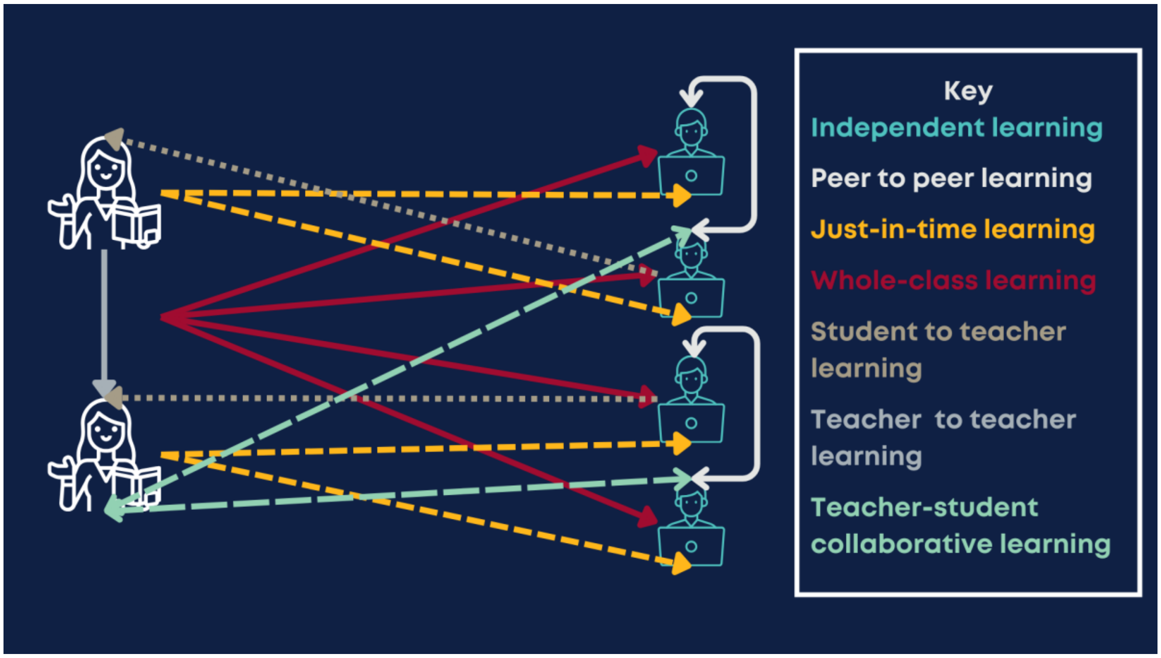
This was not a one-and-done type of learning; instead, it was a continuous process. Though they received instruction on using CoSpaces, they encountered problems which they had to solve. For some problems, this meant trial and error to make it work. Other problems required assistance from either peers or an instructor.

To solve problems, they took risks, using iteration to test their ideas. They applied creative solutions to problems, like using a purple ellipsoid to represent a giant grape in Mason's case. They tested new ideas or learn to use the tool, like applying physics in Samuel's case, in areas outside of their assignment, to decide to either include them or discard them.

Learning crossed the boundaries of the traditional teacher/student relationship. At times, the instructors took the role of student to learn from the youth. At other times, youth and instructor became partners in problem-solving. While the instructors provided guidance, they were not the primary method of learning. Much of the time, they were just observing, as youth interacted with each other to provide feedback and assistance to one another. Stacy described it well when she said, "They really had some creative ideas. And it even kind of like brought a sense of community together" (Interview, 9/8/23). As youth and instructors navigated the learning environment together, they came together in a "community of learners."

I will begin by discussing the various ways in which students learned, including independent learning, peer-to-peer learning, and teacher to student learning. Then, I will investigate the dynamics of teacher learning from both youth and the other instructor. Figure 24 provides a roadmap of learning in the classroom. Students and teachers interacted in dynamic ways to create an atmosphere that invited learning from various sources.

Figure 24. Learning in the Session



Student Learning

The learning environment was boisterous. Students narrated what they were doing and shared their feelings of excitement or frustration both physically and verbally. These exclamations frequently drew looks of those near them to see if they could see what was happening in their peer's scene. Frustrations were often met with cries of, "I'll show you how to do it!" Students moved around freely in the classroom, occasionally moving to see what others were doing and offering feedback. Occasionally, they called for me or Stacy to come help with a particularly challenging situation.

And yet, they were working consistently on their CoSpaces. In the first theme, "Max of Adventure", I noted when discussing the positive feelings about CoSpaces that they were so engaged they did not want to stop. Stacy described it as a "community built around this idea of designing a virtual reality" (Interview, 9/8/23).

Student learning happened on three planes: independent learning, peer-to-peer, and teacher to student. Independent learning happened as students worked on their assignment or through play and experimentation in "playground" areas of CoSpaces. Peer-to-peer learning was frequent among most students as they freely offered help and feedback to one another. There were, of course, times when it was necessary to get help from the instructors. The next sections will examine each of these modes of learning.

Independent Learning

Most of the time, students were working independently. They added items to their scenes, made changes and adjustments, and added coding. They would then play their scenes to see what they had done, and to see what needed to be changed. When things did not go right, they had to discover why and make the necessary modifications.

Iteration. Charlotte, for example, lost her main character when playing the scene after adding coding, as seen in observation notes:

> As Charlotte plays her scene to test her code, she realizes that her character has disappeared from the scene. She decides to turn the character to go in a different direction and replays it. When it succeeds, she exclaims, "Look, you can actually see me, now!" (Observational Field Note, 7/11/23)

In playing the scene, she could diagnose a problem, namely that her character was hidden when she played her code to make the character walk. In turning the character around, she was able to make the connection that the code to move a character forward depended upon the direction in which the character was looking.

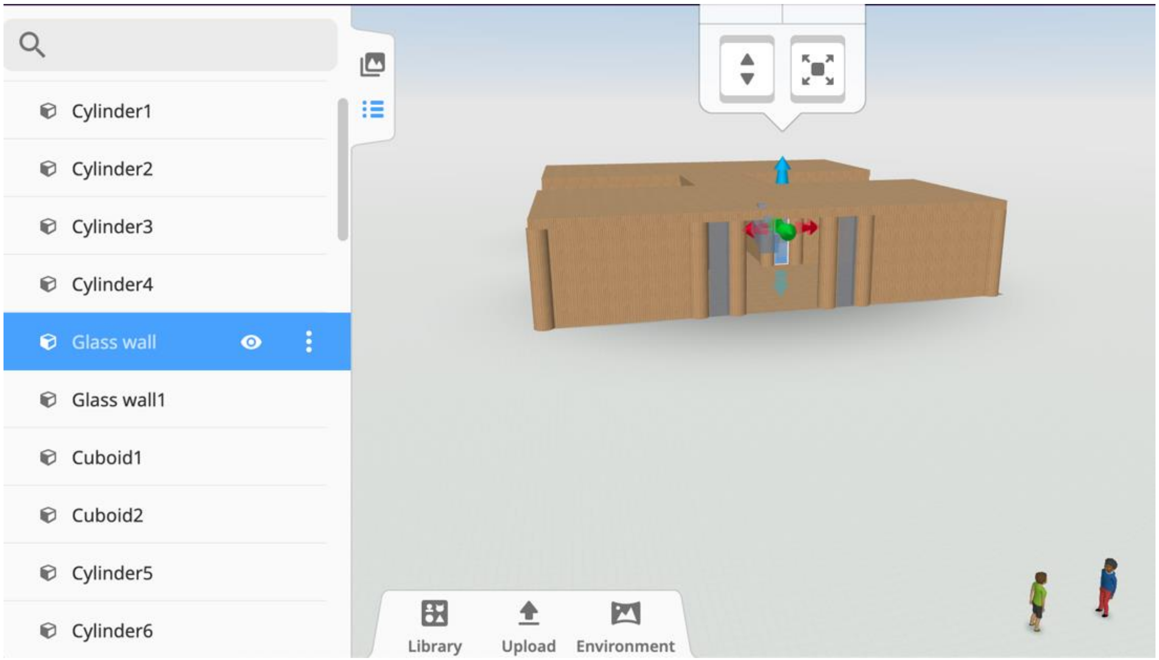
Similarly, Alex played his scene after adding each line of code to ensure it worked properly:

> Alex returns his attention to the coding in his own scene. He makes some changes, then plays his scene to test it... Alex stops the scene and makes an adjustment to the amount of time his last line is visible. He continues adding more code, playing the scene after each line of code is added to make sure that the character's speech bubble lasts long enough to be read. (Observational Field Note, 7/12/23)

In playing his scene after adding each line of coding, he's making incremental changes to his scene. With each line, he becomes more adept at coding, and better able to judge how long the speech bubble needs to be depending on the content than he was in the previous iteration.

Several students also learned how to make structures in CoSpaces. They used walls and other building materials to create buildings. Rather than use walls, Oliver used mostly shapes to create his museum, as seen in Figure 25. He then changed the color of them to match the marble walls, as described in his story. It was a very ingenious way of making the museum, and it was not explicitly taught to him.

Figure 25. Oliver's Museum Made of Shapes



Other students tried to build a house but decided that importing a pre-made house from a template was easier. They did, however, change the house. Sophia was one that did this quite seamlessly. It was noted in one observation of her: "[Sophia] duplicates a wall and moves it into place. She seems to be using the controls easily. She moves a wall with a doorway out of the way." (Observational Field Note, 7/12/23). Sophia quickly learned how to manipulate the materials to change her structure.

Playing to Learn. Although the students were expected to create their visualization in an assigned CoSpace, they also could work in a dedicated area for free play, called a "playground." Playgrounds allowed students to play with the features of CoSpaces without disturbing their assignment.

Some students used playgrounds to test features they considered adding to their assignment. Physics was a popular feature of CoSpaces that required some trial and error to get just right. For instance, in one playground, Samuel tested how gravity affected physics. The scene comprised only a girl and two text panels. It was coded so that when one of the text panels was clicked, the gravity pull was diminished by 100, which shot the girl up in the air. He tested different settings to see the effects. In testing in the playground, he was able to learn valuable information about how physics works in CoSpaces, so that he could apply it to his assignment scene.

Many students used templates or re-used CoSpaces created by others and shared in the gallery. Olivia, Liam, and Quinn all created dioramas. The dioramas contained four sections, which allowed students to create four different mini scenes. Olivia's diorama (Figure 26) included animals, many of which were animated, plants, and decorative objects. Creating in these templates allowed the youth to play with different combinations of items and animations.

Figure 26. Olivia's Diorama

Whether trying out physics and code or creating new scenes, the use of playgrounds afforded students a place to play with the features of CoSpaces away from their assignment. Rather than being off task, the playgrounds were a space to learn in a space where there were no expectations for their creations.

There were ample opportunities for the youth to learn while using CoSpaces. Throughout the camp, they learned how to use the various features of CoSpaces, both while creating their visualizations and while playing. They consistently made changes to their scenes after trying them out, working to get them to a place that told the story they wanted to tell. In the exploration of the “community of learners” theme, I next examine how students actively supported one another throughout their learning experiences.

Learning from Peers

During a focus group while students were sharing what did not go well, I asked students why it's important to share those things. The responses from Quinn and Sophia perfectly summed up the shared ethos of the group:

> Quinn: Um, so if you share with each other, it helps other people like know what you have, what you are good at and what you are not good at.
>
> Sophia: Yes, like maybe like when we share it, others can think that, like, "Oh, I can maybe help her, because I know that." And maybe that person can think that "Oh, maybe that person can add something about what they say so that they can help." (Focus Group, 7/12/23)

This was not just something they said, they put that way of thinking into practice over and over.

As noted previously, the youth did not just sit and work at their own computer screens. They frequently looked at the screens of those sitting near them, whether out of their own curiosity or because they were asked to look at something. They sat in rows, with most in groups of two to five students, making collaboration between those in rows easy. Youth were also encouraged to move around the computer lab to examine others' work. This environment set the tone for youth to help each other, rather than relying on the instructors.

Youth provided feedback to each other regularly. This was especially true for those sitting near them. One row in the lab had five students all sitting together. These students frequently provided feedback to each other, enhancing self-reflection to improve student work. For example, Alex had gone to the next seat over to look at Mason's scene when he noticed another peer on the other side of Mason.

> While playing Mason's scene, Alex looks over at Morgan's screen as she uploads a picture of a school. Alex says to Morgan, "It looks way too fancy to be [that school]."

Morgan goes back to looking for pictures and uploads a new one. She asks, “[Alex], how’s this?” Alex, back at his own desk, looks back at her scene. “That’s better.” (Observational Field Note, 7/12/23)

Because Alex had knowledge of the school in question, he could provide valuable feedback to Morgan, who wanted a realistic scene.

During a break in creating his own scene, Liam wandered down the row to Mason’s computer. Mason told Liam he wanted to change a scene that contained fire to a water scene, but he said it would not make sense, as the water would put out the fire. Liam responded it was okay because it’s fiction, so he could do it if he wanted. This provided Mason with another viewpoint as he changed his scene.

Sophia, Charlotte, and one other peer sat in a group of three and frequently provided feedback to each other, as well. At one point, Sophia asked Charlotte if she wanted to try her game in her playground, which Charlotte happily obliged. While playing the game, Charlotte showed her excitement, providing feedback that the game was enjoyable. Sophia was able to judge the difficulty and enjoyment of her game, and thus make changes based on this feedback.

Youth also helped each other freely. Samuel, as one of the two students who had used CoSpaces before, frequently offered to help his peers. Hearing that someone needed help, he would jump up and go to assist them. He was very fond of physics and coding. One day, he spent at least ten minutes helping Liam to code his pirates to fall down when the knights attacked them. Liam later applied this new knowledge of physics and coding to his water battle scene when the pirates were blown off the ship after it was hit with cannonballs. Samuel’s assistance helped Liam to create more dynamic scenes than scenes with little or no coding.

Similarly, Benjamin and Caleb sat together and sometimes relied on one another for help. Working on coding, Caleb leaned over to Benjamin to ask how to scroll through to find different codes, which Benjamin happily helped with. This ability to ask his peer sitting next to him eliminated the need to ask an instructor or to spend unnecessary time figuring it out himself.

Sophia also shared in a focus group how she and Charlotte helped each other:

> Actually, like it was kind of to both. [Charlotte] helped me like something of coding. Like, just opening the doors and something like that. Because I really wanted to go up also about the stairs. It was really cool too. And then like, I also helped her just like to give some ideas to her too. (Focus Group, 7/20/23)

She further stated that they helped each other frequently. Their proximity allowed them to help one another quickly without taking away time from their own creations.

Overall, the youth participants created a culture of sharing and learning from one another, as evidenced by Quinn and Sophia's insights into the importance of sharing successes and struggles. Collaboration was encouraged by the set-up of the lab and organization of students, as well as by instructors' guidance on moving around and exploring the work of others. This led to a spirit of mutual help and learning, reducing reliance on instructors. The collaborative learning environment allowed students to develop their CoSpaces skills and further their ability to represent their writing visually.

As I have explored the culture of collaboration and mutual support among the students within our "community of learners," it is equally important to delve into the pivotal role played by instructors in nurturing this environment. In the following section, I will examine the ways in which instructors provided guidance and assistance to complement the peer interactions, fostering a holistic and enriching learning experience.

Teacher to Student Learning

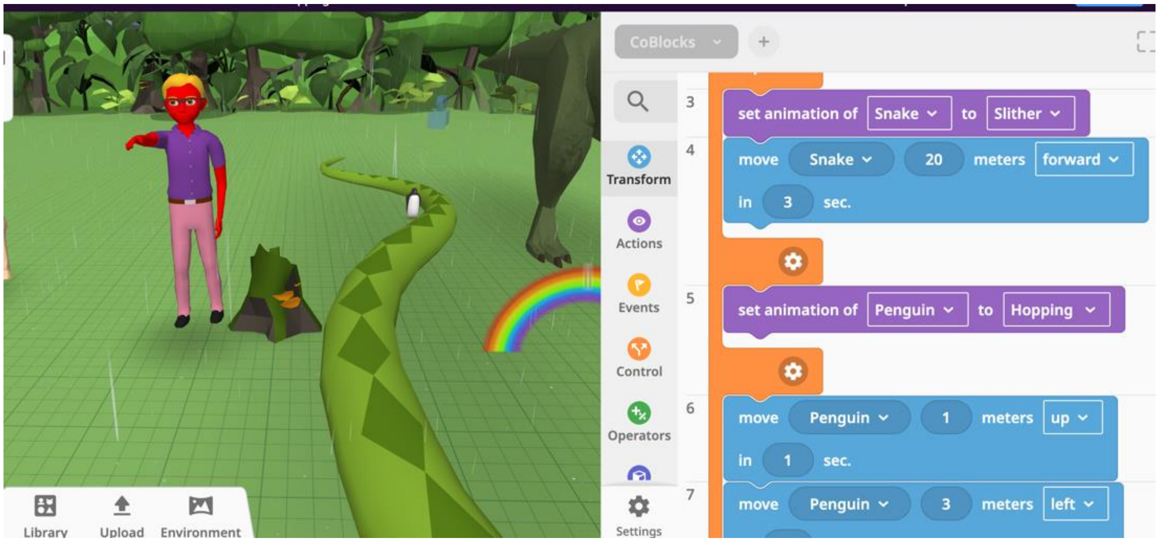
Although the youth did a lot of learning on their own, the instructors were not irrelevant. They provided both formal lessons and just-in-time learning as needed for youth.

Formal Lessons. On the first day of the study, I provided an overview of creating in CoSpaces. This overview included an example of a created CoSpace that included multiple scenes, animations, and coding. I also showed how to do the basic operations of creating: selecting an environment and working with items: adding, moving using controls, customizing, and animating. Students needed this introductory information to get started with creating their scenes.

Toward the end of the second day, students were ready to begin coding, so I did a lesson on coding. I showed them how to enable coding on items and how to choose CoBlocks as their coding editor. As mentioned previously, CoBlocks is a drag-and-drop visual programming language. I reviewed the CoBlocks most likely to be used, such as changing the animation and moving items. I further explained how to nest CoBlocks to allow events to happen simultaneously. This lesson provided the fundamentals of coding, so that students could begin to explore coding on their own. Figure 27 shows the created scene and the coding of that lesson.

Stacy also did a formal lesson on visualization with CoSpaces. Together, she and the students created a very short story which was written on the board. She then put them in groups of two to three, and they worked together on an assignment in CoSpaces to visualize the story. Afterward, we reviewed each groups' visualization and discussed the different ways that their visualizations could impact the story.

Figure 27. Coding Lesson



These formal lessons helped to prepare students for the basics of creating in CoSpaces, coding, and visualizing their stories with CoSpaces. They set the stage for the expectations of the session. The formal lessons were for all students, and were presented strategically, when each would have the most impact for the majority of students.

Just-in-Time Learning. While the formal lessons were geared toward the whole class, just-in-time lessons were provided for individual students as they were needed. These lessons were individualized based on the problem that the youth had encountered. Students would engage the instructors when they had tried to solve the problem but could not. These problems were usually related to using the controls while creating in CoSpaces, or when coding their scenes.

Understanding to Use CoSpaces Controls. CoSpaces controls were used to do a variety of tasks and applied to items added. When a student added an item, they may need to move it, resize it, or rotate it. There are also ways to customize their items, such as changing colors or adding animation or speech. Students having trouble with these controls would sometimes request help from the instructors. For example, Benjamin had wanted to have a father looking down at his baby say, “I love you.” He was able to apply the speech, but he applied it to a horse, rather than the man. After trying to make the speech bubble go away for several minutes, he finally asked me for help. I was able to show him how to delete the text in the speech bubble, effectively making it go away. As that was not a problem that anyone around him had had before, they could not help him, necessitating the need to get help from an instructor.

Morgan also had a problem that no one around her had been able to solve. She wanted to have backpacks on the backs of her characters. However, she could not get them placed quite right. Liam even tried to help her, as demonstrated in the last section. I overheard her question and taught her to attach the backpack to the character, so that it became one. Liam then used that same technique to attach his knights to horses. This instruction helped both students to make their scenes more realistic, with the items actually appearing as one item rather than items close to one another.

Conversely, Quinn kept picking up objects she did not intend to. While working on creating a house, she would duplicate walls. The new wall appeared next to the original wall. However, when she went to move the new wall, she accidentally grabbed the original wall, moving it out of place. I showed her how to lock down objects that she doesn’t want to move, which made her building much easier. Without that knowledge, she likely would have continued to get frustrated with her scene.

The controls in CoSpaces create the most basic of actions. When students struggle with those actions, they become frustrated, and may not want to continue. Having someone in the session available to assist with this needed help reduces frustrations.

Coding Help. Students requested assistance with coding the most. Some students had previous experience with coding, while it was brand new to others. Regardless of previous experience, students requested assistance with coding more than for anything else. One example is how Caleb and Quinn both received help in moving their characters. In one observation, Caleb asks Stacy how to move an animal forward. She showed him the transform block. After enabling it, he was able to adjust his code get it to move the distance and speed that he wanted. Similarly, Stacy helped Quinn to move her animals. She stated in a focus group (7/20/23), "Miss [Stacy] helped me to code my giraffe and kangaroo to move at the same time." Both students used what they learned from Stacy in other scenes. Stacy's guidance helped them to create the same coding later in their stories.

Stacy also helped students with complex coding. Samuel received help with a code that would make a cannon shoot a ball out at regular intervals but was not working as he had planned.

> Miss Stacy helped me. I was trying to make cannons that threw balls at you. And then the balls went like they were going every which way. So, I had to, like, get them to go straight at you. And it turns out I had ... not put a variable in there, so that's why the balls weren't going the way I want. (Focus Group, 7/12/23)

Stacy helped him to look carefully at his code for errors, in order to work out why it was not performing as expected.

Similarly, she helped Liam find errors in his numerous lines of code. They noticed that one his soldiers was going just slightly further than the rest of the soldiers. She states it was with my prompting that they realized they needed to go all the way back to the beginning of the coding to check, "remembering that the codes build off of each other" (Interview, 9/8/23). Liam may have been able to find the error on his own, but the sheer number of codes made it seem overwhelming. The help of Stacy, and the prompting from me, made it much more manageable.

Benjamin, on the other hand, had a request that was unique from everyone else. He wanted to have audio of his night saying, "I love you." I showed him how to record the sound and code it so that it would play when he wanted. He ended up not using it, but he probably would not have even tried it without someone to show him how to do it.

Students employed a variety of methods of learning in creating their CoSpaces. Although they picked up creating in CoSpaces with remarkable speed, there were still things that required a little more training. Students reached out to the adults in the room when they could not solve problems themselves. To give youth a baseline to use CoSpaces, instructors provided formal lessons on generally using CoSpaces, using CoSpaces to visualize a story, and applying coding to their CoSpaces. From there, students jumped in and learned independently. When that did not work, they looked to their peers or to the instructors for help.

Teacher-Student Learning Dynamics

Students were not the only ones learning in the session. While doing the lesson on coding, I suddenly got stuck. I was trying to get a penguin out of the way of a snake as it slithered past. I could not understand how to make the penguin move the way we needed it to. Samuel exclaimed, “I know what to do!” He came up to the front of the room and began working with the code. He quickly solved the problem that I could not seem to solve in the moment.

This exchange exemplified the reciprocal nature of learning in the session. Stacy and I led the session, but we did not set ourselves up as the holders of all the knowledge. Our shared willingness to learn alongside the youth contributed to the overall learning environment by placing us as co-learners. Stacy shared in her interview several experiences she had in which she helped students more as a partner in problem solving than a teacher with the answer. For example, in the previous section, I described a time that Stacy helped Liam with his coding. One of his soldiers kept moving ahead of the others. They looked at the coding together to find the error. She could have just told him to look through the code, but she admitted she was not sure why it was happening and worked through the problem with him.

Conversely, there was a time she did not have as much luck helping Benjamin. He wanted to make his horse run and then the scene would change. After looking for a few minutes with him, she had to concede that she did not know how to do it and encouraged him to ask a peer. By taking the role of a partner, she yielded the role of the expert, and therefore could admit when she did not know something. In fact, she explained, "I very much put myself in the place of a student the first week so that I could learn the moves and how to work ... everything" (Interview, 9/8/23). She knew that the second week I would not be in the session to help with issues, so she needed to be able to help.

In order to prepare herself, she did not hesitate to show students she did not have all the answers. If someone did something that she did not know how to do, she would ask them how they did it. She felt it was an important way to approach learning, to "learn and grow together" (Stacy, Interview, 9/8/23). This attitude contributed to the community of learners, by including not just the youths, but the adults, as well.

Stacy also reported that she would watch what I did, as someone with more experience with CoSpaces, to know what to do: "So, I tried, if they had a question, I tried to get them to ask you the question, so I could hear your answer or watch you model what to do" (Interview, 9/8/23). She looked to me much in the same way that the youth looked to both of us–as a mentor.

Of course, it is not always possible to have someone else in the room who knows more, so teachers need to be able to use the tools themselves. Stacy had had minimal experience with CoSpaces the previous summer, mostly in observing what youth created. She stated she learned more this year than she did last year. As she worked with students to help create their CoSpaces, she learned how to use the tool more efficiently. She could answer questions and help students through problems more often than the previous year. Clearly, a more hands-on approach was beneficial, providing an increased familiarity with CoSpaces and the ability to anticipate student questions.

When asked if it would have helped to have created her own CoSpace before the session, she responded:

> I think it could have made a little bit of a difference; I think. I think maybe it would have made me more familiar with some of the things that it can do. Or it would have allowed me to kind of think through it and come up with some questions to maybe ask you, like, “Hey, I wanted to do this. How do I do it?” And you could have shown me and then I could have been like, “oh,” and then maybe use mine as a reference to help as well. Which is what our kids started doing. And then the ones that you helped do things I would use your guide. So, yes, maybe if I had created my own it might have been better. (Stacy, Interview, 9/8/23)

Had she created her own, either before or during the session, she would have had more experience, and would have relied less on learning from me. This prior experience enhances the teacher’s ability to support students.

The role of the teacher in this VR learning environment was very much one of a co-learner. Stacy’s experiences exemplify the dynamic nature of learning, where the role of the teacher can vacillate between the role of a guide and that of a student. Stacy, as a relative novice in regard to CoSpaces, took on the role of student and partner while learning how to use it, so that she could then later apply this knowledge to help students at the later stages of creation. This approach nurtured a vibrant community of learners where knowledge was collaboratively constructed and shared.

Theme 3 Summary

This theme has explored how the dynamic learning relationships created a community of learners. The creation of CoSpaces generated natural opportunities for youth and adult alike to learn through interactions with others. Students and teachers each took the role of both novice and mentor at varying times, creating a shift in the traditional role of who holds the knowledge. The active computer lab belied the idea of a quiet classroom. At any time, a visitor might see youth working independently, while others have crossed the room to view a peer's creation. At the same time, youth are helping one another and getting help from instructors. This community of learners was one in which learning was varied and shared.

Chapter Summary

This chapter discussed how students engaged with CoSpaces to visualize their writing through VR creation and how they were supported in their creations. Three themes emerged from the data. Students aimed to find the "max of adventure" by creating CoSpaces scenes that included a chosen environment, characters, objects, and strategic placement of cameras. They built the world of their writings by adding items to the scene, and at times using creative building techniques and importing templates for faster building. They then brought their stories to life with animation and coding to make characters move and speak. The creation of CoSpaces created a sense of adventure mediated by the social interactions with peers and teachers. This creation and social interaction provided a platform for authentic, hands-on, collaborative learning.

The enactment of visualization was improved in the 3D environments through the interactions of the characters and the environment with interactive storytelling, the building of rich worlds, stretching their imaginations through enhanced creativity, and the ease with which changes were made. Comparisons showed that their VR visualizations complemented their written stories, rather than provided a direct representation of the writing. This rich visualization gave students an immersive, interactive view of their writing, allowing them to see their writing from multiple perspectives, and adjusting it accordingly.

A community of learners was created in the session, with learning happening independently and interdependently. The youth learned independently through the iteration of creation and learning through the play of creation outside of the assignment. Peer to peer assistance and feedback was continual and natural in the setting. Teacher to student lessons included formal, whole-class lessons on creating in CoSpaces, coding, and visualization, as well as just-in-time learning. In the setting, youth even provided some help to teachers at times, as they learned to do new things in CoSpaces. The dynamic, collaborative learning environment shifted the roles of the teacher and student at times, allowing each to experience as the other. Problem-solving was no longer an independent endeavor, but one in which others could help find solutions.

The next chapter will discuss the implications of these findings as they relate to the research questions and the theoretical framework.

CHAPTER V: DISCUSSSION

Though Virtual Reality (VR) has become a popular medium for gameplay and exploration, little research has been done to examine how students can create their own VR scenes. The majority of research on the subject has been focused on higher education. The creation of virtual reality (VR) in a digital makerspace, a space in which individuals use digital tools to design and create, offers a potent educational experience. It transforms students from mere receivers of information into active creators of knowledge, enriching their learning journey.

This study, therefore, set out to examine and explain the processes with which students in grades three through five create virtual reality visualizations of their writing and the teacher supports necessary. The research questions that guided this study were: How do elementary-aged youth engage with a virtual reality tool to create a virtual reality environment to visualize their writing? and What technological and pedagogical supports do teachers provide to guide youths in the creation of a VR environment.

The case study focused on a two-week half-day summer camp session, with thirteen students, a teacher participant, and me as a participant researcher. Through observations, interviews, and participant artifacts, the study examined the interactions among students, teachers, and technology, all geared towards fostering an educational experience. This comprehensive examination highlighted the dynamic interplay between students, their instructors, and the technological tools used, emphasizing the central role of these interactions in the learning process.

Analysis of the data found three key themes. The first, Max of Adventure, explored how the youth interacted with CoSpaces to create their scenes and their satisfaction with creating VR. The second theme, Transforming Writing with CoSpaces, examined the effectiveness of

CoSpaces to visualize their writing. Finally, the third theme, Community of Learners, considered the culture of learning in the session for independent learning, peer-to-peer learning, and the teacher-student dynamic.

This chapter seeks to explore the implications of the findings in this study. I begin by examining the findings in the context of the conceptual framework. Afterwards, I will discuss the limitations of the study. Finally, I will provide recommendations for future study.

Interpretation of the Findings

VR Creation Through the Lens of Social Constructivism

Social constructivism posits that learning occurs when the learner actively builds their understanding through authentic or contextual learning activities and interactions with their peers and those with more knowledge. In this study, students created VR scenes in CoSpaces to visualize their writing. Though a novel way to visualize, VR creation served as an authentic method of seeing their writing represented in images. Through hands-on creation of VR scenes, the youth learned to use the tool and to visualize their writing. The class was a true learning community, as learning was multi-faceted, encompassing independent learning, peer-to-peer learning, teacher-directed learning, and student-to-teacher learning. This interactivity helped students to solve problems and think critically through differing perspectives, an essential component of constructing new knowledge.

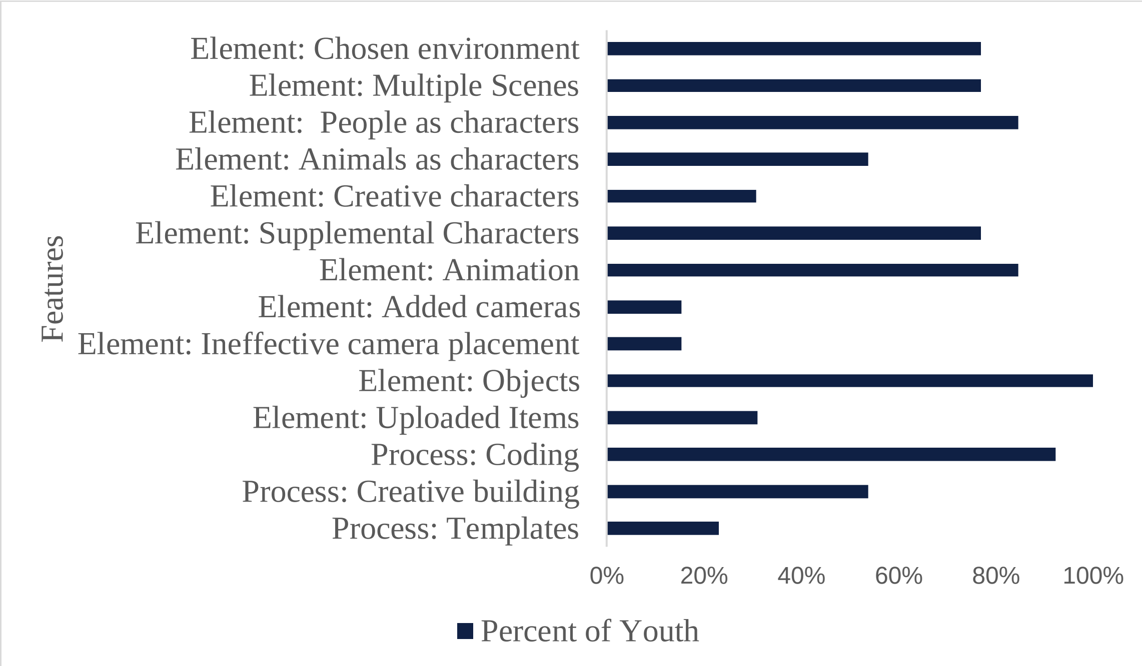
The aim of this section is to discuss how the findings relate to social constructivism. I begin by exploring the authentic, hands-on learning in the session. Next, I will discuss the social interaction and collaboration that occurred, a key component of social constructivism, in the session. Finally, I will review how learners applied problem-solving and critical thinking in their creations.

Authentic, Hands-on Learning

One of the key components of social constructivism is the collaborative and interactive construction of knowledge by learner (Applefield et al., 2001; Damico, 2019). Participants in this study, both youth and adults, actively engaged in learning activities and gained knowledge as a result.

The creation of CoSpaces required that students create and manipulate the elements of their scenes. Through adding elements, moving and customizing them, and providing interactive animations and coding to the scenes, students learned the basics of creating a CoSpaces scene. One example was Charlotte replacing a plain wall with one with a door in the house she was building. Another example is Morgan’s customization of the characters in her scene to represent herself and her friends. Similarly, Stacy learned to use CoSpaces by helping the youth to work through problems with their scenes. Figure 28 shows the features of CoSpaces used by the youth in their final scenes. The mere act of creating was a constant learning process as they learned what was possible in CoSpaces.

Figure 28. Final CoSpaces Features



The youth were also learning to visualize through the creation of their scenes in CoSpaces. Visualization helps students to see the ideas before, during, and after writing (Dinkins, 2007). They often discussed how the creation of their CoSpaces impacted their morning writing. Their creations enabled them to picture not only the settings of their writing, but the interactions of characters, and occasionally objects, in the story. They also added new ideas and details to their stories as a result of creating their CoSpaces. Caleb created three different scenes to represent possible settings for his story before deciding on one to add to his writing. The creation of the CoSpaces scenes to visualize helped the youth to make the connection between seeing the idea and writing about it.

Learning was different for everyone. While most of the students had never experienced CoSpaces before, two had used it previously, and thus needed less help in creating their CoSpaces scenes. Likewise, several of the students had done block-based coding before, so they needed less instruction and help with using CoBlocks. A lesson on coding provided a baseline for those new to coding, while just-in-time lessons guided learners with specific help, such as when Benjamin wanted to make the father in one of his scenes say, “I love you.” At times, the instructors worked collaboratively with students to find problems, especially in codes. The instructors were able to meet the students where they were on their learning journey, thus accessing their “Zone of Proximal Development” (Schunk, 2020; Vygotsky & Cole, 1978).

The hands-on nature of CoSpaces was an ideal setting for social constructivist learning. Whether learning to use CoSpaces or to visualize their writing through CoSpaces, the camp provided opportunities for the youth, and instructors, to learn with the right amount of assistance.

Social Interaction and Collaboration

Vygotsky emphasized the social nature of learning (Damico, 2019; Hoadley, 2011; Vygotsky & Cole, 1978). He believed that learning was not solely an individual construct, but that it required interaction among the learner, peers, and those who are more knowledgeable. The youth and adults in this session demonstrated this type of learning community.

The atmosphere of the session was one of a community of learners, as demonstrated in Theme 3. Peer assistance and feedback was not something that required intervention from the adults in the session; we actively encouraged interaction in the session. The youth frequently reviewed their peers’ work, provided feedback, and assisted one another. In one observation of five youth sitting in a row, I frequently observed them not only looking at each other’s work but providing feedback on their scenes and providing help when needed. This culture of helping was aided not only by the proximity of the students to one another, but by the freedom afforded them by the instructors to move around and talk as needed.

As students became familiar with using CoSpaces, they began to move from the role of novice to a more knowledgeable position in which they could then impart their expertise. Lave

(1996) called this a “community of practice”. At times during the camp, the youth took the role of the expert with the instructors as the learners, such as during a formal lesson on coding in which I was having difficulty getting my code right. Samuel, having had previous experience with CoSpaces, was eager to share his knowledge.

This reciprocal teaching created a learning environment in which students felt free to not only ask questions but to answer them, as well. During focus groups, students frequently shared their successes, challenges, and solutions. All considered this sharing to be a part of the learning process. For example, when one student shared their struggle to make something happen in their CoSpaces scene, others, upon hearing the solution, could apply that solution.

Not all problems were solved by others. Often, this was a last resort. Instead, the youth worked through problems independently. This resulted in some unique solutions to problems, such as using an ellipsoid turned purple to represent a grape. In the next section, I will describe how students engaged in problem solving.

Problem Solving and Critical Thinking

As learners solve problems, they add to their knowledge (Applefield et al., 2001; Damico, 2019; Hoadley, 2011; Schunk, 2020). Thus, being able to think critically and solve problems are important in a social constructivist classroom. Learners in this study encountered problems as they learned to use CoSpaces and with the limitations of CoSpaces itself. They solved these problems in different ways, depending upon the nature of the problem.

Students frequently encountered problems while creating. Manipulating objects in CoSpaces could be tricky, especially when first learning to use it. The youth had to learn to not only add items to their scenes, but to resize them, move them, and customize them. In addition, they often had to look at how items interacted with one another. For example, putting a soldier on a horse or a backpack on a character required the understanding of how to attach the items so that they worked together.

Other problems related to the limitations of CoSpaces. The CoSpaces item library is, while fairly large, not limitless. Several students experienced problems with finding the right items. Mason, for example, needed to visualize a giant grape from his writing. However, there was no grape in the CoSpaces library, so he used an ellipsoid and changed the color to purple. Morgan needed to represent her school but didn't see an item in the library that she liked, so she uploaded a picture of her school. On the other hand, Harper found that CoSpaces didn't have anything that represented a microcosm for her story, so she created her own atom made of rocks and clouds joined together into a circle. Each of these students exhibited different ways to address the problem, but they all applied critical thinking to solve it. Schunk (2020) describes critical thinking as "deeper thinking" (p. 285). The learners in this study had to not only solve the problem, but to apply a deeper level of thinking in order to come up with solutions.

How students solved problems was contingent on the problem itself. When trying to understand the functionality of CoSpaces, they frequently began with independent trial and error, but moved on to getting help from peers or instructors if they couldn't figure it out alone. The limitations of CoSpaces usually required the youth to be creative by building solutions with the items available. For example, CoSpaces didn't have a lake or pond as an item to be added to a scene, but several youths used a flat circle to represent these bodies of water. Less frequently, students abandoned their ideas, deciding instead to use their time elsewhere in their creations. This was the case with Charlotte, as she realized that building an entire house would take up too much time, and instead she could better use her time by adding characters and coding. Therefore, she decided instead to use a house template copied into her scene.

By solving these problems in the camp session, the youth demonstrated their ability to think outside of the box to find solutions. The social constructivist nature of the camp classroom lent itself to promoting the youth's problem-solving abilities. In any situation, a person may need to know when to get help and when to think outside the box. The social constructivist classroom prepares students to do just that.

Summary

The camp session represented a social constructivist classroom. The hands-on learning experience provide opportunities for learners to work directly with a tool, CoSpaces, to visualize their writing. Learning looked different for each learner, based on their needs, which changed throughout the camp. As students interacted with others in the session, they moved from novice to experienced, and shared their knowledge with others in the camp. Some even expressed the desire to share their knowledge with younger siblings. In addition to learning from peers and instructors, the youth engaged in problem-solving and critical thinking, thus adding to their bank of knowledge. Participants in this study, both youth and adults, actively engaged in learning activities that not only facilitated individual knowledge acquisition but also emphasized the importance of social interactions. Through shared experiences, collaborative tasks, and group discussions, participants collectively constructed knowledge.

Educational Technology

Educational technology has the potential to shape learning in positive ways. The National Education Technology Plan (US Department of Education, 2017) stated that educational technology can remake the way we teach and learn. Indeed, this study has shown a way to rethink how students can be supported with visualization beyond traditional methods. Using CoSpaces to visualize student writing is a promising method for doing so and had several benefits.

First, the youth were not only able to see the world that they were creating, but to be immersed in it. CoSpaces provides a 360° 3D environment in which the creator can imagine they are in the middle of the story. As a result, they were able to see the setting for the story, the characters, and other objects from a perspective not possible in a one-dimensional drawing. The immersion and coding actions also enabled them to show interactions between characters and objects. This brought the story to life for the youth, providing a glimpse of what they want it to look like. This supports the findings of Smith (2018) that spatial skills are improved when using 3D. VR creation through CoSpaces empowered the young writers with an innovative form of visualization, fostering immersion and interactivity.

Second, the digital format of CoSpaces made it easy for students to change their scenes, similar to what Blikstein (2013) found in his study of students using technology to visualize. Students were able to try out things, including whole settings for their writing, to see what worked best. Harper was one youth that created multiple iterations of her scene to try out possible settings. While starting over was an option, it wasn't always necessary, as students could make changes quickly and easily. When they started a scene over, the item library made adding items to the scene nearly effortless.

Just as Edwards et al. (2021) found, the ease of iteration enhanced the creativity of the youth. They frequently took chances in their creations. For example, Mason, when creating his giant grape character, Garry the Grape, began by using a cloud customized to purple before deciding to use an ellipsoid, instead. This extended to both items in their scenes and whole scenes. Caleb created three very different scenes to help him visualize possibilities for the setting in his writing. Creativity is one of the Learning and Innovation 4Cs represented in the *Framework for 21st Century Learning* (Battelle for Kids, 2019).

Third, the use of CoSpaces to visualize their scenes was appealing to students, thus increasing engagement. The youth were so enthralled in their creations that they often didn't want to stop for breaks, or even for the day. It was not uncommon to see students using gestures to show their excitement or to hear exclamations of triumph, like Quinn stating, "Perfect!" (Observation, 7/12/23) when changing the texture and color of walls in her scene. They also frequently expressed pride in their work during focus groups. This supports the findings of the 2022 Project Tomorrow Speak Up (Project Tomorrow & Spectrum Enterprises, 2022) survey, which found that investments in technology increase student engagement.

Additionally, the youth expressed that visualizing their scenes in CoSpaces helped them to better understand what to write. This application of the technology also supports the reports from students in the Project Tomorrow Speak Up (Project Tomorrow & Spectrum Enterprises, 2022) survey that technology helps them academically. In CoSpaces, they were able to easily add details, use items creatively, represent their setting, and create interactive stories that helped them to better see their writing. Almost all students reported that visualizing in CoSpaces helped them to "see the story", add details, and come up with new ideas. Morgan, for example, found that she came up with new scenes to add to her story because of visualizing with CoSpaces. Students like Morgan not only enhanced their writing with rich detail but also cultivated a deeper engagement with their creative process. This interactive and visual approach appears to bridge the gap between initial concept and final draft, allowing students to explore and expand their stories.

This study demonstrates the transformative potential of educational technology. The use of CoSpaces immersed the students in their visualizations, allowing them to understand what to write. The ease with which students could change their scenes afforded opportunities for creativity that may not have been taken if utilizing drawing to visualize. The affordances of

CoSpaces led to increased engagement and pride in their work. Students' enthusiastic responses underscore the effectiveness of integrating such technologies in the classroom, suggesting that when educational tools are thoughtfully applied, they can unlock new potentials in learning and storytelling, ultimately equipping students with the skills necessary to thrive in an increasingly complex and technology-driven world.

Digital Makerspace

The computer lab became a digital makerspace, as the youth created using the digital tool CoSpaces. Though the space was not created as a makerspace, nor intended for those activities while the camp was in session, it was filled with the features of a digital makerspace. This section will explore the ways in which it fits the definition of a digital makerspace.

Though makerspaces can look very different from one to the other, certain features are expected. For one, makerspaces are centers for learning (Halverson & Sheridan, 2014; Harron & Hughes, 2018; Marsh et al., 2019; K. M. Sheridan et al., 2013). Second, makerspaces typically allow for choice, though the extent of choice can vary depending on the purpose of the makerspace (Harron & Hughes, 2018). Third, ideally, makerspaces make efforts to be inclusive and accessible to as many makers as possible (Buchholz et al., 2014; Calabrese Barton & Tan, 2018; Halverson & Sheridan, 2014; Harron & Hughes, 2018).

In the following sections, I will explore how our digital makerspace aligned with the criteria stated above. I will then discuss the advantages of our digital makerspace.

Learning in the Makerspace

First and foremost, participants had to learn how to use CoSpaces. This included the basics of adding items and customizing them, as well as how to use items in the CoSpaces library to represent items that were not available. For example, Olivia and Caleb both used flat blue circles to represent a lake in their scenes. Some went a bit further by adding or strategically placing cameras, which affected what viewers saw. One example of this is Oliver's added camera, strategically placed to show a bear being attacked by a lion. Additionally, students learned to code using the block programming tool, CoBlocks. CoBlocks allowed the learners to add movement, speech, and more to their scenes. Sophia coded her scene to make her main character change from a woman to a dragon. This learning was essential for creating their scenes.

Additionally, students learned to visualize their writing in CoSpaces. Visualization was the primary goal of the session, so they needed to make the connections between their CoSpaces scenes and their writing. In evidence of this knowledge, the youth frequently discussed ways that their writing was changing as a result of their visualization. They added details, gathered new ideas, and found that they had a better vision of their writing after creating their CoSpaces scenes, all goals of visualization (Bomer et al., 2010; Jurand, 2008).

Student learning occurred through formal lessons, informal learning, and collaborative learning experiences. We only conducted three formal lessons in our makerspace: how to use CoSpaces, how to code, and visualizing with CoSpaces. Informal learning, an important part of many makerspaces (Halverson & Sheridan, 2014; Harron & Hughes, 2018; Hira & Hynes, 2018; Marsh et al., 2019; K. Sheridan et al., 2014), included tinkering in CoSpaces and just-in-time lessons. Several students tested how to use physics in playgrounds. This type of tinkering is seen in many makerspaces, as makers learn through hands-on activities (Halverson & Sheridan, 2014; Harron & Hughes, 2018; Marsh et al., 2019; K. Sheridan et al., 2014). Others received help from Stacy and me for a variety of issues, like how to lock items in their scene so students didn't pick them up accidentally, or, more often, coding. Collaborative learning, another significant part of many makerspaces, (Buchholz et al., 2014; Frydenberg & Andone, 2021; Halverson & Sheridan, 2014; Hira & Hynes, 2018; Kajamaa et al., 2020; Marsh et al., 2019; Martin et al., 2018; K. Sheridan et al., 2014; K. M. Sheridan et al., 2013) occurred frequently as learners helped their peers as problems arose. Samuel, who was more experienced with CoSpaces than most others, happily provided instruction for peers. These modes of learning are frequently seen in conjunction in educational makerspaces.

Choice in the Makerspace

Another common feature of makerspaces is choice (Harron & Hughes, 2018). Like the educational makerspaces reviewed by Buchholz et al. (2014), Hsu et al. (2019), Kafai et al. (2014), and Sheridan et al. (2013), the camp session had a singular focus. Though we instructed the youth to visualize their writing, the choices they made while creating were completely up to them. The students chose which parts of their writing to represent (often, it was multiple parts of the writing, as evidenced by the multiple scenes created by most youth) and how to represent the writing. They chose the environment, or background, in which to showcase their writing. They chose the characters to include, and what those characters looked like. Most of all, they chose whether to code their scenes. All but one included coding. During a focus group, many students stated they had not expected to do coding. The choices that were made by the learners likely influenced their enjoyment of the making activities.

Inclusivity and Access in the Makerspace

Makerspaces, once touted as being for everyone, have sometimes struggled to make that a reality (Buchholz et al., 2014; Calabrese Barton & Tan, 2018; Halverson & Sheridan, 2014; Harron & Hughes, 2018; Seo, 2019). The camp session showed some evidence of positive changes, while others still need work.

Though not specifically for girls, like the makerspaces studied by Buchholz et al. (2014), Kafai et al. (2014), and Norris (2014), the session had a near equal number of girls and boys. Since the youths’ participation was either self-selected or selected by their parents, it may show that makerspaces are more widely accepted as spaces for people of all genders.

Another barrier to participation in educational makerspaces is when and where they are offered. Makerspaces can be located in schools or in communities. Many community-based makerspaces include fees to offset the cost of materials and equipment. School-based makerspaces may be free for the students to use, but they must find funds for materials. Digital makerspaces could potentially require only digital devices, but they must also cover the cost of the software or web-based tools used. While there are some free tools, CoSpaces is not one.

We held this session in the summer; participation in such summer camps depends often on the cost of the camp and available transportation. The camp expected families to provide transportation for all participants, which may have excluded some who wanted to attend. The camp was also not free, which could have impacted some potential learners, although there were some scholarships available. These barriers are not always possible to overcome, but it is important to continue to try to make strides towards greater inclusivity for all in makerspaces.

Advantages of Digital Making in the Makerspace

I define digital making as the creation of a product either partially or wholly created online or using digital tools. The creations of the youth in the study fit the definition, as they created them using the online tool, CoSpaces. This study realized several advantages of digital making. First, digital making can prepare students with skills they will need in the future (Edwards et al., 2021; Kervin & Comber, 2021; Niiranen, 2021; Peppler & Kafai, 2007). VR is an up-and-coming industry, which will need people who can create it. The youth who participated in this session will not only have experience with VR creation, but it may spark their interest in a career in VR. When looking at her scene through VR goggles for the first time, Morgan stated, “It’s so cool in here! ... Like you’re in it” (Interview). Other students had similar reactions, spurring an interest in VR and in VR creation that may follow them through their schooling and into their future.

Second, they were creators of knowledge. Rather than just taking in information, they actively made their knowledge apparent in their creation. This aligns with Peppler and Kafai's (2007) belief that digital making encourages students to move beyond consumers of knowledge. Oliver shared his newfound knowledge of VR in his second scene which included a VR scene. Though most students' creations did not show that level of metacognition, their knowledge was evident in the comparisons of their CoSpaces scenes and their writing. For example, Alex's sports scenes included the facts that were present in his writing. As they created their visualizations in CoSpaces, their knowledge of both CoSpaces and visualization became tangible.

Third, as Edwards et al. (2021) found, creating digitally afforded learners the opportunities for greater risk-taking. Students frequently tried things that later failed, like Harper's three attempts to create a scene to represent her writing. The ease of starting over meant that even though the first attempts didn't meet her needs, she could then think even further out of the box by creating an atom using clouds and rocks (see Figure 15). Had she been limited to a physical representation or a one-dimensional drawing, she may not have tried it.

Lastly, similar to Blikstein's (2013) findings that the use of digital tools increase student self-esteem through more polished work, the youth expressed pride in their creations. The ease of iteration in CoSpaces meant students could make as many changes as needed to create a scene that they liked. Morgan, for instance, was frustrated when she uploaded a picture into her CoSpaces. It was flat and one-dimensional, in stark contrast to the rest of the scene. However, she was able to manipulate the picture, the characters, and the camera in such a way as to make it much less obvious that it was a picture. She expressed pride in this in one focus group, along with many other learners who talked with pride about their scenes.

Makerspaces are a growing trend in education, and the session exemplified a true makerspace experience, though somewhat limited in inclusivity. Participants learned both how to use CoSpaces in various ways and how to visualize their writing. They expressed choices in what and how they created. The session not only met but expanded upon the definition of a digital makerspace by fostering future skills like VR creation, promoting active knowledge construction, encouraging risk-taking, and boosting student self-esteem through project ownership. These advantages align with Peppler and Kafai's (2007) vision, demonstrating that digital making has a significant role in modern education by preparing students for the future of technology.

Virtual Reality

Interest in Virtual Reality (VR), an immersive, and often interactive, computer-generated environment, has skyrocketed in recent years. VR is being used in many industries, including education. Educators have begun to explore the benefits of using VR in learning activities in a variety of subjects. The current study found that creating VR had similar effects to learning with VR.

Behavioral Effects of VR Creation

I observed self-efficacy, a learner's perception of their ability to learn or perform at specified levels (Schunk, 2020), in the learners in the study in various ways throughout the camp while creating their VR visualizations. They worked independently throughout the camp, asking for help when needed, either from peers or instructors. Alex, for example, despite occasionally observing the work of his peers near him, worked steadily throughout the camp, asking for help when needed, either from peers or instructors. When faced with challenges, they persevered, rather than quitting, and adapted to the limitations presented. One notable example of this was Morgan struggling to get the placement of her one-dimensional photo to not look out of place in her 3D scene. Rather than give up on the photo, she persevered until she was successful. Additionally, they presented their ideas freely and with confidence in focus groups and interviews. This is similar to the increased self-efficacy in VR lessons found by S.-C. Chang et al. (2020), W. Huang et al. (2022) and Makransky et al. (2019).

Researchers have also noted that learners exhibit increased motivation when using VR to learn (Alfadil, 2020; Chang et al., 2020; W. Huang et al., 2022; Innocenti et al., 2019). Similarly, the youths in the study were highly motivated to work on their creations. They were eager to begin work each day, and many didn't want to even take a break while working. During focus group discussions, they excitedly talked about what they planned to do the next day. They were also highly motivated to solve problems, such as Harper's efforts to visualize her writing about the microcosm adequately. She tried several different scenes before settling on building an atom out of clouds and rocks in the CoSpaces library.

This level of motivation could have been due to the novelty of the technology, as Makransky et al. (2019) and Innocenti et al. found, but not all students were unfamiliar with VR or with CoSpaces. Two students had previously used CoSpaces, but still remained highly motivated. A few youths had experience with seeing VR and several had experience with tools that they felt were somewhat similar, though not analogous to CoSpaces. What may have explained the increased motivation was the similarity to video games. Most of the youth had also experienced immersive video games, providing a similar background to VR immersion. Creating VR scenes in CoSpaces was a new experience to most, regardless of their exposure to similar tools. Further research should explore the possible causality of motivation in creating VR scenes.

VR and Visualization

In this study, the youth created scenes to visualize their writing, thus improving their writing. Visualizing through the creation of VR is a novel approach to visualization. The creation of VR scenes was effective in helping the youth to visualize their writing because it helped to immerse them in the story, envisage interactivity in their scenes, and stretch their imaginations.

VR is, above all else immersive, as the scene surrounds the viewer. Al-Gindy et al. (2020) noted that VR can help connect the viewer to what they see better than a video or chart. In creating a 360° scene, the youth could imagine their scenes from multiple perspectives. Several students talked about how creating their CoSpaces scenes helped them to see the setting of their writing. Liam, for example, created a scene in which pirates plan to attack an island nation. He not only included the caption and mate who were talking, but other pirates, including those on a lower level performing various tasks. When writing a story, details like supplemental characters operating in the scene's background may be lost, but by seeing it in VR, Liam knew that there would not just be an empty lower deck on the ship, and therefore added the additional pirate mates. The creation of VR allowed students to feel that they were in the scene, thus enhancing their visualizations. In other words, as stated by Alfadil (2020), they were, "learning it by living it."

Stone et al. (2022) noted that through VR, it is possible to explore areas that are not readily accessible. Similarly, the youth were able to explore ideas that were not readily available in one-dimensional visualization. For example, Sophia had the idea of a dragon that could turn into a woman. In CoSpaces, she was able to code her scenes to have the two creatures overlay, and one would fade while the other appeared. This would have been difficult, if not impossible, to draw. Olivia also used the tools of CoSpaces to try out ideas in her head. In this case, it was colorful barnyard animals. While she could have drawn them, seeing them in 3D allowed Olivia to see them from all sides and truly imagine them. CoSpaces afforded learners the opportunity to try out new ideas that they might have otherwise been reluctant to show. In trying out these ideas in CoSpaces, they were able to see these ideas differently than they would have in drawings or two-dimensional visualizations.

Finally, VR creation in CoSpaces provided a way for the youth to see how certain scenes in their writing could play out. They used animations to make characters appear realistic, like Charlotte's character walking, rather than just sliding through the door. The youth also used speech bubbles to show characters talking to one another or conveying information. Alex used speech bubbles to have his character provide the facts about sports that appear in his writing. Coding was used to make animations and speech happen, as well as the movement of characters. Another use of coding was to progress the story to the next scene, or like Oliver's VR Museum exhibit scene, to switch cameras to show a different part of the scene. This interactivity is an important part of VR, creating a lifelike scene. This is similar to Al-Gindy et al.'s (2020) depiction of VR creating a closer connection to the content as users interact with it.

The immersion and interactivity seen as benefits of VR was realized in the creation of the youths' CoSpaces scenes. They were able to not just see what they wanted to write, but to be a part of the story. By coding and animating their scenes, they explored expanded ideas with their CoSpaces creations.

VR creation has similar benefits to VR viewing as educational activities. Both contribute to increased self-efficacy and motivation. Though the motivation observed in this study may be attributed to the novelty of VR creation and VR's resemblance to video games, it persisted even among those familiar with CoSpaces and other similar technologies, highlighting its appeal. The features of VR that often make it appealing, namely immersion in the content and interactivity, positively impacted students' visualization through CoSpaces. Furthermore, creation in the VR environment provided opportunities to explore concepts differently than with other forms of visualization.

Limitations

This study provides insights into the use of VR in educational settings, specifically within a summer writing camp for elementary-aged youth. However, it is important to acknowledge the limitations of the study to contextualize its findings appropriately. First, the informal setting of the summer writing camp contributed to a more relaxed atmosphere than that of a traditional classroom. As such, some youth took advantage of this in not exactly following the assignment, which was to visualize their morning writing. For example, Charlotte felt that CoSpaces didn't have what she needed to visualize a horror story, so her scenes were about her, not the subject of her writing. While her interactions and engagement with CoSpaces provided valuable data on digital making activities, it did not necessarily show her ability to visualize with CoSpaces.

Relatedly, in a traditional classroom, the writing and the visualization is intertwined, rather than separate activities. We did not have access to many of the youths' morning writings until the camp ended, which made feedback on visualization difficult. In addition, many wrote multiple stories, so they were visualizing multiple narratives. A traditional classroom setting may have provided a more cohesive understanding of the effectiveness of visualizing through VR creation as their writing and visualizations could have been continuously compared for changes. Furthermore, feedback on the process of visualization would have been immediate and iterative, allowing for real-time revisions and refinements in both writing and visualizations. This could lead to an integrated learning experience, where the visualization acts as a catalyst for writing development. The continual loop of creation and feedback in a classroom could help students to translate their writing more effectively into visual forms. Another notable limitation was the scope of the study, which examined only a single iteration within a two-week time period. A design-based research approach, involving multiple iterations of the intervention, could refine and enhance the understanding of VR creation as a tool for learning in classroom settings across a longer time period.

Another limitation is that I was only able to collect observational and focus group data for one week due to time limitations. I could have further tracked changes in student work over a longer time if I had been able to attend the camp both weeks. This would also have provided comprehensive and nuanced data to identify trends and patterns, such as peak productivity periods, common challenges as they progressed with their work, and shifts in group dynamics that were not apparent in the shorter time frame. A longer data collection period would have also enhanced credibility, consistency, and transferability of the study by ensuring that the behaviors observed were more likely to be representative of students' typical experiences over time.

A final limitation was the lack of access to the VR goggles until the end of the camp. Though I made efforts to have access to at least one pair of VR goggles, they proved to be incompatible with the CoSpaces program. Another set of VR goggles available required a personal phone to be used. As a result, this was only available on the next to last day of the camp, in which students were able to take turns in viewing their scenes through the goggles. It should be noted, however, that though CoSpaces can be used through VR goggles, the interactivity and immersion to some degree are available when viewing through a browser, and even more so when using a tablet that can be held and moved around much like the VR goggles. The main difference is that with the goggles, the CoSpaces environment appears to surround you. Although the students found that looking through the VR googles to be interesting, their responses were mixed on whether it would have been beneficial to have access throughout the camp.

In conclusion, while the study offered valuable preliminary observations on the use of VR in educational settings, the limitations stated here must be taken into account. Future research could address these constraints by conducting a study within a traditional classroom setting, incorporating an iterative design-based research approach, and ensuring the integration of writing and visualization tasks. Such research would contribute to a more comprehensive understanding of the effective use of VR technology in educational settings.

Recommendations for Implementation and Future Research

This study aimed to understand how elementary-aged youth engaged in the creation of VR scenes to visualize their writing. The findings demonstrate not only the efficacy of VR creation to visualize writing, but the usefulness of CoSpaces as an educational tool for that purpose. This study's findings provide an alternative to traditional methods of visualization when writing. Based on this study, elementary youth in grades three through five benefitted from this form of visualization.

CoSpaces, as an educational tool, was easy for all users to pick up and begin using. The learners were able to begin adding and customizing items to their scenes with just a very basic overview. Teachers should also work with the program to create their own scenes before employing CoSpaces in the classroom. Users will likely need in-depth training to use some of the advanced features, like coding. However, the visual block-based programming language CoBlocks is simple enough that users can learn it quickly. Based on the findings of this study, educators should consider CoSpaces as a tool for VR creation for any subject which necessitates creating a visual representation.

Future research should explore the efficacy of VR creation in other subjects and grade levels. This study focused on writing, but participants, both youth and adult, felt that educators could use it for many other subjects. For example, VR creation could be used to build scenes depicting historical recreations or for science simulations as suggested by Al-Gindy et al. (2020). Also, while this study focused on youth in grades three to five, researchers should examine how students in other grades engage with CoSpaces. I purposely did not select Grades K-2 for this study, as I felt that creating in CoSpaces in the younger grades would require much more teacher assistance than in higher grades. CoSpaces advertises as a tool for any grade, but it would be of significant benefit to understand exactly how the younger students engage with VR creation. Alternatively, older students may need the same or less teacher intervention to create even more involved scenes than elementary students. Research in these grades would benefit the education community to understand the effectiveness of the VR creation for learning.

This study used an embedded case study design to examine the perspectives of the youth and the instructors. Other study designs could yield further information about VR creation in educational settings. A design-based research study would help to refine the intervention of VR creation to visualize writing through iterative applications. This would provide detailed information on the implementation in the classroom. Quantitative analysis of student writing samples before and after visualization would provide information on the effectiveness of the intervention by measuring changes in specific metrics such as improvements in vocabulary usage, sentence structure complexity, readability scores, and textual coherence, thereby offering concrete evidence of any enhancements in writing skills attributable to the visualization techniques. Researchers should consider these alternative study designs to form a more complete picture of VR creation in the classroom than was seen in this limited study.

Conclusion

This study showed that the creation of VR scenes is an effective way to visualize when writing. The conceptual framework provided a lens through which the active, hands-on construction of knowledge via VR was observed. This approach encouraged students to make choices, engage in creative risk-taking and apply critical thinking, both individually and collaboratively.

The research revealed three significant themes: (1) Students engaged in the "max of adventure" to create their VR visualizations, (2) their writing was transformed as a result of their creation, and (3) a "community of learners" evolved in the classroom that included individual, peer-to-peer, teacher-to-student, and even student-to-teacher learning. CoSpaces, as an educational tool, was easy to use and enabled the participants, both young and adult, to create with little training. The creation of VR visualization shared many features of learning through VR viewing, including immersion in the content, increased self-efficacy, and higher motivation. Engagement in the activities was so high that students didn't want to stop for breaks but wanted to work on their scenes outside of the camp.

The study's scope is limited, however, by the specific populations and setting, suggesting a need for further research in diverse populations and educational contexts. Future studies could explore the scalability of VR creation across grade levels and subjects, and its impact on learning outcomes. Nevertheless, the results of this study suggest that creating VR environments is an effective means of visualizing writing for elementary-aged youth. As the education landscape continues to evolve, integrating digital making activities like VR creation could play a vital role in creating an engaging and effective learning environment.

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APPENDIX A: OBSERVATION PROTOCOL

Instructions: Select 1-2 students at a time to focus on the observation. Note the time at the onset of recording. Recordings should last approximately 20-30 minutes. Write a narrative memo as soon as possible after recording, and again after watching the recording. While reviewing the recording, use the chart below to write observations and impressions.

	Observation	Notes
Date of observation		
Equipment used		
Time recording began		
Duration of recording		
Location		
Name of youth(s) being observed		
Describe interactions with peers		
Describe reactions to challenges (spoken or unspoken). Describe any actions taken immediately after the challenge.		
Describe reactions to successes (spoken or unspoken). Describe any actions taken immediately after the success.		
Describe any discourse with self, peers, or instructors about virtual reality creation (their own creation, a peers' creation, or in general)		

APPENDIX B: SAMPLE FOCUS GROUP PROTOCOL

Focus group discussions will be held with participants at the end of the day, several times throughout the program.

Part 1: Setting the stage

Today we want to talk about what you've been doing in camp. An important part of learning is being able to get ideas from others, so we want to talk about what is working and what isn't working in your projects. We're going to be recording this. You don't have to speak during this time, but we would love to hear your thoughts. If you don't feel comfortable being recorded, you can continue to work on your project in the back of the room.

Part 2: Questions - These sample questions may be provided in any order.

- How do you feel about the work you did today on your virtual reality scene?
- What did you have trouble with today?
- What went well today?
- Did creating your scene today make you want to change anything about your story?
- What did you learn today about using CoSpaces or other technology?
- What will you do differently tomorrow?

Part 3: Closing

Thank you for being a part of today's discussion. Does anyone have anything else that you would like to share about your experience with your project?

APPENDIX C: SAMPLE LEARNER INTERVIEW PROTOCOL

This interview will be conducted with selected participants at the end of the camp experience.

Part 1: Setting the Stage

I would like to ask you some questions about your experiences during this camp session. I'm interested in learning about what went well, and what didn't go well, during the camp. This interview will be recorded. You do not have to answer any questions that you do not wish to answer.

Part 2: Questions - may be done in any order (potential follow-ups below each question)

- Tell me about your CoSpace environment that you made.
    - How do you feel about your final product?
- How did you like making your own virtual reality environment?
    - What were some things that didn't go well?
    - What were some things that did go well?
- How did creating your VR environment help with your story?
    - Do you think that creating a VR environment is a good way to learn? Why or why not?
- Tell me about something that didn't go the way you expected when you were making your CoSpace.
    - What did you do?
    - How did you get past it?
    - How did you feel about it?
- Would you want to create a VR environment again?
    - What would you do differently?

    - What would you do the same?
- Is there anything else you would like to tell me about your VR environment?

APPENDIX D: SAMPLE TEACHER INTERVIEW PROTOCOL

This interview will be conducted with selected participants at the end of the camp experience.

Part 1: Setting the Stage

I would like to ask you some questions about your experiences during this camp session. I'm interested in learning about what went well, and what didn't go well, during the camp. This interview will be recorded. You do not have to answer any questions that you do not wish to answer.

Part 2: Questions - may be done in any order

Questions (potential follow-ups below)

- How did you find the experience of working with students to create a virtual reality product?
  - What were the challenges?
  - What went well?
- In what ways did creating the VR help the participants to learn about visualization?
  - Is there anything about creating a VR that was more helpful than traditional teaching and learning?
  - Is there anything about creating a VR that was less helpful than traditional teaching and learning?
- Was there anything about the experience that surprised you?
- Tell me about a time when you helped a student with a particularly challenging situation during the project.
  - What did you do?
  - How did you feel about it?

    - Do you wish you had done anything differently?
- What did you learn from this experience?
- Would you want to do this again?
- Is there anything else about this experience that you would like to share with me?

APPENDIX E: COSPACES OBSERVATION PROTOCOL

Name of Youth:

Age of Youth:

For each CoSpace, describe any indications of the characteristics, either seen in the CoSpace or mentioned in the oral description. It is not expected that all characteristics will be present.

Characteristic	Evidence (include time stamp in screen recording or location in CoSpace)	Notes
Chosen background		
Reason for choosing this background		
Describe the scene		
How does the scene compare to the scene in the final version of the story?		
What information does the student give about their process for creating the scene?		
Does the student indicate how their 3D visualization impacted their story? If so, how?		
What other information does the student provide for the story?		

APPENDIX F: PILOT SAMPLE LEARNER INTERVIEW

This interview will be conducted with selected participants at the end of the camp experience.

Part 1: Setting the Stage

I would like to ask you some questions about your experiences during this camp session. I'm interested in learning about what went well, and what didn't go well, during the camp. This interview will be recorded. You do not have to answer any questions that you do not wish to answer.

Part 2: Questions - may be done in any order (potential follow-ups below each question)

- Tell me about your product.
    - How do you feel about your final product?
- How do you feel about the process of creating your VR?
    - What challenges did you experience?
    - What successes did you experience?
- How did creating your VR help you to understand ecosystems?
    - Was there anything that was better than the way that you normally learn in school?
    - Was there anything that was not as good as the way you normally learn in school?
- Tell me about something in the camp that didn't go the way you wanted to.
    - What did you do?
    - How did you get past it?
    - How did you feel about it?
- What did you learn from being in camp?
- Would you want to create a VR environment again?

- What would you do differently?
- What would you do the same?

Part 3: Closing

APPENDIX G: PILOT SAMPLE FOCUS GROUP PROTOCOL

Focus group discussions will be held with participants at the end of the day, several times throughout the program.

Part 1: Set the stage

Today we want to talk about what you've been doing in camp. An important part of learning is being able to get ideas from others, so we want to talk about what is working and what isn't working in your projects. We're going to be recording this. You don't have to speak during this time, but we would love to hear your thoughts. If you don't feel comfortable being recorded, you can continue to work on your project in the back of the room.

Part 2: Questions - These sample questions may be provided in any order.

- How do you feel about the work you did today on your virtual reality scene?
- What were the challenges you experienced today and how did you overcome them?
- What successes did you have today?
- What did you learn today?
    - About ecosystems
    - About virtual reality
- What will you do differently tomorrow?

Part 3: Closing

Thank you for being a part of today's discussion. Does anyone have anything else that you would like to share about your experience with your project?