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# Diffusion of Virtual and Augmented Reality in Pre-K to 12 Education: Experiences and Perceptions of Pioneer Teachers

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# Diffusion of Virtual and Augmented Reality in Pre-K to 12 Education: Experiences and Perceptions of Pioneer Teachers

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## APPROVAL FOR SUCCESSFUL DEFENSE

**Frances Nana Ofosu-Amaah** has successfully defended and made the required modifications to the text of the doctoral dissertation for the **Ed.D.** during this **Summer 2021** Semester.

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## ABSTRACT

The diffusion of the virtual and augmented reality (VR/AR) technological ecosystem into education is nascent. Research on VR/AR in Pre-Kindergarten to Grade 12 (PK-12) education has been focused on the technologies' effect on learning in various use cases. This study, grounded in Diffusion of Innovations theory (Rogers, 2003), uses a phenomenological qualitative research approach through interviews to understand the lived experiences and perceptions of pioneer teachers who have used VR/AR with PK-12 students. Critical trends and emergent themes within this study regarding pioneer teacher experiences of VR/AR adoption and integration surfaced through an inductive data analysis process. The introductory experiences of VR/AR impact teachers' perception of the ecosystems' benefits for teaching, launching their quest for information to narrow the knowledge gap that arises when adopting innovation. Pioneer teachers in this study use VR/AR in primarily two ways, for (i) The Exalted Journey (i.e., field trips to internal human spaces) and (ii) The Expression (i.e., student storytelling). Support from and access to funding provided by district/school leaders are critical for VR/AR adoption. Access to relevant content and VR/AR creation tools, bolstered by district-to-classroom level policies and protocols, proves essential for VR/AR integration in the classroom. Effective VR/AR classroom integration also depends on device availability, human resources, classroom structures, and classroom management. Teacher self-perception and educational context and philosophy affect teachers' propensity to embrace VR/AR for teaching and learning. Due to the COVID-19 pandemic, the use of parts of this ecosystem was halted, particularly immersive VR through a head-mounted display; the pandemic's long-term impact on VR/AR diffusion in PK-12 education remains uncertain. Access to VR/AR technology, inclusive of content and experience creation tools, classroom structures, resources, policies and protocols, teacher characteristics, and

leadership support are crucial elements for districts/schools to consider when adopting and integrating this ecosystem into PK-12 classrooms.

**Keywords:** *virtual reality, augmented reality, mixed reality, immersive technology, education, K-12 education, P-12 education, educational technology, instructional technology*

## DEDICATIONS

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**It took a village!**

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# CHAPTER I - INTRODUCTION

Information and communication technology (ICT) and digital technology, are ever-changing. Its proliferation and pervasiveness impact society, driving a reinvention of the way people live, work, play (Friedman, 2005) and even contemplate the principles of information (Pierson, 2001). These societal changes put pressure on education, driving integration of digital technologies into teaching and learning experiences (Billinghurst, 2002; Briggs, 1996; Pierson, 2001; Suh & Prophet, 2018). The constant and rapid rise in the enhancements of digital technologies, as predicted by Moore's Law (Moore, 1965), and new, not-yet-known technologies mean that this pressure will continue to mount.

Digital technologies, at times, rise and then lie dormant until other technologies materialize to support their re-emergence. Such could potentially be said of the re-emergence of the complex ecosystem of computer hardware, software, and digital media known as virtual and augmented reality. Virtual and augmented reality technologies are immersive digital media and information communication innovations making inroads into various fields, including education. According to Milgram and Kishino (1994), in a virtual reality (VR) environment, one views and interacts where the images are computer generated and the real world is not in view; this is known as an immersive VR experience. Augmented reality (AR) technology allows one to interact with a digital world while the real world still in view. In AR, digital images, text and video, seen through special glasses and/or smart devices (i.e., tablet, smartphone), can be overlaid onto the real world. There is a range of possibilities between virtual and augmented reality, which is dependent on how much of the real world is in view and where the interaction takes place. Milgram and Kishino term this range as the Reality-Virtuality continuum, also known as the mixed reality continuum.

The technological innovations of virtual and augmented reality are expected to diffuse into and even revolutionize education (Altınpulluk, 2017; Baus & Bouchard, 2014; Billinghurst, 2002; Briggs, 1996; Jowallah et al., 2018), changing its fundamental core of teaching and learning. According to market research reports, virtual and augmented reality's movement into the education sector is still at an early stage (William, 2018), and thus the full extent of this professed diffusion remains to be seen. Additionally, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) which causes coronavirus disease 2019 (COVID-19) precipitated a global health pandemic which may have further put into question the potential level of diffusion. Everett Rogers' seminal diffusion of innovations (DOI) theory, dating back to 1962 and developed through a review of over 400 studies across different fields, notes that the early group of adopters of an innovation are the critical influencers regarding its potential trajectory within a community.

This study first situates the current path of virtual and augmented reality within the context of Rogers' (2003) diffusion of innovations (DOI) theory. Using qualitative methods, this study aims to elucidate the experiences and perceptions of pioneer teachers, who Rogers (2003) calls innovators and early adopters, regarding the phenomenon of the diffusion of VR/AR into Pre-Kindergarten to Grade 12 (PK-12) teaching and learning.

## Background of the Study

Digital technologies have become ubiquitous in education, from preschool to higher education, and have impacted how teachers teach and how students learn. This has been heightened globally with the presence of the COVID-19 pandemic. Emerging innovative and potentially disruptive digital technologies such as VR and AR are professed to diffuse into education as instructional technologies and to revolutionize it. Although this technology was not necessarily designed specifically for teaching and learning (Antonenko et al., 2017), this technological ecosystem may very well have the capability to cause fundamental change to it.

### *The Effect of Digital Technology in Education*

The integration of ever-changing ICT and digital media into education causes teachers to continuously enhance and develop new skills, dispositions, and practices for teaching and learning unrealized without them (Mishra & Koehler, 2006; Suh & Prophet, 2018; Winn, 1993). New innovative digital technologies stimulate pedagogical changes and may cause teachers to develop new pedagogical practices (Fowler, 2015), leading to “pedagogical innovation” (Redecker et al., 2009, p. 11). In addition, studies demonstrate that the use of ICT in education positively impacts learners (Chauhan, 2017; Dalim et al., 2017; Erdem, 2017; Tamim, 2011), which is due in part to its peculiar features and affordances (Dede, 1996). A meta-analysis of 122 studies, from various content areas, conducted by Chauhan (2017) showed that the use of technology had a statistically significant medium effect on elementary student learning ($g$ = 0.546, $p < 0.001$), and when moderating factors were considered, its use in informal settings, coupled with interventions and supports between one to six months, had the largest effect size ($g$ = 0.926). Similarly, in a second-order meta-analysis, Tamim (2011) also discovered that the effect size for the use of technology in education had a moderate effect size; specifically, its use in K-12 instruction yielded a significant and higher effect size (ES = .40, SE = 0.04) when compared to its use in post-secondary settings (ES = .29, SE = 0.03)).

New innovative digital technologies have the potential of enhancing student learning (Desai et al., 2008; Wartella & Robb, 2007), and this potential would start to be realized as the early iterations of the technology begin to diffuse into teaching and learning.

### *Diffusion of Digital Technology in Education*

According to Rogers (2003), the diffusion of an innovation is a social process during which information is transferred from one group of adopters to the next, thus, propagating the innovation's adoption and integration. This theory has been leveraged in various fields since its inception to understand how innovation spreads. Ortt et al. (2017) completed a literature review of works focused on DOI studies, with a specific focus on who Rogers (2003) called the Innovators and Early Adopters, named pioneers within this study. With 70 publications selected from 470 DOI papers, Ortt et al. took note that most of the works which somewhat focused on these earliest adopters explored the diffusion of " 'electronics, IT, internet, and social media' " (20 papers), " 'medical, health, and pharmaceutical' innovations" (16 papers) with nine (9) "empirical studies of the 'agriculture and farming' context" (p. 5).

Rogers' (2003) diffusion of innovations theory and complementary frameworks have also been used to understand, explain, and predict the factors that influence how and why teachers adopt and integrate various digital technologies. Surry (1997) provides a theoretical review of how innovation diffusion theories have been applied to instructional technology, especially with the use of Rogers' theory as a backdrop. Surry (1997) provides two distinctions to the theory's use, stating that some of the research had been (i) to determine how instructional technology could be used as a school reform lever based on systems/organizational change theories, while others focused on (ii) how to use the theory to increase adoption and utilization.

Sahin's (2006) review of various diffusion studies focused on educational technology spanning the years of 1998 to 2003, with most studies coming from the higher education sector and those focused on PK-12 education being doctoral dissertations. These studies mostly focused on understanding specific factors that affect teachers' willingness and intention to adopt technology and, at times, the barriers to integration, pointing to factors similar to those explained by Rogers (2003) (i.e., perceived ease of use). Other studies have also focused on the level of use of the ICT (i.e., frequency of use), while others have used DOI theory to help gauge the potential rate of ICT diffusion (Stieler-Hunt & Jones, 2015).

A recent study on augmented reality (AR) that incorporated DOI theory focused on uncovering the perceptions and beliefs/attitudes of K-12 through Higher Education teachers/professors and administrators in using AR with students (Mundy et al., 2019). The researchers used an online survey with room for participants to answer open-ended questions. Statistical analyses were then conducted on the survey results to compare various participant characteristics linked with educator expertise, student engagement, and student interest (i.e., how did gender play a role in the perceptions of educators on student engagement, etc.). This research team also asked questions related to what educators were using in the classroom in terms of AR apps. Participants shared that they were using AR to "introduce a concept," to "set the context for learning," "to activate prior knowledge," for "examining structures we can't get to" (Mundy et al., p. 9), to create AR games such as scavenger hunts, and for students to create AR bulletin boards as a way to demonstrate their knowledge. Costs, access to the technology, and limited education-related apps were some of the area's participants mentioned as barriers to adoption. This study was the first noted by the researcher to use DOI theory and related ideas to directly uncover the perspectives of current AR users, albeit the focus went beyond teachers and K-12 education. The use of DOI theory in Mundy et al.'s (2019) study was only to contextualize who the current users of AR are. This is similar to the discussion within this study, namely that current users are who Rogers called the Innovators and the Early Adopters.

The various non-VR/AR educational technology-related studies that focus on diffusion, adoption, and integration reviewed by the researcher seemingly had an underlying premise that the technology in question should be adopted. Surry (1997) explained this as a deterministic view of technology adoption where the expectation is that the technology must diffuse because it is deemed superior to what is currently being used and that its use would lead to superior practices and outcomes. Surry (1997) suggested a balanced view is needed where the deterministic coexists with the instrumentalist perspective in which technology is viewed as a tool and the end-user as the critical change agent in its diffusion.

### *Knowledge Creation Through Innovation Diffusion*

The adoption of an innovation, the move from the current to innovation-embedded practices, creates a knowledge gap, which closes when there is a change in and/or the creation of new knowledge (Badilescu-Buga, 2013). For example, innovation adopters would first need to know what the innovation is and understand whether it would be beneficial for their use. At this early stage of diffusion and as VR/AR technology continues to be improved, the focus of research is mostly on use cases and use case effectiveness. In the case of education, a framework that is said to guide the knowledge and skill needed for the use of instructional technology is termed technological pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006). TPACK sits at the intersection of the knowledge of content, pedagogy, and the specific technology to be leveraged for specific learning experiences. During the diffusion of technological innovation into education, knowledge such as TPACK would be transferred amongst peers within the educational social system; this is proposed in Rogers' (2003) diffusion of innovations theory regarding knowledge transfer. Early in a diffusion cycle, the earliest adopters are the change agents in the community who influence the tone and pace of diffusion through the development of new knowledge and its transfer to others. This may potentially transpire concerning knowledge about VR/AR use cases, effectiveness, and related TPACK as the ecosystem diffuses into education.

### *The Potential of Impact of Virtual and Augmented Reality in Education*

According to Parong and Mayer's (2018) higher education biology experiment, students who engaged in VR learning experiences obtained improved outcomes when compared to those who did not have such experiences. Similar findings have been shared in other VR studies as well as studies related to AR. In Lorusso et al.'s (2018) Giok-the-Alien AR early childhood game, for example, preschool students remained engaged in learning and showed improved collaboration throughout the game. In Garzon and Acevedo's (2019) AR meta-analysis of 64 studies, a statistically significant medium effect size ($d$ = 0.68) was found for the use of AR, with the effect size for primary education ($d$ = .69) being higher than that for lower and upper secondary education. Similarly, Merchant et al.'s (2014) meta-analysis of studies with the use of desktop VR from kindergarten to higher education showed that this technology could positively benefit learning outcomes, with games providing better outcomes than learning through simulations or virtual worlds. The emerging VR/AR ecosystem is said to potentially enhance student learning, and it is touted as having pedagogical benefits (Dalgarno & Lee, 2010; Jowallah et al., 2018) aligned with the technology-laden future of 21$^{st}$-Century pedagogy, what Scott (2015) calls Pedagogy 2.0. Research depicts its use in all content areas of education and its positive impact on learning experiences, from preschoolers to high schoolers to students with special needs such as those with Autism Spectrum Disorder (ASD). This potential impact is attributed to its specific and peculiar affordances, namely that of immersion, interactivity, and the ability to overlay digital information on the real world. There is also caution and uncertainty on the effects of especially immersive VR on children. There are questions related to what age VR headsets should be used, given concerns that this technology and new digital media generally may negatively impact child development, especially for young children (Schmidt et al., 2005; Shifrin et al., 2015; Wartella & Robb, 2007). Age limits are usually specified by VR headset manufacturers with statements that this technology is for those ages 12 to 13 and older (i.e., Sony PSVR; Facebook Oculus). Tychsen and Foeller's (2019) study was directed at understanding the impact of using VR headsets on children under the age of 13. With a group of children ages 4 to 10 engaged in the use of a VR headset, the researchers took visuomotor measurements before and after the experience. The researchers showed that there were no significant changes to these indicators after the immersive VR experience, thus rendering headsets safe for this younger age group. It should be noted that the children were engaged in the experience for a total of an hour, so longer-term effects may still be uncertain, yet the potential benefits of this VR/AR ecosystem still stand.

***Virtual and Augmented Reality – A State of Early Diffusion into Education***

Even with these potential benefits, the acceptance of this ecosystem as a learning tool and, thus, its level of use and rate of adoption in education is still in its infancy (Blackwell et al., 2014; SpeakUp, 2016; William, 2018). Currently, in the hands of who Rogers (2003) calls innovators and early adopters, this ecosystem continues to experience technological advances in image quality, increased mobility, and reductions in hardware cost, thus becoming more affordable for adoption (Hussein & Natterdal, 2015; Jowollah et al., 2018; Suh & Prophet, 2018).

AR educational software alone is set to become a $700 Million market by 2025 (Altinpulluk, 2017), and the VR market for software and hardware is expected to be a $200 Billion market by 2020 (Reede & Bailiff, 2016). Kouri (2019) referenced a 2019 ABI Research report, which suggested that the AR education market, K-12 through Higher Education, was expected to be a $5.3 Billion market by 2023, with VR expected to reach $640 Billion. The exponential growth of VR/AR in education has been forecasted to transpire within the next five years (William, 2018). It must be noted that these projections were made before the onset of the COVID-19 pandemic; the effects of the pandemic on growth remain to be seen.

When, how, and at what pace the diffusion of VR/AR into education will occur is uncertain, and so is its long-term impact on teaching practice and student outcomes. The rate of diffusion will be determined by the relative rate at which each group of adopting teachers integrates this innovative ecosystem. The COVID-19 pandemic's impact on education may further complicate VR/AR diffusion into PK-12. Regardless of the pandemic's impact, pioneer teachers who have used VR/AR have already had to move into a future of VR/AR-embedded teaching and learning.

**Statement of the Problem**

The current body of research on the potential use cases of VR/AR in education speaks to the promise of leveraging this ecosystem to potentially improve student learning and outcomes, including providing opportunities for improving student access to therapies, with caution. Per results of a survey conducted in 2016 by Speak Up from Project Tomorrow that included students from Grade 6 to Grade 12, the expectation of the use of VR was higher for those in Grade 6 to Grade 8 than in the other grade levels. This generation of digital natives simply expects this technology to be part of their educational experience.

For PK-12 education, elementary and secondary school leaders (superintendents, principals, curriculum and instruction directors, instructional technology specialists, etc.) are on the leading edge of instigating the acceptance and adoption of technology into teaching and learning (Alone, 2017). The epicenter of this diffusion process is teachers, who are the critical facilitators of what and how technology impacts learning through their integration of it into practice (Blackwell et al., 2014). Research on VR/AR in education tends to be focused on higher education (Alfalah, 2018; Sural, 2018) and the effectiveness of this technology for teaching and learning. Research on VR/AR continues to grow, but a specific focus only on PK-12 teachers is comparatively limited.

According to Rogers (2003), early adopters are the change agents and influencers in driving diffusion into the larger community. To understand the current state and path of virtual and augmented reality in education, one must thus look to pioneer teachers as a critical group within the community. Pioneer teachers have already had to move into the world of VR/AR-embedded teaching and learning and thus can best speak to the complex phenomenon of its diffusion, including the barriers to it.

The voice of teachers in educational technology research often comes through technology effectiveness studies, and the same can be said of VR/AR research. This was noted by Mundy et al. (2019) regarding augmented reality research: that "previous research studies were performed with complex, highly designed AR software tailored to specific education content with robust curriculum designed to support the use of the software" (p. 9). These larger studies to understand the effectiveness of this technological ecosystem regarding student learning at a time when diffusion is in its infancy are crucial, as these findings would expound on best use cases and affect the technologies' design and user experience. It can be noted that many teachers may adopt virtual and/or augmented reality without the support of researchers to guide their process. In addition, at these early stages of VR/AR adoption in education, neither would they have access to a plethora of robust curriculum options (Mundy et al., 2019). This study aims to support closing this gap in knowledge by focusing on teachers' experiences untethered from specific VR/AR technology, and the levels of support received.

Given that teachers determine how and when technology is implemented in teaching and learning, understanding their adoption and integration experiences may shed light on how best to support this experience. The one recent AR DOI study reviewed (Mundy et al., 2019) to further guide this research focused on K-12 through to higher education and leveraged surveys with the inclusion of open-ended questions for teachers to provide additional feedback. The researchers would then have had to interpret teacher responses as opposed to using interviews where they could clarify the meanings teachers would give to the expression of their experiences. Educational technology research has historically leveraged quantitative methods (Foster, 2002; Hoepfl, 1997; Luo, 2011,); in Suh and Prophet's (2018) literature review of immersive technology in various fields such as education, healthcare, entertainment, and marketing, it was noted that 78% of the 54 included papers used quantitative methods with the use of experimental methods as the most commonly leveraged, followed by survey methods. It was also noted that this body of research on VR/AR has also been focused on its effects in various user experiences and its effectiveness. With that said, and given the quest of this study, a qualitative method was used to uncover perceptions and meaning given to the experience of VR/AR diffusion by pioneer teachers.

Adopting innovation causes a knowledge gap, according to Badeliscu-Buga (2013). TPACK (Mishra & Koehler, 2006) is often pointed to as a basis for knowledge related to the use of technology in education. TPACK development research is often focused on pre-service teachers. According to Daher et al. (2018), the process of adoption of new technology also relies on teacher beliefs and knowledge development, and this, per their findings, is different for in-service as opposed to pre-service teachers. Pre-service teachers, in their study of ICT use in middle school mathematics, required less of a shift in their burgeoning knowledge and practice than did in-service teachers. Given this nuance, understanding new knowledge development around VR/AR for pioneer in-service teachers, as well as the changes they potentially have had to make in their practice due to adoption, could be beneficial in addressing this gap in the literature. Even though this study is focused on new knowledge development within the process of diffusion, with TPACK being a potential guide in understanding some of this new knowledge, it must also be noted that VR/AR-related TPACK studies are ongoing but also limited. Jowallah et al. (2018) speak to TPACK in discussing how teachers may leverage the affordances of VR and their suggestions for how teachers may plan learning experiences with it. In a recent study, Jwaifell (2019) looked to understand the readiness of in-service teachers to use AR for science instruction. This study leveraged the concepts within the TPACK framework as a method by which to understand teachers' readiness prior to experiencing a researcher-led workshop and being given three weeks to test AR. An increase in teachers' readiness to use AR was found at the end of the study, and that years of teaching experience did not play as much of a role in readiness as gender; at the end of Jwaifell's study, female teachers showed a higher level of readiness than male teachers. Within that study, the researcher was directly involved in providing an option (i.e., via a workshop) for science teachers to develop new knowledge about AR, as has been done with larger empirical studies on VR/AR effectiveness.

VR/AR research is a burgeoning field. More is being uncovered about the ecosystem's use and effectiveness for teaching and learning. This ecosystem is purported to disrupt and revolutionize education. Pioneer teachers may very well chart its course. In this early phase of diffusion, the problem this research confronted was to uncover and understand the diffusion-related experiences and the perceptions of these experiences, knowledge development, and potential shifts in practice of in-service pioneer teachers who design and deliver VR/AR experiences for PK-12 students. It is in understanding the perception of experiences that the meaning given to those experiences can be understood; the meaning given by pioneer teachers to adoption and integration experiences could shed further light on VR/AR's potential trajectory in PK-12 education.

**Purpose of the Study**

An understanding of the adoption and integration experiences of VR/AR into PK-12 education is growing yet limited. Situating VR/AR within the diffusion of innovations and adjacent theories, this study aimed to narrow a gap in the literature related to PK-12 teacher experiences and perceptions of their process of adoption and integration.

Through uncovering these experiences and perceptions, this study hoped to also illuminate how teachers came to accept and adopt VR/AR, how they developed new VR/AR-related knowledge and skills and whether adoption impacted their practice and/or classroom (i.e., does it cause pedagogical shifts, increased effectiveness/efficiencies, change ideas on how to plan lessons, classroom design, etc.).  In addition, this study would strive to unearth barriers to adoption are, effects of adoption on content/curriculum and/or which whether organizational factors impacted the adoption experience.

## Significance of the Study

The VR/AR revolution in education — if, when, and at what speed it will happen — would occur through the process of adoption and integration; thus, an understanding of the tenets of the diffusion of innovative technologies becomes important. An examination of the process of the diffusion, specifically the state VR/AR diffusion in education, will shed light on the characteristics of current adopters, their motives, the conditions governing current usage, and the internal or external factors affecting adoption and integration. Such a review will also provide a context in which to understand the perceptions of pioneer teachers, as well as a context in which to uncover multiple aspects of the use of this technological ecosystem in practice. Understanding pioneer teacher experiences and perceptions is beneficial not only for soon-to-adopt teachers and education administrators who may be contemplating adoption for their school/district and policymakers but potentially also for designers and developers of this technological ecosystem.

## Theoretical Framework

Various theories, models, and frameworks were sought and reviewed in support of the development of this research study; those selected are discussed below. The Diffusion of Innovations theory was selected as the foundational framework as it provides an understanding of how innovations, such as the VR/AR ecosystem, could potentially be adopted into use agnostic of sector. A critical component of innovation adoption is the acquisition of new knowledge which provides the adopter insights and/or specific instructions on how use the innovation. An example of new knowledge teachers may need to adopt and integrate new instructional technology such as VR/AR into practice is the Technological Pedagogical and Content Knowledge (TPACK) framework which was also reviewed for this study.

***Diffusion of Innovations***

Various theories and frameworks have been developed and used to understand the acceptance, adoption and/or integration of ICT in multiple fields, including education, such as the Technology Acceptance Model (TAM), the Theory of Reasonable Action (TRA), and the Unified Theory of Acceptance and Use of Technology (UTAUT/UTAUT2) which explained 70% of the variance (adjusted $R^2$ = 70%) in adopters' intention to use digital technology, to name a few. These frameworks focus on one part or another of this process, with a dominant focus on the emergent phases and for predicting user decisions for adoption. Rogers' (2003) diffusion of innovations theory will serve as a launching point from which to understand patterns of diffusion universally. This theory provides concepts that relate to innovation emergence through sustainability and beyond (Aizustauta et al., 2015), and parts of it are sometimes incorporated into other frameworks. Given that this theory is better applied to single product or service innovations and given that VR/AR technologies comprise multiple technologies, this technological ecosystem will be subjected to diffusion theory as a theoretical construct in and of itself.

Rogers' (2003) diffusion theory spotlights why, how, and at what rate innovative ideas and technologies may "spread" within a social system, with each phase informing the next. The social system, in this case PK-12 education, per this theory, would go through a staged process of information gathering and decision-making as educators become aware of the innovation. They would then search for more information about it to decide if and when to incorporate it into their practice, and then to finally determine, based on use, whether to fully integrate this innovation or not. This staged process comes into play regardless of whether members of the social system voluntarily or involuntarily adopt and integrate or reject the innovation. Rogers (2003) goes on to postulate that the rate of diffusion is related to the relative speed at which the innovation is adopted and integrated into the social system by five distinct adopter groups – the Innovators (those who seek new technology before it becomes mainstream, sometimes supporting its development), then Early Adopters (those who see some level of proof of effectiveness and adopt), the Early Majority (where mass adoption begins), the Late Majority (where critical mass builds) and finally the Laggards. Each group influences the next through the sharing of information and experiences.

The diffusion of VR/AR in most fields, including in education, is currently in the Innovator and Early Adopters phase (Albusberger, 2015; William, 2018) and has not yet crossed the chasm into the mainstream (Moore, 2001). This early phase of adoption can be recognized through the level of sales of the technologies and the review of the Gartner Hype Cycle. The Gartner Hype Cycle (Blosch, M. & Fenn, J., 2018), developed by Gartner, Inc., is a graphical depiction of the trends and patterns of technological innovation development and levels of maturity. From year to year, using the Gartner Hype Cycle, the maturity of VR/AR technology in education specifically can be seen still in its infancy with an expectation for mass adoption within five to ten years (William, 2018) even as the technology itself continues to mature at a rapid rate.

Many factors influence the acceptance, adoption, and integration of digital technologies in education as each adopter group goes through its staged process. Rogers (2003) provides insights on the process of diffusion of innovation, acknowledging that there are critical factors affecting adoption, such as the relative advantage of the innovation compared to current methods, its compatibility with current beliefs and methods, and its level of complexity during use.

Studies specifically focused on ICT adoption in education speak to factors that influence teacher's intention to use and their actual usage. First-order factors are extrinsic factors such as the perception of support from school or district leadership and policies. Second-order factors are intrinsic factors such as teachers' beliefs about the use of technology in education and their self-efficacy. Tsai and Chai (2012, p. 1058) explain the third-order factor as being teachers' "design thinking," which is the process by which teachers create new knowledge and change practice to effectively leverage the technology's affordances for teaching and learning. To move from the current to the new, teachers would need to develop new knowledge related to the innovation.

### *New Knowledge at the Intersections of Technology, Pedagogy, and Content*

VR/AR technologies have unique affordances to be culled in diverse use cases, which would be realized through continued diffusion and ultimately through their habitual integration into teaching and learning practice. Knowledge informs practice. Knowledge creation happens at each stage of diffusion to close the knowledge gap experienced during the adoption of an innovation (Badilescu-Buga, 2013); this new knowledge would, in turn, inform practice.

A structure that supports understanding some of the new knowledge needed by teachers in integrating technology into teaching and learning is the TPACK framework developed by Mishra and Koehler (2006). Mishra and Koehler (2006) state that for teachers to leverage technology for teaching and learning, they need to bring together their knowledge of content, pedagogy, and of the technology itself to create appropriate and effective learning experiences for students. Different views on TPACK exist; some regard it as the bringing together of three distinct knowledge centers, while others state that a new knowledge center is created from the intersection of the three. Regardless of one's perspective, this framework is an important concept to contemplate in uncovering a facet of teachers' knowledge in their use of technology, VR/AR, for teaching and learning.

## Research Questions

With a focus on understanding the phenomenon of the diffusion of VR/AR technologies into PK-12 teaching and learning, this study focused on pioneer teachers. The theoretical framework guided the development of the structure of this study and informed the research questions. Specifically, this study focused on the following questions to reveal the experiences and perceptions of pioneer PK-12 teachers regarding their process of VR/AR adoption and integration:

**Research Question 1 (RQ1):** What are the experiences and perceptions of these experiences of pioneer teachers regarding the adoption and integration of virtual and/or augmented reality in teaching and learning for PK-12 students?

- How do pioneer teachers build new knowledge (e.g., TPACK) within the context of the innovation adoption and integration process?

**Research Question 2 (RQ2):** How do teachers integrate virtual and/or augmented reality into learning experiences, and how does this integration impact their teaching practice?

- How does this integration affect the planning of learning experiences, classroom structures/management, pedagogical practices, methods of assessing learning, and/or other areas?

## Overview of the Methodology

Research on technology in education has often leveraged quantitative research methods albeit increases in qualitative approaches over time (Foster, 2002; Hoepfl, 1997; Luo, 2011). This parallels trends in educational research published within a ten-year span in the *International Journal of Instruction*, with 35% of those studies using qualitative methods (Eğmir et al., 2017). Qualitative research methods are focused on uncovering how people make sense of their experiences and chronicling their interpretation of those lived experiences (Creswell, J. W., & Creswell, J. D., 2018; Merriam, 2009). This is completed using emergent and flexible data gathering and the use of inductive reasoning to make sense of the data (Creswell, J. W., & Creswell, J. D., 2018; Luo, 2011; Merriam, 2009).

Due to these features of qualitative research and given this study's inquiry, this method was selected with a primary focus on Hermeneutic Phenomenological research design. Hermeneutic Phenomenological design allows for a better understanding of the experiences and meanings given to those experiences of teachers who have used VR/AR in PK-12 classrooms. Within this Hermeneutic Phenomenological design, the primary data collection method used, interviews, was guided by Holstein and Gubrium's (1995) active interviewing theory. In addition, qualitative content analysis of lesson planning-related documentation, where available, was conducted. A review of diffusion of innovations study methods and validated TPACK-related tools (Harris et al., 2012; Hofer et al., 2011; Koehler et al., 2012), as well as insights for developing Hermeneutic Phenomenological research (Daher et al., 2017; Lauterbach, 2018; Van Manen, 2016), were leveraged to structure an interview guide as well as the process of analysis.

Throughout this study, it was critical to keep in mind and to align to the tenet that "all knowledge is created by the actions taken to obtain it" (Holstein & Gubrium, 1995, Kindle

Edition, p. 2). This meant that it was expected that the potential of new knowledge creation on the part of the pioneer teacher and the researcher may occur during the interviews which were focused on the reflection and discussion of experiences. This understanding also guided the researcher's procedures for ensuring validity and the reduction of biases.

## Limitations and Delimitations of the Study

### *Limitations*

This study did not focus on one specific technology in the Reality-Virtuality Continuum (Milgram & Kishino, 1994), which can have multiple hardware brands, as well as content and app providers implemented in the PK-12 classroom. This open posture could have meant that even with clear definitions of the types of technologies on this continuum, study participants may still have thought of specific technologies/brands when responding to interview questions, for example. This may have caused some bias in their responses, depending on their specific context and experience with those specific technologies/brands as opposed to the ecosystem being a technological construct. Another limitation of this research study is that it focused only on VR/AR technologies and ignored the trajectories of prior instructional technology adoptions and their current use. Perceptions of participants could potentially be biased depending on their experiences with prior educational technology adoptions.

A critical limitation to this study was that it was conducted after the onset of the COVID-19 pandemic. This meant that the last time teachers may have used the ecosystem similarly to its use pre-pandemic was months before their interview. In addition, given that some teachers had to move to a remote school option as schools were closed during the pandemic, the experience of such changes could have also impacted pioneer teachers' experience of the diffusion of VR/AR overall.

### *Delimitations*

Given the focus of this study on understanding experiences and perceptions of teachers who have used/are using VR/AR in PK-12 education, those pioneer adopters who may have decided not to continue the use of this ecosystem may not be included in this study. They could have provided another perspective on the adoption and integration process, as well as reasons why teachers may choose to abandon the ecosystem. Given the potential variety and uncertainty of the specific technologies/brands being implemented in schools, a choice was made for this study not to specify the type/brand of technology so as not to limit the number of potential participants. In addition, a focus on in-service pioneer teachers meant that there were no insights gathered directly from pre-service teachers, students, parents and/or administrators. Given the nature of this study and its focus on experiences and perceptions, the effectiveness of this technological ecosystem on improving student outcomes was not determined.

## Definition of Key Terms

- **Augmented Reality:** Technology that allows the superimposition of digital audio-visual information onto the physical world where both are seen simultaneously.
- **Diffusion of Innovation:** A process by which an innovation spreads through a social system.
- **Educational Technology:** Per the Association for Educational Communications and Technology (AECT), this is the ethical practice of facilitating learning and improving

performance by creating, using, and managing appropriate technological processes and resources.

- **Innovation:** An idea, technology, process, system, etc., that is deemed novel by the observer.
- **Instructional Technology:** The design, development, use, management, and evaluation of the process of learning mediated by technology applications. More specifically, the use of technology in instruction.
- **Virtual Reality:** Technology through which a virtual world can be seen and where interaction in this virtual world happens with the physical world out of sight either through a head-mounted display (HMD) or through a computer screen.

## Organization of the Remaining Chapters

This chapter introduced the background and problem to be studied through this qualitative research study. Chapter II is a review of the literature regarding the diffusion of innovation and technology acceptance; the intricacies and promise of VR/AR in education; the tenets of new knowledge creation; as well as the TPACK framework, which is one guide for the knowledge critical to effectively leverage instructional technology. The methods and procedures used to carry out this qualitative research are reviewed in Chapter III. The findings of the qualitative data analysis are provided in Chapter IV. Discussions and conclusions related to the findings, including suggestions for additional research and implications for practice shared in Chapter V.

# CHAPTER II - LITERATURE REVIEW

In this chapter, the virtual and augmented reality ecosystem is first defined with an understanding of its promise and importance for education. Second, in this chapter, there is a review of the relevant literature regarding the diffusion of digital technologies into education, especially where this ecosystem is a focus. Last, a review follows of the theories and complementary frameworks that are said to govern the diffusion of innovations to contextualize VR/AR in education. Before proceeding, it must be noted that where specific digital technology and content providers (i.e., brands) are mentioned, they are only to provide examples of the technological types and trends; these mentions are not an endorsement, by the researcher, of any specific provider/brand.

## Key Search Terms, Literature Sources, Inclusions, and Exclusions

Multiple terms were used to locate pertinent research on VR/AR technologies in education, and especially for PK-12 education. The search terms used, with their associated acronyms and substitutions, included virtual reality, augmented reality, mixed reality, education, elementary and secondary education, diffusion of VR/AR in education, factors affecting VR/AR adoption in education, and teacher experiences with VR/AR, to cite a few.

The literature reviewed was obtained from multiple sources. Electronic searches were performed using various databases accessed via the Seton Hall University Library system, such as Researchgate, ScienceDirect, ERIC, Springer Link, ProQuest, Elsevier, JSTOR, etc. Web searches were conducted using the Google Scholar (https://scholar.google.com/) search engine and Dimensions (https://www.dimensions.ai/). Reference lists of empirical studies, articles, and literature reviews in the field were studied carefully, and often-cited texts were sought and reviewed.

Literature that provided network and cluster analysis of the expanding VR/AR research arena was beneficial in supporting an understanding of the fields covered in this research and how this research has changed over time (Akcayir & Akcayir, 2017; Cipresso et al., 2018). Per Cipresso et al.'s (2018) citation network and cluster analysis of VR/AR research, it was evident that in recent years, computer science and engineering were still the largest contributors to the body of research on VR/AR, followed by health/medicine (i.e., its use and effectiveness in neuroscience, psychology, neurology, surgery) and then education. It should be noted that the period after 2013 marked an increase in VR/AR research in education (Akcayir & Akcayir, 2017; Cipresso et al., 2018; Suh & Prophet, 2018) with some seminal works published prior. Works published more than five years prior to 2018 on VR/AR were included if they focused on PK-12 Education, included information (i.e., studies) that have not yet been replicated, if they were frequently cited works, and/or if they provided anchor frameworks that guided this field. Given that the higher volume of the educational research on digital technologies, inclusive of VR/AR, focuses on higher education, such studies were reviewed if they provided critical insights into potential PK-12 use and for diffusion. A higher proportion of the accessible literature was from non-U.S. sources and scientific/technical sources.

Excluded articles were those focused solely on implementation in other fields such as healthcare, entertainment, marketing, etc., unless there was an element of education that could be potentially interesting for PK-12 education. Other excluded articles included those that were in languages other than English.

**Virtual and Augmented Reality – The Technological Ecosystem Defined**

VR/AR technologies are not new to the realm of digital technology and given the improvements in computing technology are said to be *re-emerging*. Modern VR dates back to the 1960s with Morton Heiling's one-user console, the Sensorama, and to 1968 when Ivan E. Sutherland developed a head-mounted display (HMD) (Briggs, 1996; Jowallah et al., 2018; Milgram et al., 1995). A head-mounted display can be described as a helmet that straps over the head and covers the eyes through which one can see digital images, similar to the View-Master introduced in 1939, which used color photographic film transparencies. Sutherland's HMD superimposed digital imagery over the real world and could also be viewed as an AR application. The term *augmented reality* was coined in 1990 by Boeing researcher Thomas Caudell (Caudell & Mizell, 1992). The introduction of VR into education can be traced as far back as the 1990s, but its diffusion was not extensive due to the complex technical setup required to use it. For one, this complexity (i.e., the need for special rooms, very high-powered computers, etc.) meant the purchase and the upkeep was cost-prohibitive for education. With the increase in computer processing power, desktop VR began to enter the education arena with options such as Second Life (Merchant et al., 2014), which allows for interaction in a virtual desktop world via avatars. With continued improvements in computing processing power and the rapid adoption of the Internet, this technology is re-emerging.

Fundamentally, VR/AR technologies allow users to at least view and participate in worlds that comprise only of or partially of computer-generated images (CGI). These digital images can be of the real world or virtual worlds and can be overlaid onto the real world. For the sake of simplicity and given the types of immersive technologies being made available to education environments today, this study used the Reality-Virtuality Continuum conceptualized by Milgram and Kishino (1994) to guide how the virtual, augmented, and mixed reality terminology was defined and used. This continuum depicts that one can move from a fully real physical world to one that is completely virtual; this movement is described by Mann et al. (2018) in an in-depth taxonomy of mixed reality as moving the slider from one state of reality to another.

In VR, Milgram and Kishino's (1994) virtual environment, one can see and interact in a computer-generated world that does not exist or in one that involves computer imaging of an existing world with the real world out of view using an HMD. In Desktop VR, for example, one can interact in a virtual world inside a computer/tablet; with special glasses, images can seemingly appear to be coming out of the computer screen - interaction in an environment with such imagery could be considered a form of augmented virtuality. In AR, one can view and interact with a virtual world that is superimposed onto or combined with the physical world seamlessly. This AR world can be activated when one is in a specific location or through the viewing of markers (i.e., specific pictures) placed in a specific location. In both cases, one can view the images through special glasses or on a smart mobile device. In the case of AR, the smart device or special glasses acts like a see-through screen.

With the use of this ecosystem, one can either be completely immersed and be part of the scene (Billinghurst, 2002; Milgram, 1995) or "non-immersed," where one is an observer. For example, when using an HMD for a VR experience, the physical world cannot be viewed; with full immersion, movement and interaction occur in the virtual environment in real-time. The content images and sounds one encounters and interacts with when using this ecosystem are critical to the users' experience. Interaction in a virtual or augmented world can occur through haptic devices such as gloves or hand-held controllers, including gamepads and joysticks. Haptic devices allow for tactile and kinesthetic feedback through our sense of touch. These devices may use vibrations, motions, or forces to allow users to touch virtual objects, to feel their weight when picked up, etc. VR/AR also allows for auditory feedback through the addition of sounds via speakers in the HMD, AR-glasses (e.g., Bose Audio-AR glasses), or an app on a mobile device. Experiences can also include olfactory feedback where developers can infuse scents into the physical space. For example, in the virtual reality art exhibit created by Marshmallow Laser Feast (Saatchi Gallery – London, 2018-2019), *We Live in an Ocean of Air* (https://vimeo.com/332218848), scents of a sequoia tree were emitted through an olfactory device attached to the viewer's HMD only as they neared the virtual tree. Four of the five human senses can be activated in this ecosystem - all but the sense of taste at this point in time.

This ecosystem has peculiar features said to benefit education in a new way. Hardware quality continues to improve with enhancements in image quality, growing content (i.e., experiences) (Hussein & Natterdal, 2015), and declining costs. These attributes are making this innovative ecosystem more accessible, and its use is expected to grow exponentially over the next 5 to 10 years in education. This ecosystem is often even touted to potentially be an emerging disruptive innovation for education, a concept, when understood further, sets the context on how VR/AR is being viewed in the literature.

**Emerging Disruptive Technological Innovation**

Innovations have been defined from various perspectives. Some define innovation as being the use of new knowledge in products, processes, and services (Afuah, 1998) or a revolution within a community that changes practice (Denning & Dunham, 2010). Per Rogers (2003), innovation is "an idea, practice or object that is perceived as new by an individual or another unit of adoption" (p. 11). Fundamentally, there are constructs of perceived novelty, transformation through improved effectiveness and/or efficiency, socialization, and assimilation integral to the definition of innovation of which there are two basic types – disruptive and sustaining. Terminology synonymous with sustaining in the literature is evolutionary and/or incremental, whereas revolutionary and/or radical is often used to represent disruptive (Christensen & Overdorf, 2000; Popadiuk & Choo, 2006). Disruptive innovations unsettle the status quo as opposed to sustaining it; sustaining innovations offer insignificant incremental improvements (Christensen, 1997, Christensen & Overdorf, 2000; Guo et al., 2019; Li et al., 2018; Popadiuk & Choo, 2006).

When happening in the context of diffusion, disruption is dependent on the degree of pervasiveness and "embeddedness" (Reinhardt & Gurtner, 2018) and may cause fundamental changes in structures/models, processes/practices, content/tools/experiences, knowledge/beliefs, and/or policies/protocols, etc. According to Li et al. (2018), emerging innovations also have some potential impact on socio-economic systems but carry a degree of uncertainty and ambiguity regarding their sustainability and/or impact. Some are "radical product innovations" which could be "new to the world" but may not necessarily be disruptive (Christensen, 1997; Christensen et al., 2015; Markides, 2006).

Emerging disruptive innovative technology has characteristics of both emergence and disruptiveness as it undergoes diffusion (Li et al., 2018). Emerging disruptive innovative educational technology can be hypothesized as being twofold: (a) the application of emerging disruptive innovative technology in education, and/or (b) the redefinition of the educational structures, processes, content, experiences, knowledge, and/or beliefs due to the application of technology. An example of the latter is the concept of "pedagogical innovation," which is the transformation of teaching and learning approaches to better address and achieve learning goals (Redecker et al., 2009); in a technology-embedded environment, this is termed as technology-enhanced pedagogical innovation (Law, 2018).

For virtual and augmented reality to be emerging disruptive innovative educational technologies that revolutionize education, they would need to be disruptive and eventually become pervasive. Disruption to education means that they may cause fundamental change to maybe at least one of these five constructs or even others not listed here:

- Educational models and/or structures (i.e., classroom environment and physical structure, the concept of the school itself, new educational models such as Massive Open Online Courses [MOOCs]),
- Academic and non-academic content and/or experiences (i.e., learning standards, subject-matter content and curriculum, etc.)
- Processes and/or practices leveraged in educational settings (i.e., pedagogy, assessment, lesson planning, and/or operational processes that affect schools, etc.),
- Knowledge and/or beliefs of educators, parents, and/or students (i.e., knowledge on when to use new technology for specific students in support of specific subject-matter/skill mastery, etc.), and/or
- Educational policy (i.e., ICT policies of a school, district, or even a nation, etc.).

The concept of pervasion signals reaching a critical mass of users and complements the concept of embeddedness which Reinhardt and Gurtner (2018) suggested as the habitual use in practice by adopters "across different user groups and different use cases" (p. 278). This means that for VR/AR to reach a high level of pervasion, the ecosystem would eventually need to be adopted and integrated by a majority of teachers in a majority of content areas; this degree of pervasion remains uncertain.

## The Promise of Virtual and Augmented Reality in Education

To understand the promise of VR/AR in education, it may be helpful to go back in time to understand what the early predictions were and if they have yet come to pass. For example, Briggs (1996) provided a view into the expectations and examples of how virtual reality could be used in the future in fields such as the military, business, medicine, art, supporting individuals with disabilities, education, and more. From his vantage point in 1996, Briggs describes a classroom scene in 2007 where students studying the planets travel to Mars virtually to experience its red terrain and to gain a level of understanding that may not otherwise be possible without this technology. Briggs (1996) went on to share that virtual reality could be an important tool in the future and that it also required humans to have a clear and deep understanding of how the world works to replicate reality in virtual environments accurately. What Briggs (1996) did not provide was an indication of the speed of adoption for this ecosystem. Billinghurst (2002) provides a similar view for AR. He shares that because users can see both the physical and virtual worlds in AR, they would be provided with valuable personalized experiences that would be different from students simply sitting at a computer completing tasks on their own with minimal interaction with peers. This could be quite an important feature, especially as elementary and secondary education shifts into a “one device per child” reality in certain locations, something potentially accelerated by the need for remote learning due to the COVID-19 pandemic. Mixed reality technologies provide an opportunity for students in general, inclusion, and special education settings to have a tangible approach to learning, to take charge of their learning, and to make meaning in their own way (Antonioli et al., 2014). This offering mirrors expectations of constructivist learning theory; mixed reality could provide an opportunity for students to engage in personalized, experiential, and mastery-based learning, which may allow for deeper understanding (Rizzotto, 2017). The ability of the VR/AR ecosystem to provide such peculiar educational experiences is due to its peculiar features, affordances. It still must be noted that there are concerns about the potential impact of this technology, especially the use of immersive VR headsets, on the visuomotor development of children.

### *Educational Affordances of Virtual and Augmented Reality*

The understanding of the promise of VR/AR technologies in teaching and learning is still in its nascent phase (Georgiou & Kyza, 2018). This is showcased by the literature regarding its learning affordances and research studies assessing its application to practice. With a property of immersion, VR can allow for a strong sense of physical and cognitive presence as well as emotional involvement with real-time interaction in a simulated three-dimensional (3D) digital world (Bricken, 1990). AR's superimposition of audiovisual information (text, photographs, animations, graphics, video, sound, etc.) onto the existing world enhances our viewing of it (Altinpulluk, 2017; Antonioli et al., 2014; Azuma, 1997; Billinghurst, 2002; Briggs, 1996; Leighton & Crompton, 2017). This VR/AR ecosystem affords a change in the relative size of the learner and the virtual object (i.e., a student may enter an atom to see its structure, or take a trip to outer space, etc.). Seeing and hearing can happen through digital manipulations of sounds and colors the human eyes cannot see through transducers and the reification of abstract objects and ideas that do not have "physical form" (Winn, 1993, p. 8). These features of VR/AR allow new ways of accessing and engaging the world, and could potentially enable new ways of teaching and learning unrealized without them (Radu, 2014; Tondeur et al., 2017).

Research and use case reviews echo this perspective: that this mixed reality ecosystem enables personalized (i.e., first-person) contextualized experiences that are learner-centered (Antonioli et al., 2014; Martín-Gutiérrez et al., 2017; Jowallah et al., 2018; Rizzoto, 2017; Winn, 1993). Immersive VR, for example, "allows us to construct knowledge from direct experiences not from descriptions of experience" (Winn, 1993, p. 8), as happens when learning by reading from a textbook. Said to have benefits for visual, kinesthetic, and auditory learners, this ecosystem may increase learner engagement across numerous academic and therapeutic disciplines. It is often suggested that the best use of this ecosystem aligns with constructivist learning theory, which emphasizes how learners construct meaning during "meaningful and authentic" first-person experiences and where teachers facilitate that learning through scaffolding and fostering collaboration (Fowler, 2015; Jonassen, 1994; Jowallah et al., 2018; Martín-Gutiérrez et al., 2017; Onyesolu et al., 2013; Winkler et al., 2002; Winn, 1993; Youngblut, C., 1998).

Dalgarno and Lee (2010) provide an encompassing view of the theoretical learning affordances of three-dimensional (3D) virtual learning experiences, which are applicable to this ecosystem. These are the learning affordances of (a) enhanced spatial knowledge, (b) experiential learning, (c) increased motivation and engagement, (d) contextualization, and (e) collaboration. This perspective, when paired with Jeremy Bailenson's DICE discussion in *Experience on Demand* (2018) on the best option for VR experience creation, offers additional insights for when teachers may choose to leverage this ecosystem. According to Bailenson (2018), VR should be leveraged for situations that are deemed dangerous (D) or impossible (I) to experience in the real world (i.e., going back in time to view historical sites). In addition, Bailenson (2018) suggests VR for experiences that are deemed counterproductive (C) (i.e., where one may have an experience that might otherwise be potentially harmful in the physical world but having a VR experience may support improved understanding), and those that are either too expensive (E) or rare to experience.

### *Applications of VR/AR in Education*

There is a growing body of research illuminating the potential uses and effectiveness of VR/AR in education. This body of research on the application of VR/AR in education shows that these technologies allow for increased motivation and engagement of students (Georgiou & Kyza, 2018; Lorusso et al., 2018; Metcalf et al., 2013), as young as preschoolers (Cascales et al., 2013), and changes in perspective which is a factor in socio-emotional development and empathy-building (Herrera et al., 2017). This ecosystem provides safer, error-free spaces in which to practice vocational skills (Baus & Bouchard, 2014; Sirakaya & Cakmak, 2018; Zhou et al., 2018) through what Brown et al. (1989) refer to as situated learning.

The use of VR/AR supports students in safely practicing self-regulatory strategies during encounters with anxiety-inducing experiences (Baus & Bouchard, 2014; Maskey et al., 2019; Parrish et al., 2016). Jeffs (2009) posits that this ecosystem has the capability to support therapy for sensorial and physical disabilities or injuries; it also has the capability of providing alternatives to treatments and therapies for learners with Autism Spectrum Disorder (Bystrova et al., 2019; Maskey et al., 2019; Parsons, 2016; Ramachandiran et al., 2015; Strickland, 1997; Wallace et al., 2017; Yang et al., 2017). Allowing for learning outside the classroom and remotely, inclusive of virtual field trips to places far away (Desai et al., 2008; Markowitz et al., 2018), VR/AR is being considered as a potential mechanism to promote equity for all learners regardless of where they live.

### *Impact of VR/AR on Learning*

Researchers continue to discover that students who have virtual and/or augmented reality learning experiences may have better engagement and learning outcomes than their peers who do not (Georgiou & Kyza, 2018; Parong & Mayer, 2018; Zouboula et al., 2008). On the other hand, Zhou et al. (2018) found no statistically significant difference in the mean task completion times between those who practiced assembling a computer using VR and those who did not. With no statistically significant difference, Zhou et al.'s (2018) findings could very well be a signal that VR could be a potential alternative for practicing this particular task. Metcalf et al.'s (2013) qualitative study on the feasibility of the use of a multi-user virtual environment (MUVE) for environmental ecosystem learning involved 1330 Grade 5 to Grade 9 students in 63 classrooms. Some students received the EcoMUVE curriculum developed by the researchers, while others did not. That study provided some insights into teachers' perspectives on the technology; their feedback was positive relative to the practicality of implementation, fit with learning expectations, student engagement, inquiry, and investigative learning. Teachers also shared that in comparison, students who received the EcoMUVE curriculum did better on engagement and science content learning, with no difference suggested for students' understanding of complex causality learning. Better access to the technology (i.e., more powerful computers, more time with the technology, and higher speed internet) would reduce barriers to its integration per the teachers in this study.

Additional VR studies show its impact on student learning outcomes and even biological responses to the immersive experience. In a museum education study using VR for middle school students in Greece, Zouboula et al. (2008) discovered, through a collaboration with teachers, that students who experienced VR had a higher percentage of correct answers, and females in the VR group scored 100% on all the questions as opposed to males who scored an average of 76% in the same group. Female students in the non-VR group scored an average of 36%, and male students in this group 22%. VR impacted learning outcomes in this study, during which students were said to be positive about the use of VR, and some wanted to continue its use. A goal of the study had been to find low-cost options in developing a VR experience so that teachers may follow suit themselves; within this study, teacher perspectives were not. Lamb et al. (2018) conducted a biology study within a higher-education institution using a Functional Near-Infrared Spectroscopy (fNIRS) to measure the hemodynamic response in students who were provided a lesson on DNA replication. This research team used four modes of instruction: Video Lecture, Serious Education Game (SEG), Hands-On Learning, and immersive VR. The SEG and VR groups scored significantly better than those in the Video Lecture group, but their scores were not significantly different from those in the Hands-On Group. On the other hand, the VR and SEG groups had a higher response related to memory and critical thinking per the fNIR results.

Similar to studies regarding the impact of VR on learning, studies also assess the impact of AR. In an arts education study of high school students in Australia, Bower et al. (2014) used AR not just as a learning tool but also as a means for students to design enhanced visitor experiences of a sculpture park. Students shared that using AR was highly motivating for them; it was teachers who shared that the quality of the work produced by the students exceeded what could have been produced with traditional methods alone. Lorusso et al. (2018) developed an AR-cube game, Giok-the-alien, to understand how the use of AR may affect the cognitive and social processing of children in an early education setting. Findings were that children's understanding of the game, use of strategic behaviors, and collaboration with their peers increased over time. Participation and interaction with the game were high throughout the experiment. Lorusso et al. (2018) suggested that AR games, designed on technology-enhanced learning and neuroconstructivism principles, would be beneficial to students' social interaction and the development of their cognitive ability. In working with teachers to select students to be included in the study and also having teachers participate in completing surveys about the students, this research team took note that the effective use of ICT in the classroom is dependent on teacher's ability to move from an all-knowing stance to one of supporter and guide. Georgiou and Kyza's (2018) study of 135 Grade 10 students focused on immersion through the use of location-based AR applications related to environmental science learning. Outcomes of this study showed a significant positive correlation between immersion levels (which were affected by domain-specific interest and cognitive motivation) and conceptual learning gains when AR was used. Other findings spoke to the correlations between levels of immersion and learning gains.

In a systematic review of the use of VR technology with children and adolescents on the Autism spectrum, Mesa-Gresa et al. (2018) reviewed 31 studies from clinical and technical sources spanning the years 2010 to 2018, having a total of 602 participants. Most of the studies were clinical in nature, focused mostly on social-emotional learning for children with Autism Spectrum Disorder (ASD). Interestingly, even though this systematic review focused on VR, four of the studies within this review leveraged AR as well. Given the span of time of the studies in the review, it was noted that many of them used Second Life, where participants could interact in a virtual world through the use of avatars. Mesa-Gresa et al. (2018), per review, asserted that there is moderate evidence for the effectiveness of the use of VR for ASD treatments. The research team also noted that the use of AR would be a beneficial and promising option for children with ASD.

Garzon and Acevedo (2019) conducted a meta-analysis of augmented reality's impact on student learning outcomes through the review of 64 studies using statistical methods to standardize and compare effect sizes. This meta-analysis showed a significant medium effect size ($d$ = 0.68) for augmented reality, which was larger than that of other digital technologies per Chauhan's (2017) meta-analysis and Tamin's (2011) second-order meta-analysis of ICT. The effect size of AR in primary education ($d$ = .69) was higher than that of AR in lower and upper secondary education; it was higher education implementation which realized larger effect sizes. Similar to Chauhan's (2017) results, Garzon and Acevedo (2019) also discovered that AR had a larger effect size in informal settings ($d$ = .80, $p$ < .01) than in formal classroom settings ($d$ = .67, $p$ < .01). It would be important to understand the use of these technologies in informal settings such as museums and/or the home environment.

Merchant et al.'s (2014) meta-analysis on the effectiveness of Desktop VR focused on K-12 and Higher Education. The Desktop VR included in this meta-analysis took the form of games, simulations, and virtual worlds. Studies included had to have used experimental or quasi-experimental methods and must have had results from the measurement of learning outcomes. All three VR opportunities provided positive learning outcomes for declarative and procedural tasks. It was found, in this study, that VR games provided higher learning gains (FEM = 0.77, SE = 0.03; REM = 0.51, SE = 0.13) than simulations (FEM = 0.38, SE = 0.04; REM = 0.41, SE

= 0.11), or virtual worlds (FEM = 0.36, SE = 0.03; REM = 0.41, SE = 0.09). Similar to the AR study by Garzon and Acevedo (2019), this meta-analysis by Merchant et al. (2014) also provided additional insights into the potential benefits of a form of VR.

There is promise in the use of VR/AR in education. Teachers' current perspectives of the ecosystem's impact on student learning are seemingly positive. This ecosystem could positively impact student engagement and learning outcomes due in part to its learning affordances. This impact would only be realized through its diffusion into education, as can be said of the impact other ICT and digital media have had.

**Impact of Information and Communication Technology (ICT) on Education**

ICT and digital media change rapidly and continue to diffuse into society globally, changing how we live and innovate. What became known as Moore's Law in 1965 (Moore, 1965) proposes that computing power doubles approximately every two years with form factors shrinking. This means that the ability to share information in a variety of formats (i.e., text, video, audio, etc.) at high speeds is becoming more widespread. This has allowed for computing technology to be housed in smaller devices such as the laptop computer, the smartphone, and even the HMD. For example, Facebook's 2018 Oculus Quest HMD has all the computing power needed for a high-quality VR experience without the need to be attached to a high-powered computer. In addition, smartphones now allow for immersive VR experiences with the use of Google Cardboard as well as for stand-alone AR experiences. The use of digital media continues to grow exponentially in education as schools and districts strive for a "one-device-per-child" ideal. This has been precipitated by the decreasing costs of computers and the diffusion of the Internet, which is said to be an innovation with one of the fastest diffusion rates next to the mobile phone (International Telecommunication Union (ITU), 2018). According to the 2018 International Telecommunication Union's (ITU) "Measuring the Information Society Report, Volumes 1 and 2," 51.2% of the world's population uses the Internet; in the United States, this is at least 75% of the population. These enabling technologies are supporting the re-emergence of the VR/AR ecosystem.

Growing investment from governments and school districts (Blackwell et al., 2014; Erdem, 2017; US Department of Education's National Educational Technology Plan Update, 2017) and the establishment of learning standards that codify 21st Century skills (Scott, 2015; International Society for Technology in Education (ISTE), 2017) signal the importance granted to digital technology in education. The reauthorized Every Student Success Act (ESSA) of 2015 even includes provisions for the pursuit of accountable innovation at the state level.

Digital technologies impact student learning. A short review of meta-analyses focused on the use of computer technology in education is shared below. Meta-analyses are beneficial in bringing understanding to the research done in a particular field, as they are fundamentally a statistical review of various research studies about the same area. Caution may be needed given that research studies, even about the same question using the same research methods, may have some individual implementation nuances. These analyses provided insights into various study findings, which further guided this study.

In a meta-analysis of the effect of information technology on elementary-level students, Chauhan (2017) reviewed 122 studies found in peer-reviewed journals. The studies included in the analysis had to meet the criteria of having a control group with pre- and post-tests administered; if no such group was designed into the study, it had to include at least pre- and post-testing. The findings of this meta-analysis showed that technology had a significant medium effect on elementary student learning ($g = 0.546$, $z = 13.297$, $p < 0.001$). This meta-analysis also included a review of four moderating factors, namely, domain subject, type of computer application used, duration of the intervention, and the learning environment. Informal learning environments, coupled with interventions between one and six months, had the largest effect size ($g = 0.926$, $p < 0.001$); the next largest effect size was for when technology was used in informal settings with learning-oriented applications (i.e., applications specifically designed for educational learning as opposed to general applications such as those found in the Microsoft Office suite for example) ($g = 0.700$, $p < 0.001$).

In comparison, a second-order meta-analysis of ICT in K-12 and post-secondary education, including data from forty years of studies (1968 to 2008), showed a small to moderate effect size when computer technology was used (mean effect size [ES] of 0.30 to 0.35 for the second-order meta-analysis and its validation study for both fixed and random effect models) (Tamim et al., 2011). This second-order meta-analysis focused on studies conducted in formal learning environments; these findings are somewhat similar to Chauhan's (2017) study, where the effect size for formal learning environments was moderate ($g = 0.534$, $p = 0.000$). Tamim et al. (2011) also found that the effect size for the use of technology was significant in K-12 instruction (ES = .40, SE = 0.04) and this was higher when compared to use in post-secondary settings (ES = .29, SE = 0.03).

Even with these positive effects, the impact of ICT on education and students is still a cautionary tale. It is noted that teachers may be leveraging ICT as an end in itself (i.e., teaching learners how to use computing software and not necessarily how to use the technology to develop solutions), substituting for analog practices as opposed to redefining the teaching and learning process to manifest Redecker et al.'s (2009) pedagogical innovation.

Puentedura's (2006) SAMR model provides a synopsis of the potential progression of technology integration in teaching, what could be deemed as the quality of integration. According to Puentedura (2006), teachers may use technology to either enhance or transform current pedagogical practices and learning experiences. Enhancement starts with teachers having students use technology for a task that was done before the technology's introduction; this he calls substitution (S). The next level of integration is augmentation (A), where teachers use technology to increase the effectiveness of completing a task. As teachers move from augmentation to modification (M), they enter the realm of transformative integration. In the modification stage, teachers begin to redesign student tasks; for example, students now use a computer to complete writing assignments and can provide feedback to each other virtually through a file-sharing platform. The final step in integration, according to Puentedura (2006), is where teachers redefine (R) tasks through the creation of new tasks that were not possible prior to the use of the technology.

Whether teachers using VR/AR reach Puentedura's (2006) stage of redefinition of teaching, a parallel to Redecker et al.'s (2009) pedagogical innovation, could only come to be if the ecosystem diffuses into education. Teachers are the critical determinant of the extent of the diffusion.

### *Digital Technology's Diffusion into Education*

Studies on the diffusion of innovations, namely digital technological innovations, in education may shed light on the potential path for VR/AR. These studies often speak to the multitude of factors that drive teachers' acceptance, intention to use, barriers to adoption, and actual usage. Surry's (1997) review of how diffusion of innovations theory has been used to study the adoption of instructional technology provides two variations. He shares that (a) some research has leveraged innovation diffusion theory to determine how instructional technology could be a lever in school reform, while (b) others have used the findings from applying diffusion theory to increase adoption and use. Sahin (2006) reviewed early educational technology diffusion studies spanning 1998 to 2003. Most of these studies were from higher education, and those focused on PK-12 education were interestingly doctoral dissertations. This is somewhat congruent with the search and review of the literature regarding DOI within the educational technology arena; more often than not, the literature has been focused on higher education. The examples found within elementary and secondary education, and sometimes higher education, provide insights on diffusion within those educational settings.

In a quantitative study, Daher et al. (2018) monitored the integration of ICT by in-service middle school mathematics teachers as they also mentored pre-service teachers in mathematics instruction. As the pre-service teachers, still being supervised by the training college and its researchers, were being supported to adopt ICT, the in-service teachers were to also adopt the same technologies in their practice. Semi-structured interviews were used to understand the knowledge base, beliefs, and experiences of in-service teachers, and observations were used to evaluate actual ICT integration. In their findings, the researchers shared the difficulties in persuading in-service teachers to adopt ICT for math instruction given their lack of prior experience using ICT, even though they had positive beliefs about ICT's benefit. This was different from the researchers' experience with pre-service teacher ICT adoption; interestingly, it was the support of pre-service teachers that improved the in-service teachers' knowledge and thus integration over time. The use of the diffusion of innovation theory in the study was to guide what adoption constructs would be the focus, namely teacher beliefs and decisions, and to support the contextualization of the findings from the study. The understanding that in-service teacher adoption experiences may differ from that of pre-service teachers is an important distinction.

In a qualitative study with the use of semi-structured interviews, Stieler-Hunt and Jones (2015) set out to uncover the day-to-day experiences of teachers who leveraged digital gameplay (DGP) in their elementary and secondary classrooms to better understand why they used DGP. Believing that DGPs could benefit student learning was a starting factor in educators' use; these educators saw the value of and, at times, enjoyed using DGP themselves. The key findings from this study were then categorized using the five characteristics of an innovation a potential user must perceive (i.e., relative advantage, compatibility, complexity, trialability, and observability) which is part of Rogers' diffusion of innovations theory. Stieler-Hunt and Jones (2015) used this five-characteristic review to predict that the adoption of DGP would continue to remain low at that time primarily because observability was difficult to attain. Unlike other DOI studies that use diffusion theory to structure the research or understand findings, Stieler-Hunt and Jones (2015) leveraged this theory to gauge the potential rate of diffusion.

Hoerup (2001), through an ethnographic research design, studied factors affecting Grade 5 teachers' computer technology adoption and the degree to which collaboration played a role in this process. In learning more about each teacher and using Rogers' DOI theory, Hoerup was able to determine their level of innovativeness, which adopter category they belonged to, and when they may adopt computer technology during the research study. Access to and contact with the change agent in the school, found in Rogers' (2003) early adopter group, increased the likelihood of adoption for teachers who were late adopters in the research study. The early adopters, who were more comfortable with the use of technology, instigated collaboration around its use; they supported the laggards in their adoption.

Blankenship's (1998) goal was to determine the factors that drove teachers' use of computers for instruction and to develop a set of recommendations for a specific PK-12 school district to improve usage. Usage was defined as frequency as well as how computers were used (i.e., computer skill instruction, whole group instruction, student-directed learning, practice, etc.). With a survey followed by five focus groups that included teachers in certain PK-12 grade bands (i.e., PK-2, 3-5, etc.), Blankership (1998) discovered that overall, training was the critical deciding factor for a teacher's propensity to use computers for instruction, followed by attitude, support, access, and age. He also discovered that the priority given to these factors, when broken down by grade level as well as curriculum area, varied.

Shaban's (2017) study aimed to understand the degree to which DOI theory explained the decisions made by in-service "intensive English Language teachers" (p. 36) to adopt computer technology for instruction. Through an offering of researcher-led workshops to introduce the technology, surveys, interviews, and other anecdotal methods, Shaban discovered that the perceived value of the technology was a key driver for adoption. On the other hand, through this study, Shaban also uncovered some of the barriers to adoption – time, limited resources, nostalgia for old methods, and technology's unreliability.

Research studies, inclusive of literature reviews, on factors affecting ICT acceptance, adoption, and integration in education show that in addition to perceptions of the technologies' features, there are three levels of factors influencing teachers' intention and usage of technology. First-order extrinsic factors are institutional-level/school-level factors – perceived support from school leadership, what Alone (2017) calls the "patronage factor," technical support, the school's technology policy, student characteristics, professional development, and accessibility (Blackwell et al., 2014; Buabeng-Andoh, 2012; Makki et al., 2018). Second-order factors are intrinsic factors (teacher-level) that also influence intention and use. Teachers' perceived ease of use (PEOU), perceived usefulness (PU), attitudes about technology and their levels of comfort and self-efficacy are second-order factors; these are in addition to age, gender, the value teachers place on technology for teaching and learning (Blackwell et al., 2014; Buabeng-Andoh, 2012; Makki et al., 2018) as well as their workload (Buabeng-Andoh, 2012). Tsai and Chai (2012) bring forth the concept of a third-order factor, teachers' "design thinking," which is the "dynamic creation of knowledge and practice by teachers when they are confronted with the advancement of ICT and its associated pedagogical affordances" (p. 1058). Makki et al. (2018) support this concept of third-order factors, concluding that supporting teachers' design thinking abilities so that they can effectively harness the affordances of the technology for instruction is also critical. Teachers must create different types of new knowledge when encountering innovations.

This research study looked to the various theories and frameworks, which intrinsically explain the findings from diffusion studies reviewed and shared above as a guide. These theories and frameworks provide insights into the potential process of diffusion and development of new knowledge during the adoption of an innovation such as VR/AR.

## The Diffusion of Innovations Theory and Related Frameworks

Diffusion, the process of acceptance, adoption, and integration of innovation by a social group, starts with an individual learning about the innovation, even if requested to use it involuntarily as part of a larger group initiative. Diffusion happens within the context of a social system, and an innovation's spread is a group phenomenon. A critical theory that supports the contextualization of VR/AR in education in this study is Rogers' (2003) Diffusion of Innovations theory. In 1962, Rogers, a professor of rural sociology, published a seminal book developed through the study of 408 diffusion cases, "The Diffusion of Innovations." Now in its fifth edition, the theories presented in this frequently cited work have informed how innovation diffusion is understood in many fields.

Rogers (2003) defines diffusion as "a process in which an innovation is communicated through certain channels over time among members of a social system" (p. 5). Rogers goes on to define technology as "a design for instrumental action that reduces the uncertainly in the cause-effect relationships involved in achieving a desired outcome" (p. 13), infusing an element of improved efficiency and/or effectiveness. For innovations to diffuse, in this case, the virtual and augmented reality technological ecosystem, four elements have to be at play, they are (a) the innovation itself, which has to be seen as being novel, (b) the critical communications channels for information sharing, (c) time and (d) a social system. Diffusion is ultimately a social process where individuals within a social system who have adopted an innovation share information through their communications channels, mass media included, to non-adopters, and then must take action regarding full integration of the innovation at some point in time.

Per Rogers (2003) DOI theory, for an innovation to diffuse, individuals in the social system, in this case, PK-12 education, go through a five-stage process of information gathering and decision-making. They are (a) the knowledge stage where an individual becomes aware of the innovation but does not have much information about it yet; (b) the persuasion stage where the individual seeks out information about the innovation out of interest; (c) the decision stage where the individual weighs the pros and cons of usage to determine whether to adopt or reject the innovation; (d) the implementation stage where the innovation is being used, but its usefulness is still being assessed, and finally (e) the confirmation stage where the individual makes a final decision to continue to use the innovation. This five-stage process transpires regardless of whether members of the social system voluntarily or involuntarily choose to adopt and integrate the innovation (Rogers, 2003). It must be noted that at any stage, an individual may discontinue the use of the innovation, oftentimes due to a dissatisfactory experience; with that said, understanding adopters' experiences and perceptions of those adoption experiences becomes important in understanding diffusion.

According to Rogers (2003), there are five different adopter groups with distinct characteristics. The first group to adopt an innovation is the Innovators, who make up 2.5% of the population. Innovators tend to use new technology before it becomes mainstream and sometimes are involved in the technology's development. Innovators are visionaries with a complex, heterogeneous social system that extends beyond their primary social network. They are followed by Early Adopters (the next 13.5% of the population) who see some level of proof of effectiveness from the Innovators and begin to use it themselves.

It is actually the Early Adopters and not so much the Innovators who have the most influence on future adoption, as this group's composition includes spokespersons, those who are in high regard within the social system. Innovators are seen, at times, as being mavericks and not mainstream. Following the Early Adopters are the Early Majority (the next 34%), a group of pragmatists; it is at this point where the chasm is crossed, and mass adoption starts. The Early Majority communicates within a more homogeneous segment of the social system, which may exclude the Innovators. They prefer to purchase established innovations from established providers and tend not to purchase until they witness other Early Majority members using the innovation. The Early Majority tends to adopt and integrate an innovation because others in this group have done the same; this becomes a paradox. The chasm is thus a critical juncture, which, if not crossed, could mean the demise of the innovation's diffusion. It is when the Late Majority (the next 34%) adopts that there will be a critical mass within the social system using the innovation; the Laggards (16%), per Rogers (2003), are the last group to adopt if they do at all. Each group influences the next through the sharing of information and experiences (Rogers, 2003). The rate of adoption is related to the speed at which each adopter group integrates the technology.

In addition to providing insights on the process of innovation diffusion, Rogers (2003) shares five critical factors affecting adoption. They are:

- The *relative advantage* of the innovation compared to current methods and tools,
- Its *compatibility* with current beliefs and methods,
- Its level of *complexity* during use,
- Whether the innovation can be experimented with giving it an element of *trialability,* and
- Whether the results garnered from the innovation's use are visible with an element of *observability*.

Rogers' (2003) theory provides organizing concepts related to an innovation's emergence through sustainability (Aizustauta et al., 2015). This theory spotlights how innovations may spread within a social system, with each adopter group informing the next. Critics suggest that the diffusion of innovations theory does not take into account all the factors affecting individual adoption and integration and some nuanced reasons for adoption. For example, the complexities of digital technology can mean the need for complementary technology for a specific technology to be adopted (i.e., computer hardware cannot be adopted without software applications to render it useful for tasks or content). In addition, individuals and/or organizations may have to adopt technologies due to mandates, regulations, competitive forces, changes in policies, and/or external pressures (Lyytinen & Damsgaard, 2001). In such cases, the decision-making process may be highly truncated.

Communication, within the diffusion of innovations theory, is seen as mostly uni-directional, where the innovation's creator and current adopters inform those downstream. On the other hand, communications could indeed be bi-directional, especially where participatory decision-making facilitates improved adoption. Last but not least, digital technology changes often, and the technology adopted by the Innovator, or the Early Adopter may be quite different from that which the Late Majority adopts, adding further complexity to the application of diffusion of innovations theory. It is thus beneficial to also understand frameworks that are complementary to the diffusion of innovations theory, especially those that focus on the acceptance, adoption, and integration of digital technology. These, including the Theory of Reasoned Action (TRA), the Technology Acceptance Model (TAM/TAM2), Theory of Planned Behavior (TPB), the Motivational Model (MM), the Model of PC Utilization (MPCU), the Unified Theory of the Acceptance and Use of Technology (UTAUT/UTAUT2), etc., have also influenced research on the adoption and integration of ICT in various settings including education.

UTAUT/UTAUT2 (Venkatesh et al., 2003) was developed through a six-month longitudinal empirical comparative study of eight such technology acceptance models with 32 constructs in total, inclusive of the diffusion of innovations theory's factors affecting adoption. It was found that the UTAUT model explained as much as 70% of the variance (adjusted $R^2$) in intention to use ICT and 48% of the variance (adjusted $R^2$) in usage behavior. Even though the four organizations from which the data were collected were not PK-12 education organizations, this framework is generalizable to most settings. The findings from a complex set of statistical analysis allowed the researchers to "theorize that four constructs will play a significant role as direct determinants of user acceptance and usage behavior:  performance expectations, effort expectations, social influence and facilitating conditions" (p. 447-447) with gender, age, and voluntariness of use as moderating factors. With an update to UTAUT2, Venkatesh et al. (2012) included additional factors, that hedonic motivation and price value directly affect behavioral intention, and habit directly affects use behavior. Habit can be viewed as a parallel to Reinhardt and Gurtner's (2018) concept of "embeddedness". UTAUT/UTAUT2 is a helpful framework in understanding the potential variations in attributes of pioneer teachers and was leveraged for this study related to participant selection.

## New Knowledge at the Intersection of Technological Innovation and Education

### *New Knowledge Creation*

The movement from current practices - even of models, content, processes, policies, etc. - to future innovation-embedded practices creates a knowledge gap, which the development of new knowledge, skills, and dispositions will close (Badilescu-Buga, 2013; Scott, 2015). Adopting innovation causes "an initial knowledge gap between the current knowledge and the knowledge needed for using the innovation effectively. Addressing the knowledge gap is an important challenge in the adoption of innovation" (Badilescu-Buga, 2013, p. 903). The creation of new knowledge is "a spiraling process of interaction between explicit and tacit knowledge" which allows "self-transcendence" from old to new (Nonaka & Konno, 1998, p. 42). The knowledge required changes during each phase of innovation diffusion as information moves from one adopter group to the next (Rogers, 2003). This knowledge is related to the understanding of causal, conditional, procedural, and relational information (Zack, 1999) as well as of the thing in and of itself. For this technological ecosystem, knowledge developed through the adoption and integration may thus center on:

- The technology itself and how it works (the know-what),
- Its benefit to enhance the instructional process or its hindrances to that process (know-what, know-why [causal knowledge]),
- When (know-when [conditional knowledge]) and how (know-how [procedural knowledge]) to appropriately use it for specific learning activities (know-why),
- How specific learners will best be able to access and engage in learning with it (know-with [relational knowledge]), and
- How to integrate it into the instructional process (planning, content delivery, assessment, etc. (know-how [procedural knowledge])

As the technology continuously improves, so is there a need for new knowledge: a new all-encompassing “know-how” that will drive action in practice (Nonaka & Konno, 1998).

VR/AR technologies have unique affordances to be exploited within diverse use cases, which would be realized through continued diffusion; this would occur through continued, habitual integration into teaching and learning practice. Knowledge informs practice. With knowledge building at each stage of diffusion to narrow the innovation adoption knowledge gap, understanding is needed regarding how teachers are currently building new knowledge and what this knowledge is. Harnessing the full potential of VR/AR into teaching and learning requires an interplay between technology and pedagogy (Jowallah et al., 2018). The new knowledge needed to adopt and integrate new technologies would be one that allows teachers to leverage specific technologies to deliver learning experiences to students through specific pedagogical practices.

***Technological Pedagogical Content Knowledge (TPACK)***

A framework that guides an understanding of the knowledge teachers may need to integrate technology into teaching and learning outside of classroom management, understanding learners, etc. (Shulman, 1986) is Technology Pedagogical and Content Knowledge (TPACK). TPACK, a framework developed by Mishra and Koehler (2006), is an expansion of Shulman's (1986) Pedagogical Content Knowledge (PCK) framework. Mishra and Koehler (2006) argue that teachers need to bring together their knowledge of content (i.e., what needs to be mastered by learners), pedagogy (i.e., instructional methods), and technology to design innovation-embedded experiences for learners. They must do this by leveraging appropriate technology-infused pedagogical practices. Technology comes with its critical affordances and limitations; thus, knowledge building to minimize its inappropriate use becomes imperative (Koehler et al., 2013; Mishra & Koehler, 2006). With new technology adoption and integration comes the need for new knowledge on how this technology can effectively be used to enhance instruction and, ultimately, student outcomes.

Mishra and Koehler (2006) posit that there must be "thoughtful interweaving of all three key sources of knowledge" (p. 1029) to design and implement technology-infused lessons. When using emerging educational technologies, such as virtual and augmented reality, teachers would need to "reconstruct the dynamic equilibrium among all three elements" (Koehler et al., 2013 p. 17). Mishra (2019) recently furthered this TPACK framework with the explicit addition of a concept surrounding TPACK, namely Contextual Knowledge (XK). Mishra argues that understanding the context in which one is operating is critical; this context regarding the classroom environment, the political climate of the district or school, etc., is akin to first-order extrinsic factors as enunciated by Makki et al. (2018).

TPACK as only a technology-enhanced extension of Shulman's (1989) PCK is debated, as is the concept Mishra and Koehler (2006) put forth: that TPACK is the juxtaposition of the three centers of knowledge. Critics argue that TPACK is not only created from the use of these three knowledge centers or an augmentation of PCK but, in fact, a new knowledge center that is created through the merging of these three (Voogt et al., 2012). Even with differing perspectives on the theoretical definition and evolution of TPACK (Archambault & Barnett, 2010; Voogt et al., 2012), it is a critical conceptual framework that must be deliberately considered in understanding what and how knowledge may guide teachers' integration of new technology into their teaching practice. Emerging new technology, such as the VR/AR ecosystem, often requires not just a building of new knowledge but also a change in teachers' TPACK*,* making TPACK a fluid concept (Voogt et al., 2012). Given that technology is leveraged within specific classroom and subject-matter contexts, Voogt et al. (2012) conclude in their review of TPACK literature that additional study is required to further develop subject-matter-specific TPACK. For example, TPASK was developed for science (Jimonyanis, 2010 as cited in Voogt et al., 2012), and Guerrero (2010) developed concepts around TPACK for mathematics instruction. This is a critical request that must be pursued but it is also critical that the peculiarities of the specific technology, especially its affordances/limitations, also be considered outside of specific subject-matter contexts.

**Contextualizing the Virtual and Augmented Reality Diffusion in Education**

The diffusion of the VR/AR ecosystem in PK-12 education is currently in the hands of Rogers' (2003) Innovators and Early Adopters, named pioneer teachers within this study. The chasm has not been crossed yet to reach the Early Majority. To understand the current state of diffusion, one has to pivot from the educational literature to market analyses. Reports such as those from Gartner Research, a preeminent market research organization, suggest current adoption in all education is about 5% to 10%, signaling an early market introduction where current users are Innovators and Early Adopters.

Recent changes in information and digital computing technologies, especially the use of the smartphone, have enabled the VR/AR ecosystem to be accessible to a wider range of users (i.e., smartphones allow for the use of a $15 Google Cardboard, which offers a low-cost immersive virtual reality experience; smartphones also allow for free downloadable apps that make characters come alive in augmented reality children's books, etc.). The acceptance of this ecosystem as a learning tool and, thus, its level of use and rate of adoption in education are still in their infancy (Blackwell et al., 2014), and the COVID-19 pandemic may further impact the trajectory of future adoption.

Over 500,000 teachers, students, and parents completed a survey within a SpeakUp (2016) annual K-12 Educational Technology survey focused specifically on virtual and augmented reality technologies. When asked to envision their "ultimate school," middle school students (Grades 6-8) responded that they would like to see VR (47%) and AR (33%) applications in their classroom; teachers 23% for VR and 13% for AR whereas 36% of District Administrators envisioned VR use with 20% for AR use in future classrooms.

Dalim et al. (2017) conducted a literature review of empirical studies focused on the effectiveness of AR in education to extract and understand the factors that may influence teachers' acceptance of augmented reality. They identified six such factors:

- The technology must be tied to content and pedagogy ("Curriculum")
- The AR application must be able to provide a seamless experience from start to finish ("Stability of Interaction")
- Students must be able to self-guide through the AR experiences ("Self-Learning Capability")
- Parents must participate in supporting the use of AR ("Parent's Involvement")
- The context surrounding students should be considered ("Student's Background")
- The AR application and enabling tools/devices must support the experience ("Platform")

As this study was a review of other studies, the voice of teachers could not directly be captured.

As noted by Mundy et al. (2019), it is through large empirical studies that teachers' perspectives arise about VR/AR. Thus, Mundy et al. (2019) embarked on a related study regarding the use of AR in K-12 and higher education with a focus on understanding the beliefs, attitudes, and perceptions of teachers, professors, and administrators on using AR with students and what they believed the effect on student interest and engagement were. Through an online survey with the use of a Likert scale and open-ended questions, Mundy et al. (2019) first discovered some level of confusion between AR and VR (i.e., participants speaking of virtual trips while referencing AR). Per the 35 participants who completed the survey, AR was being used to introduce new concepts, to examine structures, or to go to faraway places. In addition, some had students use AR to create interactive bulletin boards to show their knowledge. In this study, DOI theory was leveraged as a way to contextualize who the current AR users are, namely

Rogers' (2003) Innovators and Early Adopters. DOI theory was not used to explain the results of this study, as was included in some previous ICT studies. The perspectives of teachers and educational leaders were seen through this study; however, given that a survey method was used, the researchers would have had to interpret some of the insights from the participants without having an opportunity to check for understanding in situ as would be done in an interview.

VR/AR has the capability to positively impact student engagement and learning outcomes. This ecosystem has pedagogical benefits and could be a driver of new pedagogies (Dalgarno & Lee, 2010; Desai et al., 2008). To be emerging disruptive educational technologies, as they are being touted to be, their use should potentially go beyond the emulation of current pedagogical practices and become pervasive. On the other hand, care must be taken regarding its use, given potential data privacy and security concerns that arise with its affordances (i.e., eye tracking, etc.) (Craig & Georgieva, 2018). Some researchers have also warned against the possible negative effects on children (e.g., the potential for the development of false memory for young children given that their pre-frontal cortex is developing still) (Segovia & Bailenson, 2009) and thus the potential need for new educational technology policies (Blackwell et al., 2014; Georgiou & Kyza, 2018; Jensen & Konradsen, 2018). Regarding the increased use of AR as the technology improves, Azuma (1997) also cautions that social and political concerns should not be ignored; even though his suggestion was not education-focused, it is an important point to contemplate.

The use cases for the VR/AR ecosystem continue to be better understood, designed, and implemented. The impact of this ecosystem on students' learning experiences, motivation, engagement, and outcomes are mostly positive thus far. The voice of teachers comes through empirical studies where research teams are working to determine the effectiveness of this ecosystem (Mundy et al., 2019). Teachers' voices in published studies are thus far mostly positive regarding how this technology motivates students, and some have taken note that the learning outcomes are better than when traditional methods alone are used. A caution here is whether this assertion in the literature of VR/AR's contribution to better motivation, engagement and, learning outcomes could potentially be due to the technologies' novelty (Oprean & Balakrishnan, 2020) or even to publication bias. The researcher is anecdotally aware of two cases where educators abandoned the use of the ecosystem.

Dalim et al.'s (2017) review of studies provides information on what teachers may expect related to the acceptance to use this technology. Mundy et al. (2019) uncovered, using a survey method, the perspectives of teachers and administrators on the use of AR with students, including what teachers may be using AR for. Given the methods selected, there was no capture of teachers' first-hand experiences on how they came to adopt AR, how teachers developed new knowledge to be able to use AR, and/or how the use of AR has impacted their practice. Given the potential for this ecosystem to revolutionize education and the fact that pioneer teachers may very well be the influencers of further diffusion, it is important to understand their experiences and perceptions of those experiences alongside the research on the ecosystems' use and effectiveness.

The diffusion of this technology hinges on ensuring continued momentum with the community of pioneer teachers, as they would be the critical influencers of other teachers. Pioneer teachers have had to make a conscious effort to embark on Rogers' (2003) five-stage information gathering and decision-making process ahead of others; this means that they would have developed new knowledge (e.g., new TPACK) in order to accept and adopt this innovative ecosystem into their teaching and learning. A focus on just the experiences of PK-12 teachers currently using AR/VR has not been prominent in the literature to date.

Intending to balance what Surry (1997) calls the deterministic and instrumentalist perspective of instructional technology diffusion, this study aimed to focus directly on the experiences and perceptions of pioneer teachers to shed light on current adoption, integration, and the possible paths to further diffusion. The various theories, frameworks, and structures presented here informed the process by which this study strove to answer the research questions. In Chapter III, there will be a review of the design and methods used in this study such as the approach to finding participants, the procedures used for data collection and organization, and the process and systems for data analysis.

# CHAPTER III - METHODOLOGY

The purpose of this chapter is to introduce and review the research method used to conduct this study regarding pioneer teachers' experiences of adoption and integration of the virtual and/or augmented reality, their development of new knowledge (e.g., TPACK) related to this emerging technological ecosystem, and the impact on their practice when using these technologies for PK-12 teaching and learning.

## Introduction to Research Approach

Given the purpose of this study to understand the experiences and perceptions of pioneer teachers, a qualitative method was selected and implemented. This study specifically used a Hermeneutic Phenomenological research design methodology focused on the use of interviews, with further qualitative content analysis where lesson-planning documentation was available. Hermeneutic Phenomenological research methodology is a process by which to understand and interpret lived experiences and the meaning they are given (Kakkori, 2009; Laverty, 2003; van Manen, 2014, 2016). This design allowed for a deeper understanding of the lived experiences and perceptions of participants regarding the phenomenon of the diffusion of VR/AR innovation, thus being best suited to answer the research questions.

This qualitative approach, with a focus primarily on the use of interviews, is further discussed in this chapter through a review of the research plan and its execution. This plan includes details of the research design, the selection of and interaction with the participants in the study, the procedures used to conduct the study, the process of analysis, the maintenance of reliability and validity, and the mitigation of ethical concerns.

### ***Research Questions***

As stated in Chapters 1 and 2, this study first situates virtual and augmented reality within the diffusion of innovation theory to provide a context in which the experiences and perceptions of pioneer PK-12 teachers may be understood. The following research questions were pursued:

**Research Question 1 (RQ1):** What are the experiences and perceptions of these experiences of pioneer teachers regarding the adoption and integration of virtual and/or augmented reality in teaching and learning for PK-12 students?

- How do pioneer teachers build new knowledge (e.g., TPACK) within the context of the innovation adoption and integration process?

**Research Question 2 (RQ2):** How do teachers integrate virtual and/or augmented reality into learning experiences, and how does this integration impact their teaching practice?

- How does this integration affect the planning of learning experiences, classroom structures/management, pedagogical practices, methods of assessing learning, and/or other areas?

Firstly, RQ1 allowed for an understanding of how the pioneer teachers came to adopt and integrate this emerging technology. Secondly, RQ1 allowed for an understanding of how pioneer teachers developed new knowledge related to the technology. RQ2 exposes how the integration may have affected (i.e., caused modification to, etc.) teaching and learning or not.

## Research Design and Methodology

Research on the use of digital technology in education is often conducted using quantitative methods (Foster, 2002; Hoepfl, 1997). However, given the purpose of this study to understand and explain lived experiences, knowledge creation, and integration's effect on teaching, a quantitative method, which primarily looks at the relationships between predetermined variables, was an inappropriate approach for this study. A qualitative research method was thus selected for this study. Qualitative research methods provide processes by which to understand the participants' perceptions of how they constructed meaning from their lived experiences and their impact on them within their specific contexts. These elements of qualitative research were well suited to adequately and appropriately answer the research questions.

During the research design selection process, care was taken to understand the philosophical underpinnings of various qualitative design options, especially their ontological and epistemological roots, and thus their implications for research (Kakkori, 2009; Luo, 2011). A relativistic philosophy and an interpretivist perspective, where truth is not seen as an absolute but rather as peculiar to the specific context of the participant, was adopted for this study (Laverty, 2009; Luo, 2011). Thus, within the sphere of qualitative methods, this study used a Hermeneutic Phenomenological research design with interviews based on active interviewing theory (Holstein & Gubrium, 1995) and where possible, qualitative content analysis. Hermeneutic Phenomenological research design was selected as it focuses on uncovering the meaning participants give to their experiences as they recount them. Holstein and Gubrium's (1995) active interviewing theory calls for an interview that is focused on the "hows" of the interview and the "whats" - what is being asked and communicated. Through active interviewing, participants make meaning about experiences and their knowledge creation *in situ* through collaboration with the researcher, who consciously asks questions to elicit the meaning of what is being conveyed. It is the participant, not the researcher, who puts emphasis on the elements of their experience that are most important to them and declares how these experiences may have impacted them. In effect, this study required teachers to reflect on past experiences, which could not be replicated in the moment; thus, the use of active interviewing supported a deeper understanding of that history. This understanding of active interviewing plays on two concepts from Nonaka (2008). The first concept is that the creation of new knowledge is not passive; it involves the self and its reinvention; the second is that making meaning may signal a movement from tacit knowledge to explicit knowledge. The use of active interviewing supports the interpretivist view and permits the development of new knowledge in situ regarding teachers' perceptions of lived experiences and knowledge creation, for example, by making teachers' tacit knowledge explicit.

In addition to interviews and qualitative content analysis where possible, a starting point for this study was the collection of interest and demographic information from potential participants; it was from this pool that the researcher determined final participants. This survey allowed potential participants to express their interest in being included in the study and also provided insight to the researcher on their demographic profiles, as age and years of teaching experience can impact the propensity of teachers to adopt and integrate technology (Venkatesh et al., 2012). It was when lesson-planning documentation was available that qualitative content analysis was performed to further understand how teachers leveraged their new knowledge in designing learning experiences for students and their intentions for those experiences. The use of a Hermeneutic Phenomenological research methodology through the implementation of active interviewing, inclusive of document analysis where possible, best supported answering the research questions.

**The Study Participants**

The population for this study was teachers who have designed and implemented VR/AR learning experiences for PK-12 students, as information on the use of VR/AR for this age group is not as prominent in the literature. Considering that the data required to answer the research questions were to be obtained directly from pioneers' recount of their experiences and their perceptions of those experiences, and given the nascent use of this technological ecosystem, the participant selection process was a critical and complex undertaking. The concepts of purposeful, maximum variation, yet convenient sampling (Hoepfl, 1997; Merriam, 2009; Patton, 1990) informed the methods used to locate and select participants. Purposeful sampling calls for the selection of 'information-rich' subjects who can be studied in depth.

According to Rogers (2003), pioneers are those who gravitate towards innovations and are those who may very well set the tone of the trajectory of the use of an innovation in their community. In addition, Rogers speaks to the idea that the process of innovation diffusion can either be voluntary or involuntary on the part of adopters, and peer-to-peer information sharing often supports this process. These concepts of voluntariness and communication channels provided an anchor from which the modes used to locate pioneer teachers were developed. For example, sometimes the district and/or school selects the technology (i.e., making it involuntary to some degree for teachers in terms of adoption), and at times the teacher voluntarily adopts the technology use outside of district/school-wide initiatives. The search for participants thus had to be through both districts/schools and networks to which pioneer teachers and their supporters may belong.

To find districts/schools to engage in the study, a review was conducted through news articles, conference proceedings, research publications, industry reports, etc., on companies providing the technological hardware, software, applications, tools, and experiences for education. To locate teachers who may have adopted this technology outside district initiatives, various networks were leveraged (i.e., member organizations such as the International Society for Technology in Education (ISTE), VRARA, Educators in VR, VR/AR in education Meet-Up groups, presentations and findings shared during conferences by researchers and educators, etc.). Discussions were held with various authors, and experts focused on educational technology who were able to provide further insights into where this ecosystem was being leveraged. The researcher also used personal technology and education-related networks to locate participants as well as social media (i.e., Twitter).

For districts/schools that agreed to have the researcher interview their teachers, teachers were asked to volunteer to participate in the study if they so wished; they had to complete the Interest and Demographic survey (Appendix I). For teachers who voluntarily selected to use VR and/or AR, the method of solicitation via member organizations, for example, also included a link to the Interest and Demographic survey for them to express their interest in participating.

### *Interest and Demographic Information*

This web-based survey, housed in the researcher's University-hosted Qualtrics account, ensured that the same data were obtained from each potential participant. The survey was to be kept open for four weeks but due to the lower-than-expected levels of interest due to the complexities surrounding the education sector during the COIVD-19 pandemic, the Interest and Demographic survey was kept open for approximately six months. A link to this survey was provided in the participant solicitation emails/letters and postings (i.e., flyers) shared through the various channels described. The survey (Appendix I) included questions about the years of teaching, months using virtual and/or augmented reality technology for teaching and learning and personal use, gender, grade-level taught using VR/AR, and for what subject-matters/content areas. When the survey was closed, the data was downloaded onto an external hard drive and backed up to another external drive.

Based on the data collected in the Interest and Demographic Survey, and with the concepts of maximum variation, purposeful, and convenient sampling in mind, the researcher was guided by the following additive participant selection criteria (Appendix II – Participant Selection Criteria):

- Participants must have used/be using VR and/or AR in their teaching practice with Pre-K to Grade 12 students in various content areas, classroom contexts, and/or with various populations
- Participants are preferred to be based in the U.S.; interested participants from other countries with schools similar to those found in the U.S. could be included (i.e., those in International Schools, American Schools, etc., outside the U.S.)
- Participants may be in a public district/charter, private, parochial, or independent school
- Participants must have used/be using VR and/or AR during regular school hours, not during afterschool program hours
- Participants must be in-service teachers and not pre-service/student teachers

This study aimed to include at least twelve participants (Appendix II – Participant Selection Criteria) with whom the researcher had no prior relationship. The complexities presented to schools related to the COVID-19 pandemic meant that the level of participation was lower than expected; data from nine final participants are included in this study. Given the sparse response to solicitations, the researcher contacted all legitimate survey respondents, but not all chose to participate, and some who completed the survey enough to be contacted did not respond to multiple requests (i.e., via email and/or text). Participants were presented with a $40 gift card for their time if allowed by the member organization or district/school policy. Even with data from nine participants, as shown in Chapter IV, similar themes were uncovered across the data collected; there was a level of saturation experienced.

Schools, districts, and member organizations provided an agreement to authorize the researcher to access potential participants once the University's Institutional Review Board (IRB) had granted approval for the study to be carried out. Some schools/districts shared that given the COVID-19 pandemic and what teachers were saddled with, they would not be able to participate until the school year was more settled for teachers. Generic non-identifying nomenclature was used (i.e., the school, the district) to protect the identity of the schools, districts, and member organizations throughout this study. In addition to reaching participants through the channels mentioned above, the researchers also used personal networks within the field of education and technology to locate additional participants.

## Procedures

### ***Procedures – Pre-Data Collection***

The dissertation proposal was presented to the Dissertation Committee, and once approved, the researcher submitted all required documents to the University's Institutional Review Board (IRB). Given that the IRB required information on where the study would be conducted, the researcher had to discuss the early preliminary study proposal with some districts/schools and member organizations to be granted permission to potentially be an organization that could be leveraged to gain access to pioneer teachers. Upon the IRB's final approval, the researcher solicited participants through the various channels described above.

Each interested participant completed the Interest and Demographic Survey from which the researcher contacted potential participants. A section of the online Interest and Demographic survey included links to information on the procedures of the study, as well as expectations of participants and the researcher. Even with the relatively lower level of responses, variations in certain characteristics of interested participants were noted (e.g., age, years of teaching experience, location, school/district initiative and not, etc.). With that said, interested participants who were contacted and provided informed consent agreeing to participate in the study were included. Ten discussions were held; however, given that one was within a higher education context, only data from nine interviews were included. Participants, at any time, had the option to exclude themselves from the study.

***Procedures - Data Collection and Organization***

Each participant was assigned a pseudonym under which all participant data were electronically filed. These pseudonyms were updated to ensure gender-neutrality given the gender profile of the final group of participants. All participants completed and signed a consent form, which was where participants indicated agreement to be interviewed, whether they agreed to have the interview audio recorded, agreement for the researcher to contact them or not after the interview, and their preferred communication method post-interview. The consent form also requested participants to provide the researcher with lesson planning documentation for a VR and/or AR learning experience; this request was optional for those who had such documentation and wished to share it. The consent form was linked from the survey, shared through the school/district leaders, and linked in all participant solicitation communication.

Consent forms provided by participants were downloaded and kept electronically on a secure external hard drive only the researcher had access to; this drive was backed up to another external hard drive and was not backed up to the cloud. A securely maintained password-protected master list was kept of participants, which included each participant's name and pseudonym.

## Data Collection and Handling

The primary data collection method for this study was the use of active interviews. A semi-structured interview guide was developed with a list of open-ended questions to be asked of each participant around key topics to be examined. Within this guide, a protocol for a think-aloud was also embedded and leveraged where appropriate; it was critical to keep an open stance to follow the participant's lead during the discussion. The interview guide (Appendix IV) was developed through the review of concepts and questions related to diffusion of innovations theory and related studies, UTAUT/UTAUT2-related studies, the valid and reliable TPACK interview guide developed by Harris et al., (2012), TPACK-related studies as well as suggested strategies for conducting Hermeneutic Phenomenological studies (Lauterbach, 2018; Van Manen, 2016). The questions in the interview guide were piloted on two educators and updated based on their feedback prior to use.

The use of a semi-structured interview guide allowed the researcher's biases to be minimized and ensured that significant deviation from the topic during the interview was minimized. The researcher maintained a level of flexibility during each interview, and where appropriate, a think-aloud type discussion strategy was leveraged to unearth the participants' thought process (Charters, 2003; Lauterbach, 2018) where suitable in the discussion. This flexibility and open stance allowed room for follow-up and probing questions to solicit more details, clarification, and implicit meanings. A level of fluidity was needed as ideas emerged that were critical to understanding the diffusion experience, which the researcher had not and/or could not have anticipated.

The interviews were planned for 60 minutes and took that amount of time on average. Given that this study was conducted during the COVID-19 pandemic, to ensure the health and safety of all participants and the researcher, all interviews were conducted remotely via the Zoom audio/video conferencing platform (https://www.zoom.us/). Per participant's consent, interviews were video-recorded; in one case, the participant chose not to be on camera, and thus only the researcher appeared in the video recording. Any time there was a break during the interview (i.e., the participant experienced a short interruption), the recording was paused and restarted when the interview continued. Interviews were recorded for transcription and analysis purposes only.  Recordings were saved to the master external hard drive. Details on the recording and transcription process can be found in Appendix III (Appendix III – Interview Recording and Transcription Protocols).

At the start of each interview, the researcher shared the intentions of the study and assured each participant that their identity would be protected through the use of pseudonyms. The participant was also informed when the recording of the interview was about to start. During each interview, the researcher captured low-inference field notes focused primarily on non-verbal communication. With the choice of Hermeneutic Phenomenological research design methodology, the researcher did not navigate the process of bracketing, epoché, called out in Edmund Husserl's expectation of Phenomenological methodology where one documents and then suspends one's knowledge and judgment of the phenomenon before entering the inquiry (Laverty, 2003). Instead, the researcher wrote memos throughout each step of data collection and analysis to capture thoughts about the phenomenon of diffusion being studied, the process of the study, and the knowledge being exposed through it. For example, after each interview, the researcher wrote a memo to capture key ideas that came to light, what was noticed, and impressions of the interview (e.g., things-gone-right (TGRs), things-gone-wrong (TGWs), information about the process, follow-up questions that may need to be improved in the protocol, participant's general tone of voice during the interview, and how the story was relayed (e.g., the pace of speaking, chronologically, autobiographically, relationally, descriptive of location of experiences, etc.). A personalized thank-you note was sent through the preferred contact method indicated by each participant; these were sent the day after the interview.

### *Document Collection and Handling*

A segment of the interview related to RQ2 involved discussing a specific VR/AR learning experience. Such a discussion allowed for how and why teachers were using the technology in those learning experiences, how they planned and implemented those learning experiences, and what might have shifted in their thinking/practice as they integrated VR/AR. Participants were asked to share recent lesson planning documentation, if available and if they so wished, where virtual and/or augmented reality was used in the classroom. The lesson planning documents were a tool to support the discussion. Participants were to discuss the decision-making, planning, and potential changes to practice related to this learning experience using the documentation for jogging their memory. Where not available, participants were still asked to recall and discuss VR/AR learning experiences with the same focus. The researcher asked clarifying questions whenever feasible and appropriate so as not to interrupt the participant but to also ensure a clear understanding of the participants' shared information, especially around meaning and decision-making. For these remote interviews, when documents were shared via email prior to and/or during the interview, they were saved onto the external hard drive in the participant's folder.  Where links were shared during the interview via the chat feature in Zoom, the chat was saved with the Zoom recording on the external hard drive as well.

## Data Analysis

### *Interest and Demographic Survey Data Analysis*

Data from the Interest and Demographic survey were constantly reviewed to ensure that final participants allowed for some level of maximum variation. The survey data also provided some level of insights into pioneer teachers, what technology they were using, and where they were using it for (i.e., grade level, content area, etc.). A summary of these data is tabulated and discussed in Chapter IV and can be found in Appendix V.

### *Interview Data Analysis*

Throughout this study, interview data collection and analysis happened simultaneously through an inductive analysis process with a constant comparison of the data each time a new set of data was collected for the first three interviews; this strategy was shifted to more of a batch data analysis process which is discussed below. After each interview, the recordings were reviewed within 24 hours and with sometimes additional listenings within 48 hours. After listening to the recording, a one to two-page summary of the interview was generated and sent back to the participant for feedback to ensure that the discussion had been accurately captured and understood. Included in this correspondence was a list of clarifying questions for the participant to provide feedback on. While waiting for the feedback, the audio recording of the interview was loaded into Otter.ai (website: otter.ai), where the recording was automatically transcribed.  The transcribed text still had to be corrected through a painstaking, multi-listening process, as the system did not always pick up the correct words spoken and affect, or tone was not included. Once the final transcript was completed, it was uploaded into Dedoose (https://www.dedoose.com/), a computer-assisted qualitative data analysis software (CAQDAS). When feedback was received from the participant, it was added to the transcript in Dedoose for coding. This was the process for the first three interviews; from then on, one to two passes of correcting the transcript was done within the Otter.ai tool, after which the "draft" transcript and the feedback from the participant were loaded into Dedoose. Once in Dedoose, the fourth and subsequent transcripts were coded while listening to the recording and correcting any minor wording errors simultaneously. This was deemed a better process for the researcher as the voice of the participant was then present during the coding process, which brought in an element of the participant's tone into that process. After the sixth transcript was coded, the codes were reviewed, and the prior six transcripts rechecked to ensure correct code application. From then on, the last three transcripts were batch-coded using the same process as those interviews happened roughly around the same time as did the prior three. There was a continuous merging and addition of new root codes during the coding process. The researcher used memos to document thoughts after each coding process was completed to ensure that bias was minimized for any subsequent interviews; being aware of this possibility was critical throughout.

The coding process entailed a review of each line in the transcript multiple times in Dedoose and the assignment of a code to a word or a string of words related to the concept being conveyed by the participant.  For some transcripts almost, every line was assigned a root code. A root code consisted of a word or a short phrase (i.e., the first introduction to VR). Each code was applied regardless of whether it could or could not be tied to either of the research questions. This was so that concepts discussed that were outside the scope of the research questions but deemed critical to the participants were captured; these may inform future research opportunities.

This inductive open coding process transpired for each interview after which the researcher re-reviewed the transcript in totality with the codes in mind to further understand the participant's experiences and perceptions; this being a practice congruent with the hermeneutic interpretive cycle where understanding the parts helps understand the whole and vice versa (Heidegger, 1962; Laverty, 2003).

When codes were complementary, they were combined and/or grouped into a category. After the first six transcripts were coded, with over 130 root codes, a review of the code log ensued, and these root codes were linked to the research questions; then, they were put into categories that were also linked to the research questions. It was then that the categories were collapsed into larger themes which were then also linked to each research question. A spreadsheet log was kept of the definition of each root code, category, and theme. With each theme linked to a specific research question, a review was conducted to ensure that the data collected were not only sufficient in quantity but that they answered the research questions. Further reviews were conducted related to the frequency of use of the root codes, the categories, and the themes to further improve code application. Where a root code was applied over 30 times and/or was often concurrent with another code, a deeper review of related excerpts in the context of the transcripts was done. This allowed for the shifting of some of the excepts into other codes. Even after the coding of the last transcript, this level of review of root codes, categories, and themes transpired at least twice, resulting in seven larger themes which will be discussed in Chapter IV. During the code, category, and theme reviews, the researcher had a collaborator review one transcript with the list of draft themes on hand; feedback was then compared over a sample of transcripts, and updates were made to areas within each theme to be highlighted.

Dedoose was used as the repository of the transcripts and the codes, as well as a system from which the evidence that answered each question was efficiently extracted. It must be noted that the Dedoose platform shifted from being web-based to Desktop-based during this study. Included in the data analysis process was the comparison not just of root codes from the interviews but also of the participant's experiences and perceptions themselves. This process of comparison provided further insights into the ways in which they experienced VR/AR adoption and integration. After each cycle of code review was completed, the researcher documented, in a memo, ideas about the process, the preliminary findings, the researcher's thoughts about their own potential bias(es), and key next steps.

### *Document Content Analysis*

When provided by a participant, an analysis of the lesson planning documentation ensued alongside their interview transcript. Key themes were also captured from these documents and triangulated with the interview coding outcome. Only two participants provided lesson planning-related documentation, and two shared student work and/or student reactions to using VR/AR.

## Trustworthiness

### *Limitations*

A critical limitation in the research design and methods used for this study was that there was neither an observation of teachers in action nor students' direct use of the technological ecosystem for learning, creation and knowledge demonstration. This exclusion was because this study focused on teachers' lived process of adoption and integration as well as their perceptions of these experiences. The use and review of the lesson planning documentation, when provided, was beneficial in discussing specific learning experiences and teaching practices during the interview; on the other hand, a limitation was that this documentation was not provided by all who were interviewed; thus, some had to remember learning experiences from memory with no detailed support to fully jog that memory.

Given that this study called for teachers to discuss lived experiences with no direct observation of them in action, the researcher could not verify the accuracy of the memory of those experiences. In addition, given the focus solely on teachers, the perspectives of students, district superintendents, school leaders, and those who may have supported the implementation of the technology were also excluded. Should a case study approach have been selected, these multiple perspectives would have been gathered. A case study may have also shed more light on the macro-level factors regarding the diffusion process, albeit for a limited set of locations. The current method provided more breadth in addition to depth with respect to uncovering teacher experiences and perceptions.

### ***Reliability and Validity***

The researcher has worked in both the private and public/non-profit sector, with one project focused specifically on technology transfer. With degrees in both engineering and business, the latter including a focus on marketing, operations, and technology management, the researcher worked in management roles within a high-technology company before joining the education sector through a residency program. Even though the researcher's work in the education sector has been in leadership roles within early childhood education, given prior experiences, the researcher's perspective is that technology will continue to impact teaching and learning to some degree. The researcher also believes that emerging technologies must be carefully studied with respect to their effects on children and must be implemented with clear policies and protocols in place.

Surry's (1997) writing urged the researcher to assess potential personal biases as the development of this study was underway, and this drove an internal quest to balance a deterministic view of technology in education with an instrumentalist one. The researcher's personal interest in innovation led to this new path of understanding VR/AR and this ecosystems' diffusion into PK-12 education. The researcher also has interests in potentially collaborating with others to use this technological ecosystem to create new experiences for children and adults.

The researcher first looked to instruments that were reliable as well as validated by groups of researchers of studies related to the theories and frameworks selected. These instruments and a review of the principles of conducting hermeneutic phenomenological research were used to guide the development of the interview questions and the process of analysis (Daher et al., 2017; Lauterbach, 2018). This brought some level of reliability to the study's process in that other researchers had used similar principles and questions in the past. All findings were supported with data in the form of quotations from the participants' stories; this assured a level of validity. To further promote validity, the researcher consistently used memos to capture ideas and potential biases. The researcher also invited a collaborator to review a transcript and cross-check it to the list of draft themes; this added increased reliability. In addition, the researcher incorporated a process by which participants reviewed a one to two-page summary of the interview. Participants were then later engaged in a member check process during which they were provided with the key themes, the definition of those themes, and the concepts from their discussion that mapped into those themes for review, verification, and feedback. One participant did not wish to be engaged in a member check; thus, eight were provided with the needed documentation for this process. Of the eight, four provided feedback to the researcher. This supported increased validity for the findings.

This chapter presented the methods by which this study was carried out. Chapter IV is where findings are shared, and Chapter V provides a discussion of the findings as well as their implications for future research.

# CHAPTER IV - FINDINGS

In this chapter, information about the participants from the Interest and Demographic survey will be provided, as well as the findings of this phenomenological study with regards to answering the following research questions:

**Research Question 1 (RQ1):** What are the experiences and perceptions of these experiences of pioneer teachers regarding the adoption and integration of virtual and/or augmented reality in teaching and learning for PK-12 students?

- How do pioneer teachers build new knowledge (e.g., TPACK) within the context of the innovation adoption and integration process?

**Research Question 2 (RQ2):** How do teachers integrate virtual and/or augmented reality into learning experiences, and how does this integration impact their teaching practice?

- How does this integration affect the planning of learning experiences, classroom structures/management, pedagogical practices, methods of assessing learning, and/or other areas?

## Interest and Demographic Survey Results and Participant Sample

As described in Chapter III, pioneer teachers were solicited through various member organizations, agreements with districts/schools, emails to MeetUp groups, the researcher's personal and professional networks, and via social media with over 2000 views on Twitter. Since data collection for this study occurred in 2020 during the COVID-19 pandemic, which drove communities to close schools, the complexities that ensued for districts/schools - administrators, teachers, students, and families – meant that the commitment level for participation in this study was less than expected.

Potential participants who were interested in volunteering for the study completed an Interest and Demographic survey. There were 31 attempts at completing the survey, of which 14 were blank. Seventeen surveys were filled with enough information to contact the potential participant; two were deemed fraudulent as the locations from which the two surveys were completed were the same (per the IP addresses), but the location specified in the survey by the interested participant was different. Of the remaining 15 potential participants, five were contacted but did not respond further to requests for information. A discussion was held with one potential participant; however, with a use case in higher education, this data was not included in the results; it must be noted that there were parallels between that one experience and those of the nine included in this study. The results of this study are based on data from nine volunteer participant interviews. The data from the survey can be found in Appendix V with identifiable information about survey respondents removed or modified.

Of the nine interview participants, seven were female, and two were male; all were in-service teachers and not pre-service/student teachers, as specified in the selection criteria. All but one participant was based in the US; the one participant not in the US was based in Europe. Those in the US spanned the East Coast to the West Coast. Two participants were in the age range of 22-34, two in the range of 35-44, three in the range of 45-55, and two were over 55 years of age. The average years of teaching for participants was approximately 16 years, with the years ranging from five years to 33 years of experience. One participant taught Elementary through Middle School students, while one taught in Grade 2, with another teaching Grade 5. One taught from late Elementary to Middle School students, while three taught only Middle School students; two participants taught at the High School level. Subjects taught by the participants ranged from Social Studies and History to STEM and English Language Arts, with some having Gifted and Talented as well as Students with Special Needs in their classrooms. Some pioneer teachers had students with disabilities in their classroom, while others had students who were English Language/Dual Language learners.

Three of the nine participants had used only VR with students; the remaining six used VR and AR with students. Three pioneer teachers reported using VR/AR as part of a larger school/district initiative, with four reporting that it was not.  For the remaining two, even though specific data was not provided in the survey, they were the only teachers using VR/AR in their schools. Seven participants used VR/AR only during school hours, while two also used it during afterschool hours. Six participants shared that they used VR/AR personally, while two did not. The other did not provide direct information on personal usage. The average number of months participants had been using VR was approximately 36 months; it must be noted that the survey capped the number of months at 80 months, so there could have been instances that went beyond that timeframe; the average for AR was approximately 40 months with the same survey caveat applied. Four had used some form of VR often (2-3 times per week), while two had used it sometimes (2-4 times a month) and two had used it rarely (1-2 times a month); this was in reference to pre-pandemic usage per discussion. For those who used AR, two participants had used AR often, while three had used it sometimes. Of those who participated, one expected to use VR very little in the future with five somewhat, and two to a great extent, with one unknown. For AR, one expected to use it very little, one not at all in the future, three somewhat, and two to a great extent, with two unknowns.

It must be noted that given that only two participants were male, to protect the identity of the participants further, gender-neutral pseudonyms were used to discuss the results of this study.

## Interview Findings

Three themes emerged from the interview data that provide answers to Research Question 1 *(i.e., Early Experiences, Channels of Learning, Leadership Role)*, two themes emerged regarding Research Question 2 *(i.e., Content, Implementation)* whereas there were two themes *(i.e., COVID-19 pandemic, Self-Perception and Context)* that emerged which were not directly related to the Research Questions but had some implications for them; these are included in the study findings. A discussion of the Research Question 1 themes will ensue, followed by those related to Research Question 2, after which the two emergent themes are discussed. A summary of themes can be found in Appendix VIII.

***On Experiences, Perceptions and Knowledge Building (On RQ1)***

The findings related to Research Question 1 are embedded in the themes of (i) Early Experiences and their impact on pioneer teachers, (ii) Channels of Learning about VR and/or AR, and (iii) the Role of District/School Leaders in Adoption.

**Theme 1: Early Experiences and Their Meaning Impact Teacher Trajectory.** This theme speaks to the first and early experiences of pioneer teachers that put them on a path to adopting and integrating virtual and/or augmented reality into their teaching practice. Included in this theme are the meanings pioneer teachers gave to these early experiences.

***First/Early Experiences of VR/R.*** In order to understand pioneer teacher's experiences of adoption and integration of virtual and/or augmented reality into practice and the perception of those experiences, one has to step into their early encounters of virtual and/or augmented reality, if not their first, as well as the meaning they placed on those early experiences. Five out of the nine teachers interviewed specifically remembered how they first learned about either VR and/or AR. Both Marley and Ryan had their first introduction to VR during conferences.

> *"I first learned about VR in - at Learning and The Brain conference in Boston, I want to say three years ago, three or four years ago…They had researchers from Stanford University, and they had - my first foray, or my first view into goggles, virtual reality goggles. Where, um, was the Homeless Project."* **(Marley)**

> *"I think my introduction to VR was - I went to South by Southwest on the like SXSWEdu, which is like a week before the real one and the very last workshop that I went to was on VR…. And I never really seen it or anything like that. And it was just neat."* **(Ryan)**

For *Dilyn* and *Lezli*, the introduction came through courses within higher/continuing education settings.

> *"So, I was doing a graduate course for international education. And it was a technology class. And my professor…she came out, and she brought these kind of portable Google Cardboard headgear thingy - throw your cell phone [in] and then you can like, look through some apps or whatever…. And so, that was my first introduction to it - it kind of spiraled from there…So, I did a professional development for maker education; from there, I think I learned that I could code in AR and that is what kind of got connected me to the AR and the VR."* **(Dilyn)**

> *"I went for a doctoral program in technology…I believe they did like at a required course. So, this was probably one of the tangential, you know, touch up on this topic, not an in-depth study of this topic, but this was primarily my interest in my own learning on AR and VR."* **(Lezli)**

*Drew's* first VR experience came through a New York Times subscription.

> *"I'm a New York Times subscriber. And I received a cardboard - VR cardboard… And I was hooked…it just captivated me."* **(Drew)**

For this group of pioneer teachers recounting their introduction to VR and/or AR, gatherings of educators, be they in a graduate course, or conference, was the mode of introduction for four of the five, with one, *Drew*, being introduced through New York Times' provision of the Google Cardboard headset to subscribers. All but two had direct experience with a VR headset during their first encounter and for the remaining three, learning on the periphery still piqued their interest.

Other pioneer teachers did not necessarily remember a specific incident but spoke about somewhat already being aware of the technology or that they were one to keep up with new technologies with a thought to how it may impact teaching and learning. *Ari* somewhat knew that the introduction to VR came during an International Society of Technology in Education (ISTE) conference but could not necessarily recall a specific moment; for AR, *Ari* did recount a buzz at what would have been the 2016 ISTE conference. Similar to *Marley* and *Ryan* above, *Ari* was quite sure that the learning came through a conference even though no specific instant was recalled.

> *"But I remember distinctly seeing a big boost in attention to augmented reality around the time of the ISTE conference in Denver when Pokemon GO came out with their app."* **(Ari)**

When put in new teaching situations to teach students about technology, *Sydney* and *Blake* sought new options to bring into the classroom. *Sydney*, out of frustration, began meeting with other educators; for *Blake,* it was the desire to give students new tools of expression which drove the search and the design to bring VR/AR into the classroom.

> *"Because the teachers and the classes I were in could not mentor me in the way; not project-based, and thankfully, they both allowed me to do that. So, I stopped using the textbooks and started doing other things, but they couldn't give me feedback. So, I was really frustrated, and that's what led me into -- I started meeting with some educators on Google Plus."* **(Sydney)**

For *Blake* and *Kai*, the recollection of an early memory of VR introduction/use was more related to peripheral events. For *Blake*, being asked to teach a new class steeped in technology lead to a search for new tools.

> *"I was looking for ways to give my students a voice through the art form of VR design. The class initially focused on how these tools can enhance our lives, and we spent quite a bit of time brainstorming practical applications."* **(Blake)**

For *Kai*, the knowledge of VR came through generally keeping up with research, but no specific source was recalled; using it with a student came spontaneously.

> *"So <student> comes over, and he sits next to me at another computer. So, I said, <student>, let's see what I can pull up. And, again, you know, children are all about the game system. And so, I said, let me see if I can find something on the computer. So, I went through virtual reality. And I think, I'm trying to remember what came up don't remember what it was."* **(Kai)**

***The Meaning of First/Early Experiences of VR/AR in Words.*** These experiences and the words and emotions used to describe this introduction to VR/AR give a glimpse into pioneer teachers' perception of these introductory experiences and the ecosystem. These first/early experiences and the technologies were viewed positively by teachers with the two most frequently used words to assert their initial perception of the technologies were "*wow" and "amazing."*

> *"And I was so excited that I really, I literally googled at that point, what Google's toolkit was, because they have a software developer's toolkit, right, you know."* **(Drew)**

> *"I was like, (GASP), this is cool. I was like, wow, this is so amazing, I have to do this."* **(Dilyn)**

***Teacher Renewed When VR/AR Ecosystem Discovered.*** From these words, it can be noted that these early experiences of introduction to VR and/or AR brought some level of excitement to pioneer teachers. *Ryan* and *Marley* spoke directly on how finding immersive VR reinvigorated their view of teaching and learning.

> *"I'm going to be going into my 12th year. And like, after a while, it does get a little bit stale...So for me, I saw VR as a way to kind of do something different that's going to be - that completely transforms what they would already be doing…it gives you that opportunity to just really be creative."* **(Ryan)**

> *"This is my I think I'm entering my 34th year…So, it kind of invigorated me. I was so excited…So, when I was there at the conference, it just like jazzed me up, got me excited*

> *about just, you know, just about VR and the future, the future of teaching. It just really invigorated me and made me so excited".* **(Marley)**

*Ryan* expressed being refreshed and renewed like *Marley,* who felt "invigorated" after 34 years of being an educator. Finding immersive VR had quite an impact on pioneer teachers; most were referring to immersive VR for this theme and not so much AR in these early experiences.

***The Meaning of Including VR and/or AR into Teaching and Learning.*** Understanding why teachers chose to adopt and integrate VR/AR into teaching and learning can provide additional insights into their perceptions of the technology and their experiences of its adoption.

*New Opportunities for Students*. Some pioneer teachers looked at how this technological ecosystem was going to benefit their students, not just their teaching practice; the perception was that it would allow for deeper student learning and support students' individual needs. Others expressed how these technologies generated new opportunities for students; others believed that these technologies might very well be in students' futures as they live in the age of technology already.

*Sydney* knew early on during the learning process that VR/AR was going to be helpful for student learning; *"So, I was interested, and I saw that it was gonna be beneficial." Kai* spoke to the potential of how these technologies can support students with challenging behaviors, while others spoke to providing students with new opportunities for learning and skill-building.

> *"This is what's working for these type of children with this severe behavioral issue."* **(Kai)**

*Ryan* expressed excitement about how VR brings something new to change what students do.

> *"I saw VR as a way to kind of do something different that's going to be - that's completely transforms what they would already be doing…this is something completely new for them that they can do".* **(Ryan)**

For *Lezli*, *Drew,* and *Blake*, given the communities in which they served, namely lower-income urban communities and/or Title I schools, there was a sense that without their initiative and a concerted effort, this ecosystem would not be available for their students, and it was thus essential to include VR/AR into student learning – to expose students and to support new skill-building, as shared by *Blake*.

> *"I know that we have limitations; our students come from an inner-city, urban background, and usually don't, they don't have access to these gadgets… it's no fun, especially for our students, because they are so distracted in their real lives. Only an immersion environment can help them focus.*" **(Lezli)**

> *"Because most schools, especially Title One schools, do not enable students to really express themselves in any way. So, innovation and free-thinking it's not a norm, and unfortunately, that is conditioning them for another type of life."* **(Drew)**

For *Blake*, at times, this was a way to give struggling students a new way of learning and expression.

> *"I make a big fuss with those type of scholars because I want to make it clear that they can excel. Like they could excel in school, like all because they're failing math, failing science, and maybe they're not good at the routine of being a student. They still have strengths, and so I feel like those are like my little gems in this class that - I like to build students up."* **(Blake)**

For *Ari,* the goal was to ensure that students built new skills that they could use in multiple disciplines.

> *"a big piece is how could I give them something that they could use to create that could be used in another class and build in those interdisciplinary kind of connections."* **(Ari)**

Whereas, for *Dilyn*, the possibility of leveraging the affordance of immersion for VR was significant for students to be able to walk in another's shoes.

> *"So when I originally got interested in virtual reality, I was like, this is an amazing opportunity for people to - our students to actually literally step into that moment in history, or time or a place or a person and actually see what it is to be part of that person's life or that experience, and that is a true or as close to an empathy experience, as we can maybe get our kids to."* **(Dilyn)**

When it came to the macro-level reason as to why pioneer teachers expressed the need to include VR/AR into teaching and learning for PK-12 students, an underlying concept was that it would fundamentally benefit students. This benefit was described as being an alternative to support a reduction in challenging behaviors, to provide equity in the access of technology that would affect students' futures, as well as an option that could be leveraged in multiple disciplines in support of student learning.

*In the Age of Technology and In Students' Future.* Further regarding the benefits of VR/AR for students was an element of acceptance that students currently live in a world of technology and therefore must be exposed to emerging technologies. This sentiment included an understanding that these technologies may very well be in student's future and thus, they must be prepared for it. Echoed by *Marley* in that this technology is the "wave of the future," *Kai* acknowledged that students are living in an era of technology.

> *"In an era of technology, children love Gaming and other technology applications. So, therefore, if educators incorporate educational methods using Virtual Reality (VR) applications, this might just eliminate interruptions by those students who struggle with behavior challenges...This is the technology era, and it's all about the computer. It's about the videos. It's about gaming."* **(Kai)**

This idea that VR/AR technologies are in the future was further expanded on by *Sydney*, *Ari,* and *Drew,* who called out the desire to prepare students for the future now.

> *"I think part of it is, like, there is the side of preparing kids for the future. And trying to understand, well, what is this emerging technology? Is it going to have an impact once they're older? Is it something to understand and know about? It seems like yes."* **(Sydney)**

> *"I really just wanted them to have fun and learning about these, these different things that are out there that are definitely going to impact not just their future, but like right now...especially 10, 20 years from now, when your students are older, who knows if PowerPoint to be around? I mean, I know tech moves around very quickly, and you never know what the next thing is. So, they have to build some skills of how to learn quickly."* **(Ari)**

*"The purpose behind [what] I started was really to expose students to the 21st-century skills that they would need - if they were grown, and we're looking for a job in computer science or engineering, the question would be, what skills would they need today?"* **(Drew)**

This first theme focused on the first/early introductions and experiences of pioneer teachers with respect to VR/AR. For pioneer teachers, these first/early experiences allowed for a positive view of the technological ecosystem itself. The meaning attributed to these experiences and the view that they provided a benefit to students is what drove pioneer teachers to begin their adoption process.

**Theme 2: Channels of Learning - Groups, Social Media, and The Individual.** The introductory experiences teachers had instigated their foray into using VR/AR in the classroom, but first, given the novelty of these technologies, teachers had to find ways in which to build new knowledge about how the technology worked, how to use for teaching and learning, and what options were available for them to use with students. The channels of learning through which pioneer teachers built knowledge about VR/AR were organized groups, social media, connections with an Influencer/Collaborator, online research, and self-exploration. Additionally, some pioneer teachers inadvertently also became the Influencer for those who were yet to journey into using VR/AR.

***Learning Within Groups.*** Pioneer teachers described learning from others during conferences, adult learning sessions such as during a university course or professional development, as well as group discussions with others involved in using VR/AR, be they in education or in other fields.

***__Learning through Educator-focused Conferences.__*** *Ryan* and *Marley*, as shared above, started their journey into VR/AR at conferences that focused on teaching and learning. During SXSW EDU, *Ryan* not only got an introduction to immersive VR but also begun to understand how the technology worked and what it was best used for; in the eyes of the SXSW EDU presenters, it was best used for an overview as opposed to teaching about details. For *Marley*, it was participation in the Learning and the Brain conference that provided the introductory insights into VR/AR.

> *"The people who presented [at SXSW EDU], they were real pros about like creating VR - what they did is they showed us some examples of some of the VR experiences that they had created. And they kind of walked everybody through, like, here's what doesn't work when you're using VR. And here's what does work. And so that that just helped me to see some of the possibilities of like, what VR can be used for and what VR is not very good for."* **(Ryan)**

> *"So that, [Augmented Reality], also at conferences, Learning and The Brain and other conferences, I've gone to for schools, where we share everything."* **(Marley)**

***__Learning through Internal District/School Groups and Collaborations__.*** *Ryan* went on to further describe learning within a group of teachers in collaboration with the technology-focused team within the school district. This group was explicitly called together to discuss VR/AR technologies and their use in the classroom, inclusive of the logistical protocols of sharing VR headsets across schools and classrooms.

> *"[The Head of the Science Department] just brought together a few of the teachers and some members of like the tech staff and we just kind of tested it out…But the goal I think, was going to be like, well, we'll, like test it out for the first year and we'll kind of get everything - get all the kinks worked out as much as we can and we'll figure out like, how can we share these devices with the rest of the school and even with the high school and without having suffered damage or loss or things like that. So, what sort of procedures need to be followed, and…what sort of rules do you need within the classroom? What rules do we need amongst teachers just to share these devices, like signing it out, things like that? And then some of the time is also like just spent, like sharing what we had done with it and the experiences a bit. So, I think it started with just a few teachers maybe like, maybe like four or five teachers plus members of the tech staff. It wasn't like we were meeting for anything else*." **(Ryan)**

It was *Kai* who also spoke of collaboration and support needed from the technology teacher in the school who was the one to discuss further usage and integration with teaching and learning.

> *"The technology teacher said, he said, Oh, <Kai> that is awesome. He said, this is what we need to do"; I'm not sure if that's probably something that has to come from the technology teacher because he's the tech person in the building. And he has to try to see how he can implement that in the curriculum."* **(Kai)**

***Learning Through External Groups – MeetUps.*** Out of frustration, it was *Sydney* who found groups external to the school, one of which went beyond an education focus.

> *"So, I was really frustrated, and that's what led me into -- I started meeting with some educators on Google Plus…I think it was a weekly with a group of like four, usually four of us three to five educators about using augmented reality in the classroom... I [then] started going to…VR/AR meetups in [the city]...I mean, the AR ones were focused on how it could be used. That was really the only one that was specific to education...[other was a] general group. So, the topics are anywhere from how it's being used in different industries, like how to actually develop and design."* **(Sydney)**

***Learning Through Social Media and Internet Searches.*** In addition to learning as part of a group, pioneer teachers also shared that social media played a critical role in their learning more about VR/AR, including the various tool/app options available to them. Twitter, as a source of information, was the social media platform mentioned the most by five of the nine pioneer teachers interviewed.

***Social Media – Facebook.*** *Marley* shared that, albeit not being an avid user of social media, learning about VR/AR came through belonging to Facebook groups.

> *"I'm just on Facebook. Other than that, I'm not really into social media, but I learned a lot from - I joined some Facebook groups, the Google one; some of them actually turn up but to a certain extent, free for teachers."* **(Marley)**

***Social Media – Twitter.*** When asked about how they learned about this technological ecosystem and how to leverage it for teaching and learning, other pioneer teachers often spoke about Twitter. For *Dilyn*, Twitter was mixed in with searches on YouTube to learn about available options.

> *"[I] started researching that [VR]. And then from that exposure, then I started learning about AR just from like, Twitter, and like YouTubing, and whatnot…so I started looking for things on Twitter about people who were developing stuff, and I was watching conferences and webinars and all of that stuff."* **(Dilyn)**

For *Blake* and *Drew*, it was the high engagement in Twitter that provided information about what VR/AR options were available.

> *"I'm pretty active on Twitter…Twitter, totally on Twitter. Um, so my, I'm a - I used to be more active in Twitter chats. I was pretty active in #satchat in the past."* **(Blake)**

> *"Twitter, that's where I find my latest and greatest…you know, Twitter suggests, oh, since you like this person, you should follow this person, and so I just continue to accept those great suggestions."* **(Drew)**

*Ari* also spoke about joining chats session on Twitter as *Blake* did with a focus on connecting with others, learning from others, and share personal experiences as well.

> *"I think that being able to join in different opportunities like Twitter chats or webinars where we can connect with other educators who are just getting started with augmented and virtual reality or to share our own experiences with them definitely makes a big difference. The concept of it itself can seem overwhelming, but with having these options, it makes it easier to get started right away."* **(Ari)**

*Sydney's* use of social media, inclusive of Twitter, was focus on building knowledge by following other educators.

> *"There's a number of educators I follow via like Twitter and Social Media. Because using VR is so siloed if you really have to, search online."* **(Sydney)**

***Google Searches and "For-You" Pages.*** Similar to how *Drew* followed the leads from suggestions on Twitter, *Lezli* also leveraged suggestions from Google for-you pages based on Google searches.

*"Yes, honestly, nothing works better than, you know, the Google discover page for me...and that keeps me up to date, you know, with the advancements and the progress in any field. AR, VR included".* **(Lezli)**

***Learning from The Influencer.*** Pioneer teachers not only searched and scanned Twitter feeds and other social media platforms to learn about VR/AR options, but they also participated in group discussions and chats, and also learned from Influencers, be they a public figure they followed or someone they knew personally. For *Sydney*, *Blake,* and *Ari*, some of the key influencers were highly followed – on social media (i.e., Twitter) - teachers and those who had transitioned from the classroom to writing and speaking about VR/AR in PK-12 education.

*"Benjamin Kelly, okay…Oh, Steve Bambury. He hosts a lot of events that are education specific for VR. He's based out of Dubai."* **(Sydney)**

*"so, Eric Sheninger. Okay, the former Principal of [a] High School, like Digital Principal of the Year…He ran a conference at his high school called Edscape or Eduscape. But I would go there, and I would hear all these tech ideas".* **(Blake)**

*"Jaime Donally…through Twitter…reading her book for anybody is…I went through it and read it just to kind of build more of my awareness…ARVREdu because Jaime Donally has all of these resources available."* **(Ari)**

For *Ryan* and *Dilyn*, the Influencer was a friend/colleague who collaborated in sharing ideas and their own findings. For *Ryan,* this was during the introductory experience at SXSW EDU, and for *Dilyn*, this was during a graduate-level course.

*"so my friend that I went with [to SXSW EDU]…when it ends…we go out to get dinner, and it just naturally becomes like we're just now taking everything that we've just experienced, and now we're figuring out like, what can we do in our own schools or what sort of what sort of ideas could it lead to and put into action."* **(Ryan)**

*"then someone said from that [graduate] course, actually that I took, there was another teacher…We like, collaborate quite a bit. And, and he was like, oh, have you ever heard of this thing called CoSpaces, and I was like no, what's this? And he introduced me to that. And so that also introduced me to this kind of like VR, like the kids started this three-dimensional world."* **(Dilyn)**

***Self-Taught and Experimentation with Students to Build Knowledge.*** In addition to group learning, social media, google searches, and influencers, pioneer teachers were often self-taught, experimenting alone and/or taking a risk by experimenting to learn about using VR/AR with students.

***Self-Taught and Experimentation.*** *Ari* and *Blake* spoke specifically about being self-taught by tinkering with the tools themselves.

> *"I just played with it. … "[I can be] very independent…I don't have any formal degrees in technology. My master's degree is just an education in general. But I just sort of play with things until I figure it out."* **(Blake)**

Like *Blake*, *Ari* jumped right in as a way to learn the tools but also as a way to know where students may have challenges when using VR/AR - *"I didn't want to watch tutorials, and I don't even know if there were any available, but I'm the type of person that I just want to - okay, what does this do? Okay, great. Let me go in and create an account, kind of navigate around because I want to anticipate where students might get hung up."*

***Experimentation with Students.*** Three pioneer teachers spoke directly about taking the risk and experimenting with students in the classroom after getting some learnings on their own along the way. When moved to a new school that already had VR headsets, *Sydney*, who had continued to research about VR/AR even when not using, started to experiment in the classroom to determine how best to integrate the technologies. For *Ari*, experimentation was a co-learning process with students.

> *"But bringing new ideas into my students for them to interact and see what it looks like for them to give feedback …part of it was learning for me to see how could I use this maybe in other classes, or maybe have a more specified focus point for them later on…it's important for me to be like a co-learner with them, and I think that they value it whenever you learn something from them, and you acknowledge that."* **(Ari)**

Engaging students in the experimentation process can be complex when things go awry, as described below by *Blake*.

> *"in class, sometimes students, they don't want any frustrations, they just want it to work the first time they do it. And if it doesn't work, they want me to do it for them…I don't touch the mouse; I don't touch the kids' keyboard…[per] the research, students will learn from each other more than they [would] learn from me…if you think your peer knows the answer, go ask him [or] her; that's what I always say. Go ask and have that classmate walk you through it. Because your brain will absorb more of what they're saying than what I say".* **(Blake)**

Like *Ari* and *Blake* co-learning with students, it was *Dilyn* who provided a relatively extensive description of how this co-learning experimentation with students happened in the classroom; also, like *Ari*, learning from the students while students learned from each other, like *Blake*.

> *"to be really honest, and this is how I always test everything I try. I tested, I tell all my kids, guess what, aren't you super excited? You get to be my guinea pigs today. And they're like, Yay!... I say we're gonna try this thing called CoSpaces. I have no idea how it works. I've only done that tutorial. So, I'm gonna show you the tutorial too. And then you're gonna teach me okay…And then they do; they teach me about it. …I find I can learn some nice tricks from a teacher's perspective from YouTube, which is super good. But I find that it's, it leaves a lot of it up to them too and it's also that - them learning through their experiences, and them teaching each other, which I also think is very powerful."* **(Dilyn)**

Pioneer teachers learned about VR/AR - what it was, how to use it, and what options they could leverage in the classroom - through groups, social media, influencers, and through experimentation; some quickly became influencers themselves.

***Pioneer Teachers Become Influencers.*** Within their schools and in external group settings, some pioneer teachers also become the Influencer for other teachers yet to leverage these technologies in the classroom. Some of this process of influence happened within their school settings, while others happened externally.

***Influencing Internally.*** Influencing internally within their schools was what pioneer teachers did to support and/or try to convince more teachers to begin to use VR/AR. For *Marley*, it was finding time to attend department discussions to share options with others.

> *"I would pick a technology…and I would say, please give me 15 minutes of your 55-minute meeting; I have this app to show, this cool app to show you...And I started doing it in all of the meetings…and that's how I got people to like really understand what it was because they also just didn't understand what the goggles were."* **(Marley)**

Besides sharing during department meetings, *Marley* also had an opportunity to provide immersive VR experiences to teachers and students during a special event that the school had structured. This was a way that *Marley* got other students and teachers to experience immersive VR to introduce them to the affordances of this technology. Based on *Marley's* description and pictures shared of the experiences teachers and students had, it was a memorable event.

> *"Word spread around the building that this was going to happen…they had like a cooking class…they had stuff related to Black History. So, I had mine; I think I did two days in the library. I said, I need space, I need the kids…I want to say 20…So 20 was the max… They were crying tears, the one girl on the left. I think she had tears coming down her face".* **(Marley)**

*Lezli* also created a buzz in the school by supporting another classroom to implement an immersive VR biology-related experience.

> *"I took [VR] outside of my department…with biology classes, and students were able to get the simulated experience with the anatomy of human body, and different organs inside. Fascinating experiences, although, you know, that was not the main curriculum but, you know, I was able to insert that, and it was quite an excitement at that point".* **(Lezli)**

*Dilyn* and *Sydney* expressed continuing to try to work on having colleagues use VR/AR for learning experiences. The grant that allowed for the purchase of VR/AR was for the whole school, but since *Dilyn* became the "trial teacher," there was a propensity to share VR/AR apps and content with other colleagues, albeit it being a "slow process."

*"So, I'm hoping to introduce [VR] better to some of the teachers; this year's my first year there, and [I am] learning who would be open. That group of teachers that I did the Expeditions with, I'm going to - now that I have the Quest too, that's going to help because I can literally just walk to their class and be like, hey, you want to do this, rather than the entire Rift I have to set up, and it's a huge process. So, I'm excited for that because it's just more accessible".* **(Sydney)**

*Sydney* also includes context here on being new to the school and thus trying to determine which other teachers may be interested in using VR as well.

***Influencing Externally.*** In addition to influencing internally within the school, *Marley* also shared the work externally during conferences of schools.

"*In the winter…we go up to [a special location], and they have an unconference which is amazing, and I'm expected to share what we do at [my school] you know, so there's expectations…it was like a presentation of what everybody's sharing. So, I got up and shared [about VR]. I had short little video clips…and we were the only ones that had VR goggles. So, the next day my boss got emails from his friends at other schools; they were like, we just ordered some [VR headsets], and it was kind of fun because, yeah, it was really fun because, you know, they kind of work together".* **(Marley)**

Others pioneer teachers also facilitated learning opportunities for other teachers; for *Sydney*, this was done locally outside the school environment, and for *Ari,* it was presenting at various national conferences.

*"this year started teaching [about VR] like locally."* **(Sydney)**

*"for years, the person who didn't like public speaking started to do different conference presentations. Because I found my comfort level was talking about what my students were doing with the different tools we were using…I've been doing more heavily the AR, VR, AI over the last couple of years."* **(Ari)**

*Ari* began to present at conferences, and *Sydney* took to teaching other teachers locally. *Marley* found opportunities to share the technological ecosystem in relevant ways with school leaders, teachers, and students during special occasions, and like *Marley*, *Dilyn* began to share the technology with colleagues, hopeful they would also adopt it eventually. Influencing others, especially within the school/district environment and even the process of adopting VR/AR, according to pioneer teachers, was also influenced by leaders.

**Theme 3: District/School Leadership Role**. In uncovering the experiences of teachers as they adopted and integrated VR/AR into their teaching practice, the third theme that surfaced was the role and impact of District/School leaders. Pioneer teachers' adoption of VR and/or AR in the classroom with students or not was somewhat influenced by District and/or school leadership. Some adopted this technology as part of a district/school-wide initiative (i.e., Ryan, Marley), while others were lone-rangers in their adoption (i.e., Dilyn, Blake), but even they were also impacted by leadership, especially when it came to funding the purchase of VR/AR-relate devices and content/platforms. Funding and thus the number of devices on hand affected teachers' level of VR/AR implementation in the classroom; implementation will be discussed later related to RQ2.

> *"So, I went back to my bosses, and I was like, you know, there's this thing called VR goggles. And they [the bosses] are like, look into it."* **(Marley)**

Even though the information gathered during SXSW EDU was not the impetus for Ryan's District's pilot of VR/AR, it was the unexpected District-approval to attend forward-thinking sessions at that conference is what opened the door to the introduction of immersive VR for *Ryan*.

> *"And so, I just said, Okay, I'll ask my district if they'll send me and I asked around, I asked um, you know, my supervisor, my principal, they were both like yeah, like, it's not gonna happen, but sure we'll support your …and then, sure enough, I got approved [by the Board]".* **(Ryan)**

*Sydney* took note that in the new school, VR headsets were already available, but there were questions on the frequency of use prior to *Sydney's* arrival; either way, support was provided by leadership.

> *"when I got there, they already had three headsets. I think they'd kind of run them once. But I, maybe the other technology teacher, wasn't interested in it before. So, I get a ton of support in what I need and what I asked for."* **(Sydney)**

*Sydney* was the only participant who spoke of testing a particular application for a technology company using Microsoft's Holo Lens.

> *"I got to use a HoloLens a little bit. And we use Lifelike and I use this heart thing it was more like bring it and see. I don't think the content was really is really there yet. Our school got to test out the Lifelike stuff. Then they winded getting to keep it".* **(Sydney)**

Not only were District/School leaders instrumental in opening the door for teachers and encouraging them to learn anew, but they were also critical in the acquisition of the technology to be used in classrooms, especially for the more costly VR headsets, by providing access to funding.

> *"My district is extremely supportive and pretty much anything I need, they provide. The program is very well funded."* **(Blake)**

It was *Lezli* who, when previously in the role of a district administrator, supported the start of using VR in a school through budget allocations.

> *"So luckily, when I was in administration [up until the prior school year], I was able to set aside the budget for, you know, 10 devices at once. And we bought it."* **(Lezli)**

Even with supportive leadership, processes vary across schools; *Marley* alluded to the differences in purchasing practices between public and non-public schools, also sharing the support received from school leadership.

> *"And one advantage to being a [non-public] school versus public…public, by the time you get funding approved by the Board event, it's already gone…Here, for the most part - now, they used state money but generally speaking - like say if I want styluses for all the*

> *kids for a certain grade, and I make my case they can just order it that day, and I'll have it from Amazon the next day."* **(Marley)**

The state funding *Marley* speaks off above came through grants available for schools.

> *"They came to me and said they had some state money and that the goggles would qualify under the parameters that the state set for the money. And that's why I got them."* **(Marley)**

The use of grant funding to purchase VR headsets was also echoed by *Ari, Dilyn,* and *Ryan*; grant funding was offered by District/School leaders even if the pioneer teacher did participate in the grant writing process. For *Ari*, the initial VR headsets in the district came from a grant written by the Librarian. *Dilyn* wrote the grant for the school.

> *"I wrote a grant to get these VRs for us. And so, I kind of have been like the trial teacher."* **(Dilyn)**

> *"So I had no idea if we were going to be able to use VR, we didn't have the cameras or the headsets or anything and shortly thereafter, [the District leader]… he shared that like he was putting in a grant where he was going to be trying to get some of the VR headsets…he was able to combine like several different grants together and was able to get everything that he needed for them for a full cart…and then he also just - he got two cameras, those he just got recently".* **(Ryan)**

For *Marley* and *Ryan*, Department Heads in the District/School were also instrumental in furthering the use of VR. For *Ryan*, it was the lead of the District's Science department who set up the forum for a group of teachers to come together with the Technology Team to discuss using VR/AR.

> *"[The Head of the Science Department] set it up, [the group meetings], just for the VR one…I think the goal was to kind of meet like, on a pretty regular basis, we met a few times throughout the year".* **(Ryan)**

For *Marley*, it was the department leaders who drove additional interest and adoption.

> *"the department heads, like the science department…experienced the goggles and…then would say during their planning…remember, Marley had that chemistry app? Let's do it*

*here…So, I would say the department heads are a big part of the push this year".* **(Marley)**

Only one teacher, *Kai*, was informed that the school did not have the funds and was asked not to dive deeper into virtual reality.

> *"[The Principal] said we were not able to do it because we don't have the funds and all this stuff."* **(Kai)**

*Kai's* experience of having a school leader halt any further exploration of VR meant that *Kai*, along with the technology teacher for the school, stopped using Desktop VR after the second try even though they felt it might have been very beneficial for students. This particular experience may very well be a signal that District/School leadership buy-in may be critical for the adoption of VR/AR or any new technology within the District/School environment. It was *Drew* who provided a potential solution to get more school leaders open to considering leveraging the power of these technologies; buy-in and promotion from District-level leadership.

> *"a Chancellor or District Superintendent could and should embrace it so, it isn't just looked upon as fun and games because that's pretty much - the side of entertainment that VR tends to play on is we're entertained."* **(Drew)**

The role of District/School leaders was critical at the start of the adoption process. This support was twofold; leaders provided time and space for teachers to build new knowledge about VR/AR and access to funding.

### *On Content and Implementation (On RQ2)*

From the early experiences to learning about options and leadership support, the next step for pioneer teachers was integration. In this segment of the discussion on interview findings, the focus will now be on Research Question 2 regarding how teachers integrate VR and/or AR into teaching and learning. The two overarching themes found here are (i) the process of finding and selecting content and tools/apps – the content experience, as well as (ii) the implementation of VR/AR into learning experiences, inclusive of the structures pioneer teachers put in place and the challenges encountered. First, there will be a discussion on the findings regarding the content experience – finding, accessing, selecting, and engaging VR/AR experiences, apps, and tools followed by the process of implementation.

**Theme 4: The Content Experience – Selecting and Engaging.** Study participants were of varying minds when it came to how content for teaching and leering was found, selected, and how it was used in the learning experience. Some expressed that for certain subjects, there was enough content to support their students' learning using VR/AR; for others, sifting through to find relevant content that would augment the intention of their learning experience was cumbersome, while for others, there was simply not enough content and thus a sense of the need to create experiences.

Teachers found content - tools, apps, and experiences - to use in the classroom in the same manner by which they learned about VR/AR – through social media and google searches.

> *"so, this is typical how I find stuff you just Google, and you have to read. And if you have your own goggle, you can just quickly download it and test it out."* **(Marley)**

> *"Twitter, that's where I find my latest and greatest…The European companies tend to be a lot of the first to have tools and sure enough, a German company called CoSpaces, or has a product called CoSpaces - some European after-school program was commenting on - and I'm like, that's it, and they offered it for free. That was even better."* **(Drew)**

To integrate immersive VR into lessons, *Marley* expressed that there was enough content for the needed learning experiences, but this was for the sciences and for some history.

> *"it was like once a unit for science because the Science Department was on board and most of the content is science-based…We use MEL chemistry, Gala-360. No, sorry. Solar System, the body VR. So, most of it is science…A little bit of history".* **(Marley)**

Four of the nine pioneer teachers shared that the content was limited for the learning experiences they wanted to provide students. For *Marley*, it was the lack of content for diverse historical perspectives that caused some challenges.

> *"I found an app for the Oculus Go called The People's House. Because it's not it's not easy to find content, you would think it'd be easy. It [was] so hard to find the content [for Black History Month]".* **(Marley)**

*Sydney's* perception was that seated experiences would be best for students, but options were limited, and the length of time for experiences was too long and thus inappropriate for students.

> *"there's just not enough content - more seated events [are needed] which are really good for the classroom...But again, like content isn't there yet. So, like the Anne Frank experience. I think that would be really good for students. The challenge with it is it's a longer experience".* **(Sydney)**

For *Lezli*, new and better 360-degree video recording technology signaled the possibility of having more content developed.

> *"And [there is] limited content. The content, luckily, is now expanding exponentially, and it wasn't there before...but now the 360-degree video recording - it has also developed exponentially, and that is helping to build the content."* **(Lezli)**

On the other hand, *Ryan's* quandary with content was subject-matter-related, not finding content that connected to the intended learning experience.

> *"I'm early American history. So, if I was modern-day you probably get so much more; early American history, you know, you're - it's just tougher because you don't have film that you're able to - that people took even like [in] the early 1900s and whatnot that you're able to use...And so, I think that kind of hurts for me."* **(Ryan)**

*Ryan* spoke further about limited content availability, especially as one got more granular in specific subject areas.

> "*So the content available online is not great. There's not like a ton of it for each subject in total; there might be a lot, but like when you get down to your subject, and your specialty, you kind of have to be selective. And so that's definitely one barrier."* **(Ryan)**

In contrast to the share of lack of content, *Dilyn's* perspective was that with a constant review of potential content, oftentimes, experiences were found that somewhat connected to the expectations of a unit of inquiry; unless pioneer teachers create their own content, there would have to be a reliance on what is already available and appropriate for learning expectations and students.

> *"I found at least one experience per unit of inquiry."* **(Dilyn)**

In thinking of other options for students in the future, *Ryan* continued but sharing an idea related to creating specific content for specific learning experiences given the limited options; however, in this ideation, an issue surrounding content creation, access to locations was raised.

> *"I had thought about maybe driving somewhere and taking the 360 camera and just seeing like, if I could create something of my own…we're not too far from Valley Forge, and I wonder if they would let me like – hey, an hour before you open or something like that, I just get in there with the camera and just take the video and pictures".* **(Ryan)**

Concerns related to teachers having to create their own content went beyond access to locations; for *Sydney* and *Ari*, there was a question of the ease-of-use of the tools for content creation and the steep learning curve of some tools.

> *"I couldn't use Unity in the classroom because the learning curve is too steep. It wouldn't be worth investing that time".* **(Sydney)**

> *"at the time, two other tools that I used, the one was CoSpaces, which was new and then also Metaverse and when I tried to create with both of those initially, it took me a really long time."* **(Ari)**

Further discussion of finding and selecting experience/apps continued to shed light on the challenges pioneer teachers faced with the integration of VR/AR into teaching and learning. *Marley* was the only pioneer teacher who spoke specifically about a process to vet the quality of content to be used; all content had to be reviewed with *Marley's* involvement. This became somewhat of a policy within the school, a concept that will be discussed later. For *Marley,* the barometer by which to test experience quality was the Stanford University Homeless Project.

> *"Teachers cannot put it [experiences] in the classroom unless they look at it and to make sure it's what they want…I have to review it…For the most part, they are very high quality; once you start with Stanford's projects,…it's got to be up to that quality. So, with the stuff, you have to just put on the goggles and test it out and not judge it before."* **(Marley)**

On the other hand, three pioneer teachers spoke about the inappropriateness of the content and/or apps/tools for students with respect to their age or levels of development. This can also be tied to the concept of experience quality. For *Blake* and *Dilyn*, there were concerns that the content was not designed for young students, and thus it may invoke some level of trauma due to the developmental level of students in their classrooms. It was *Dilyn* who shared that the amount of content was increasing.

> *"I have to pick and choose which [are the] right clips because it's not designed just for students. So, I have to be cautious with which ones I pick...I want to invoke an emotional response, but I don't want that response to be traumatic."* **(Blake)**

> *"every time I go on, I find something else that seems to fit in some way…the only thing I struggle with sometimes is content for age levels. So, I find that there's a lot of content for a grown person or a teenager…but 10-year-olds? I find that sometimes the stories are too realistic. You know, there may be something that they're not quite ready for. So, I will say that way that's a bit harder; I have to be cautious about what they see. And now I have to be cautious about the idea they're 10 and 11 years old and that what they see, they really embody much more than maybe you and I will…it's just because of the cognitive - developmental level of a child at that age. So that I think is more my caution when introducing them to virtual reality."* **(Dilyn)**

For *Sydney*, the structure of the experience did not allow for an effective learning experience.

> *"as I like, look back and reflect, my students didn't get it. <<participant struggled to express sentiments in words at this point in time>>. Yeah, my students didn't get out quite what I wanted them to...I'll start with what didn't go right. I think the experience is a little bit too long for them to retain what I was looking for. I think the content jumped too much; it wasn't focused enough. So, it covered a lot of different things, but not a lot about those different things. So, it didn't pull out as well."* **(Sydney)**

For *Drew*, the focus was not on the experience of immersive VR but rather that the apps/tools used to create VR experiences were also not design for PK-12 students; it was therefore critical when selecting tools to focus on those that are specifically designed for this age-span.

> *"So as far as virtual reality and augmented reality, CoSpaces is the most appropriate tool for K through 12. Because the other AR and VR is strictly made for adults, and the interfaces are just not there, just a little bit too savvy; that for a five-year-old, it's an interface that just wouldn't, would kind of not be appropriate. CoSpaces has - it's specifically created for kids, so I like that part, and it's robust enough…I've looked at other ones, and this is still the one that I would say is, it's accessible enough…I don't like to have huge learning curve where we have to spend time learning how to use the system, as opposed to jumping in and using the technology for what it's worth."* **(Drew)**

Finding and selecting appropriate content – experiences, tools/apps to be used in the classroom, especially for immersive VR, was a critical step that required multi-layered consideration. Pioneer teachers spoke of the growing yet limited amount of appropriate content available for their subject matter and/or specific lesson, as well as the quality and ease of using tools to create content. Additionally, it must be noted per these examples that pioneer teachers were not necessarily creating new learning experiences matched to the available content but instead, they were relying on already developed lessons and determining what available content would be a match to support the intention of a lesson. All these factors impacted the choices made during the integration of VR/AR in the classroom.

**Theme 5: Integration and Its Effect.** When it comes to pioneer teachers integrating VR/AR into teaching and learning in the classroom, there are many factors that come into play after the decision to adopt VR/AR for a learning experience and the search for and selection of what VR/AR content to incorporate.

First, a review of how teachers integrated AR and then VR experiences into lessons would be shared. This will be followed by the structures put in place during implementation, inclusive of challenges and the impact on teachers. It must be noted that two of the nine teachers who participated in this study shared lesson planning documentation while another shared student work and an introduction to VR/AR presented to students, with the remaining speaking of specific lessons/units of study where VR/AR was integrated.

***How Pioneer Teachers Used Augmented Reality for Teaching and Learning.*** Pioneer teachers in this study used AR as a source of information, with a focus on having students create within AR to share knowledge. *Blake* speaks of having students use AR to share knowledge about a classroom in support of students who transition into the school mid-year; AR was a vehicle through which information from student research and creations were broadcasted.

> *"With one of the projects with AR, students adopted a class and created a video, completed the classroom footage, teacher interview snippets, images, and text. Then the students created a sign with the teacher's name to be hung outside the classroom. At an initial glance, it looked like basic sign, but when it was scanned with the HP Reveal App [previously Aurasma]…the video would appear."* **(Blake)**

For *Dilyn*, the use of AR was a method by which students shared their knowledge of books read or created, a way to have students bring others into worlds within these stories from their perspective. *Dilyn* goes on to also share that AR was leveraged so that students could see their creations come to life in 3D.

> *"for AR, we've been using it more for constructing worlds and stories. So, I use a lot of like Merge Cubes. And so, we start off kind of more simple with like writing, making, designing Merge Cubes for like book reflections…showing characters and settings and places…Towards the end of the year, we do a full fantasy writing unit. So, they publish a book, and with the book, they will design their [3D] fantasy worlds on the Merge Cube. So, each side of their cube is one of the worlds in their books and their chapters."* **(Dilyn)**

What *Dilyn* shared above was quite similar to how *Sydney* suggested using AR in the future – having students create and view their designs in 3D, this time, prior to using a 3D printer to bring them into the physical world.

> *"I think the Merge Cube and AR would be useful for - if they create a 3D design, but if we put it in AR first before we print it, use that time, use the material, that we should be able to see and understand a lot better how to use it."* **(Sydney)**

Within these examples of how pioneer teachers used AR in the classroom, the ideas of supporting visual learning, being transported to 3D worlds, as well as how teachers may use AR to understand student knowledge began to appear; these ideas will be further expanded on.

***How Pioneer Teachers Used Virtual Reality.*** Similar to the use of AR to have students demonstrate knowledge and create worlds, pioneer teachers harnessed the power of VR for students to enter inaccessible and alternative realities regardless of whether this was through Desktop VR images/videos or the use of a headset (HMD). The idea of the field trip was center stage; however, the meaning of a field trip took on new dimensions when juxtaposed next to the traditional field trip, which, for most students, would involve neighborhood walks and/or bus rides to a museum or other location. For these VR-related field trips, there was a sense of being transported to worlds students would typically not be able to access whether in another location, outer space, within the human body, and even in their community which may have been inaccessible due to neighborhood safety concerns.

***Desktop VR.*** Using these technologies to enhance the learning experience can also be gleaned from the use of Desktop VR. In one learning experience described by *Marley*, this part of the ecosystem was used during a language class to get students to visit and hear the language and music of China, after which students were given an opportunity to discuss the cities visited.

This type of discussion was standard practice in that classroom but the use of Desktop VR was novel.

> *"[With] the Gala 360, we went to different cities in China...It gets the kids in there looking at the landscape or looking at the cities…The kids had to watch it and then take off their goggles and have a conversation with each other about the cities. So that was kind of interesting because it was pretty much what they usually do except for they added the visual with that".* **(Marley)**

On the other hand, to ensure that students witnessed a virtual trip simultaneously, *Blake* strategically decided to forgo the headset and used Desktop VR instead. This was because all students did not have access to a headset at the same time.

> *"[for Desktop VR] the whole class could be together. Like, I think the Oculus Go, like sure it's cool, but you can't get a class set…So, in terms of like, taking a virtual class field trip, where all like 25 kids could all be on… [we used] Google Expeditions…and it's their first time ever doing VR. And they're like, wow!"* **(Blake)**

*Blake's* selection process parallels *Lezli's* choice to use Desktop VR, albeit for different reasons. *Lezli's* intention to use immersive VR with a headset changed as "right now" due to the COVID-19 pandemic there was no choice but to shift to Desktop VR. *Lezli's* disappointment, which was echoed by *Blake*, was that the Desktop VR used (Google Expeditions) was not a video experience but rather had panoramic images.

> *"right now [due to the pandemic] it's most mostly in the web, [what] we are experiencing is panorama. Just not you know, 3D…even it was last week, I took them on a field trip, virtual college field trip, that's what we used."* **(Lezli)**

*Marley*, *Blake,* and *Lezli,* in these learning examples, began to shed light on other ideas that emerged from pioneer teachers regarding how they integrated these technologies into their teaching practice. The standard practice of having students discuss findings during a lesson continued even when using Desktop VR; on the other hand, the number of headsets a teacher had access to also played into how learning was structured in the classroom and lastly, the impact of the COVID-19 pandemic on the use of these technologies in shifting teachers' choices was evident.

***<u>Immersive VR.</u>*** The use of VR for an enhanced field trip was most definitely visible for fully immersive VR learning experiences with headsets used. Teachers spoke of trips outside of planet earth, to trips inside objects – the human body, atomic structures, and the like. These examples were pre-pandemic in timeline and showed visits made by students to internal spaces to faraway places.

For *Dilyn*, within a unit of inquiry, students took a trip into someone else's shoes – in this case, senses – to develop empathy.

> *"I try to use a VR mostly for empathy walks…And so, for each of our units of inquiry, we also step into the perspectives and looking at people - from their lives, and how you can connect….Our students literally step into that moment in history, or time or a place or a person and actually see what it is to be part of that person's life or that experience."* **(Dilyn)**

*Dilyn* also spoke to using immersive VR for students to visit maker labs to get a view into how airplanes, robots, etc., were designed and developed. In *Marley's* example below, students took a visit inside atomic structures while using standard practices of journaling to document reflections; what *Marley* also highlights is how the lesson was structured – short encounters – in consideration of students' health and safety.

> *"MEL chemistry [is] like three-minute little videos…They watch one or two, take off the goggles, do something else, and then put them on. That [was] best. I'm just so paranoid about young children…So, the lesson when designed it was…they were allowed to do 2. They took off their goggles, and they wrote in their journal, some kind of reflection."* **(Marley)**

It was *Lezli* who took students in an alternative high school to visit colleges and universities in order to support them in identifying with those institutions of higher learning, and in the same vein, gave them an opportunity to visit the insides of a computer – a way to provide a view into career and technical education options.

> *"I wanted to get them motivated to [go to] colleges, and I know college field trips were a big thing, and we couldn't take them…So, I took them on the virtual [college] field trips…Just looking at the buildings generated some level of,…so you can identify yourself being there or wanting to be there. I think that is the fundamental pedagogical relevance of an immersion technology; that you start identifying yourself with that setting… [Also], I showed them…the digital simulation of the innards of a computer, so, they were able - you know, this is the memory…this is the RAM, and these are the ports for audio, this is the graphics card and all that. So, they were able to identify digitally, virtually, while it wasn't there."* **(Lezli)**

Like *Lezli*, *Ari* also used immersive VR as an opportunity for students to visit other lands to hear language while incorporating an element of assessment built into the Nearpod system.

> *"I've been using Nearpod for about six years; they had…the virtual tours in the platform. So as a language teacher, being able to use and create the lessons where my students could then instead of me going, hey, like, check out the book, look at those mountains, imagine what it's like walking there - instead, be able to have them use this platform where they can hold it up, look at it, ask questions."* **(Ari)**

Like *Ari, Lezli* also continued the process of helping students identify with the unfamiliar by having students in an English Language Arts class visit places that authors of old, such as Ernest Hemingway, frequented, to get an overview of the situation the authors may have encountered, doing further research, and then coming back to VR to reinforce the learning. After integrating VR into the lesson, *Lezli* shared that students began to use the relevant vocabulary, and per *Lezli*, "*that's where, you know, you feel the real reward of using VR in education."*

In contrast to the other pioneer teachers who had students use immersive VR to visit unfamiliar spaces, it was *Ryan* who provided an opportunity for students to see the everyday school environment in a new way.

> *"[For the propaganda lesson, as per the lesson plan], only part 4 made use of the VR headsets…The lesson was about propaganda…For the lesson, students were first given a primer on what propaganda is. Then, they would rotate between these stations…they put on the headsets…and then I go on to the next slide, so like the next part of the [school]*

> *building, and you know, they're getting excited as well, because like I put in the faculty room where they've never been".* **(Ryan)**

*Ryan* also offered an experience for students to go back in time to understand the importance of how the accuracy of describing places was critical to historical texts.

> *"That one was, we were doing a lesson on like exploration out west with Lewis and Clark. And, um, that we were kind of did it as like the introductory activity…two kids would get to view a scene from this guided tour and then they would have a minute to just look around and view everything while I'm reading them kind of the prompt as like the tour guide, and then they would - when that time was up, they had to describe what they saw to the other two people in their group who had to draw it on like poster board with colored pencils…it was also done to kind of show them how, like, we're relying on the journals and drawings that they took on the expedition."* **(Ryan)**

*Ryan* further discussed how VR could potentially be used in the classroom; to have students engage in town planning activities, with *Ryan* supporting by gathering digital assets to help students create a virtual town.

> *"I was going to do like a mock Town Council type of thing…I was going to have them kind of decide like, okay, what should go here in this town, but then I was going to take the 360 cameras around and just kind of give them like, make this town and you know, just drive around the surrounding towns and be like, okay, I need a good park and, you know, here's our park that it says on the map, like, here's what it looks like. And so, something like that could definitely - it could be used for."* **(Ryan)**

In these shared examples of how and where teachers use immersive VR through a headset, it can be noted that this enhanced definition of a field trip was the core feature of the learning experiences to develop student knowledge. These enhanced visits to *micro-spaces*, *marco-spaces,* and *time-spaces* provided students with an overview of topics and concepts to build context, to also engage in the experiences of others, and to begin, in a new way, to imagine and identify with the unfamiliar.

***Students Create in VR.*** While pioneer teachers took students on journeys to experience molecules to faraway places, it must be noted that some teachers used VR/AR as a way for students to understand concepts and content, while others used VR/AR as a way for students to express learning and ideas, as a creative outlet. *Dilyn* provided an opportunity for students to begin to create spaces in VR.

> *"I also put them in another app called Gadgeteer, and it's like a gravity physics kind of space. And it's a room-scale space. And they get to build in this space…The idea is that they can take a marble and drop it, and then it goes through whatever design. And so, they have this space to kind of tinker and play and rebuild in there, and they can make it however they like."* **(Dilyn)**

*Blake's* core belief and perception about integrating VR/AR into teaching and learning were that having students create using this technological ecosystem was paramount.

> *"then after we experience, students create, and that creation piece is really important…if you can't shift into creating, yeah, I just think they're a fun, entertaining toy but they're not like – in terms of STEM education, they're pretty shallow. But so like, wet their whistle with this, but then I said, okay, now we need to create".* **(Blake)**

A strategy *Ari* discussed for using VR/AR in the classroom was introducing students to various tools so they could select what they preferred for creations.

> "*You have conversations, but then pick one of the tools at a time and gave them a chance to create and open - you read a book, okay, what type of a book trailer book summary would you create with this or what's your ideal place to travel - to me just random and let them create."* **(Ari)**

*Dilyn* shared a similar belief to *Ari*, which was that students needed to experience various tools so that they could select which tool to use to create as a way to share knowledge and understanding. In the student creation process, *Blake* commented on the importance audio has when creating in VR.

> *"a lot of people, when they're designing virtual reality, they spend a lot of attention on the visual piece, but I said, the audio piece is equally as important.* **(Blake)**

During this student creation process, *Blake* uncovered students' perspectives about using digital assets *(e.g., images, music)*; students did not think of the boundaries associated with using media.

> *"a lot of times, my students aren't used to having filters on the media that they use. So, I said, you can't just grab any Beyonce clip and put it in your project; you have to follow digital citizenship [rules]."* **(Blake)**

*Blake's* discovery begins to make apparent the potential need for establishing prerequisite structures, protocols, and/or policies for students when using VR/AR *(i.e., similar to Marley's example about the care taken in immersive VR due to the age of students)* – in this case, the ideals of digital citizenship. During this study, *Blake* shared samples of student work with the researcher, which very much mirrored the description of the process and work *Drew* engaged students in. Instead of having students experience a VR trip to a museum, *Drew* had students create a museum/gallery experience related to a social justice issue of their choosing using CoSpaces; this was done with students from age five and up guided by students' developmental levels.

It was *Sydney* who had students create three-dimensional objects of art in Google Tilt Brush, paralleling what might be done in a sculpting process. Students researched the needed components outside of VR to develop the story and design the sculptures; a challenge *Sydney* raised was that sketching and designing *"in a VR space or 3D which was really challenging for them."* A commonality between *Dilyn, Blake*, *Drew,* and *Sydney's* examples of having students create in VR was having them go through a process of research outside of VR to build knowledge and then being open to having students take the lead in how they wanted to present their knowledge through a design and creation process. All four teachers supported students in developing the knowledge, skill, and methods of design, development, and creation.

The examples shared above from pioneer teachers provide an insight into how teachers integrate VR/AR into learning experiences, the types of lessons in which this ecosystem was included for student learning and creation. It can be noted that VR/AR was used in these examples to provide students with a context surround the content to be learned, to introduce a topic or concept, or to provide students with a way to share and express their knowledge and ideas.

***<u>Other Potential Use-Case Discussed.</u>*** Like *Ryan* above with a forward-looking Town Planning idea and others during their interviews, *Kai* also brought up some suggestions on how Desktop VR could potentially be used to support early elementary students, who may have behavioral challenges cope with transitions during the day.

> *"I think that [VR] would be a good tool to use in the AM and at before the end of [the day], before dismiss[al]. It's an instrument that - it's about change…So that would be a good way to transition the children; it's boring and then they [have challenging behaviors]. But this way would be a little bit more interesting."* **(Kai)**

*Drew*'s perspective somewhat mirrored *Kai's* in terms of using VR/AR to provide positive outlets for students. For Drew, this is tied to the use of VR/AR for therapeutic purposes.

> *"augmented reality can be used to deal with trauma, to deal with things that could very well work as a therapeutic process for students that might be dealing with things that they can't deal with. It could probably [be] used for restorative justice, [or an] aspect of it in so many ways where if a student, it's, you know, I see AR and VR as a tool for expression…[a way for students to] channel what it is that got them into that circle to begin with."* **(Drew)**

*Kai* and *Drew's* suggested potential use-cases centered on student supporting well-being can be found in the literature and per the researcher's discussion external to the formalities of this study.

This next segment of the review of study findings will focus on the process of integrating VR and/or AR into classroom learning, starting with what some pioneer teachers consider when deciding to leverage VR/AR.  There will also then be a discussion of the impact of using VR/AR for teaching and learning related to the structures that needed to be put in place and the impact it has on classroom environments, teachers' practice, and students.

***Starting Considerations for Planning with VR/AR.*** Further understanding of how pioneer teachers implemented VR/AR learning experiences involves a look at what they considered when developing these experiences. It must be noted here that when the implementation of VR/AR-related learning experiences was discussed, there was a tendency for pioneer teachers to focus on virtual reality, especially immersive VR, even if they used the full spectrum of the ecosystem.

*Marley's* lesson plan example (Appendix VI) showed a primer on VR headsets before having students engage in the immersive experience. *Ryan* also provided a primer (Appendix VII), but it was focused on giving students context around the lesson with the use of immersive VR as a final step in the learning process. *Sydney's* perspective on using immersive VR was related to optimizing student learning through deciphering what students would gain using VR and if that was a better option than other teaching tools.

> *"I guess my two things - what are the students learning from this? And is it better than anything I can give them on a normal computer screen? Because if it doesn't meet those two things, the usability and the expense of a VR device doesn't outweigh just using the computer screen".* **(Sydney)**

*Ari* brought in an aspect of using VR/AR as a critical option when students are called on to imagine an inaccessible place; this can be considered as advice to others.

> *"before even picking something [to use VR/AR for], think about something in the class that [I am] teaching, the content, whatever it is that maybe. At some point, you've said, Oh, just imagine, or you try to really describe something to students. And no matter how good you think your description is like, it doesn't quite capture it, but it's something that the best would be going there and being able to look, but when it comes to say, I don't know the moon or 10,000 feet under sea [VR/AR works best]."* **(Ari)**

This somewhat parallels *Sydney's* perspective of planning with VR as would be done when planning field trips, giving students an opportunity to witness something firsthand.

> *"whenever you're designing [a VR experience for students], or at least when I'm designing something, I'm considering, okay, what is the best experience…I guess my style*

*is very experienced-based, or I'm trying to design an experience for them…VR is very similar right now to how I designed for field trips, or potentially."* ***(Sydney)***

*Blake's* view was that as students learned to use VR/AR, they should be given opportunities to leverage it for other subjects; they should not only be using VR/AR only during the class in which they are learning about how to use the technology *(this was a concept Ari shared when discussing the meaning using VR/AR has to practice/students)*. This would open the use of VR/AR, reducing the potential of it being relegated to specific subjects.

For pioneer teachers, VR/AR was a tool to leverage in the learning experiences when it could optimize student learning, giving them access to new field trip-like opportunities across multiple disciplines. A critical element that affected planning with this ecosystem, especially with immersive VR, was the number of devices on hand in the classroom for students to use. This will be discussed next.

***Impact of the Number of Devices on Integrating VR/AR.*** VR/AR planning and implementation were inextricably linked to the number of devices pioneer teachers had access to for their students. With one example from *Ari* about not having enough AR-related technology, namely Merge Cubes, all other discussions about devices were related to the headset used for a fully immersive VR experience.

*"even with Merge Cube initially, I didn't have - I mean - I had one or two that I had bought…those are just some of the kind of typical things that you would experience".* **(Ari)**

Three teachers, *Marley, Ryan*, and *Drew,* spoke about the school/district having enough VR headsets for all students in a classroom, with extra for when issues may arise.

*"we have 20, and our class size is16, max 16. So, we have plenty".* **(Marley)**

> *"It's around like 25 to 30 headsets plus the one tablet for the teacher to use to lead the expeditions, the tours. And then he also just - he got two [360 degree] cameras, those he just got recently".* **(Ryan)**

> *"we work out the budget, and then I purchase the appropriate materials we need."* **(Drew)**

Five pioneer teachers spoke directly about the challenge of not having enough headsets and how that impacted their planning and the learning experiences, especially the use of time and schedules. *Ari* spoke of *"access to devices"* as a barrier to the integration of immersive VR and thus needed *"backups"* planned for implementation. This was also reiterated by *Dilyn,* who had a class of 20 students and only nine VR headsets; this meant not being able to have all students share an experience at the same time. *Sydney* began to share one solution to not having enough units; pairing students.

> *"barriers are limited devices and time…because I was in charge of their schedule, I could have…a partnership, [a pair of students], go in...Most teachers don't have that flexibility. Even with having it was still challenging to get everyone enough time to build their designs".* **(Sydney)**

*Blake* voiced having to shift to Desktop VR to ensure that students had the same experience at the same time.

> *"So, in terms of like, taking a virtual class field trip, where all like 25 kids could all be on [we used Google Expeditions Desktop VR]."* **(Blake)**

*Lezli* remained hopeful of working with school leadership to obtain more units over time, especially as prices dropped.

> *"this year, my Principal was agreed - got on board with buying Nearpod, and everyone got trained on that. So next year, that's my intention; I will ask the Principal now to even invest some money into Quest, let's see if we could, you know, get at least 10 of those… because now the price is down to $300."* **(Lezli)**

For *Dilyn* solving this challenge of not having enough devices meant structuring a learning experience into three parts and rotating students through each segment, an idea related to how pioneer teachers managed space and students within the space.

> *"So, it takes at least three rotations to get all the kids in…all nine kids into a VR set…And like, if the experience is 30 minutes, you know, it's like, it takes almost an hour per session. So, I have allocated three hours within a unit…So, what I've tried to do is kind of create pre, middle, and ends, like, reflections or kind of like lead-ups, and reflections."* **(Dilyn)**

In reflecting on a particular VR lesson during the interview, *Sydney* cautioned that planning lessons that include VR might not necessarily enhance student learning due to the structure of the content and also that having one device was detrimental to the learning experience.

> *"And then, on top of that, I only had one device. So, I had to design a lesson in which or the structure of my class time that they were all getting the experience at different times, and it didn't allow for a good discussion and to really make sure what was supposed to be happening and getting done, did get done. So, I think a combination of - wasn't quite the right story and facts in it, as well as how it was incorporated into the lesson.* **(Sydney)**

The number of VR headsets available for students was a barrier and affected lesson planning and the use of time in the classroom. To mitigate that risk, pioneer teachers took to splitting students up into groups or pairs and used a rotation approach; this will be discussed below, but first, what and how space was used during immersive VR learning experiences will be discussed.

***Classroom Structure and Management – A Focus on Immersive VR.*** Aside from the number of devices affecting planning and use of time in the classroom, the physical space used to experience fully immersive VR and the management of students in the space was an essential element in VR integration. According to *Sydney*, solutions are still needed to support teachers with classroom management when it comes to this ecosystem.

> *"I think that's something to think about too - as like there's more advocacy for VR, is what does that classroom management look like? And I think there really has to be a lot of work done."* **(Sydney)**

Three teachers discussed using their regular classroom space for such experiences, while others had to use alternative spaces. *Blake* spoke of having a classroom already set up with student desks, computers, etc., arranged around the room, a layout also used for immersive VR experiences.

> *"like all of the computers are facing out…So, there's a row of computer stuff here. And so, like I could see just from standing in the middle what everyone is doing. I rarely do like sage on stage."* **(Blake)**

*Ari* also did not have to change the classroom layout because immersive VR was being leveraged. To *"improve student engagement,"* which was *"something that evolved over time," Ari's* classroom *"shifted into stations"* from rows. For Ari, this was a structure recommended "*when teachers may not have enough devices or tools available that they can use, so all students have an opportunity to explore."* It was *Ryan* who spoke of using an alternative space only when two classes of 25 each were brought together for an experience; otherwise, the standard classroom space was used. In this example, the element of having some students in the VR experience while others were idle onlookers was highlighted; this was echoed by other pioneer teachers.

> *"And so, we had like 50 people together with only like 25 desks. And we kind of spread everything out and…you only need just a few feet around you just to be able to walk around…And then since it's eighth grade, like you're going to have some kids who are just goofballs, so; like I had one kid who is doing it, and his buddy is like poking him while he's doing it."* **(Ryan)**

Like *Ryan* had to host a VR learning experience outside the classroom due to the number of students involved, others used alternative spaces even if not for the same reason. *Dilyn* used space outside the classroom with space specifically marked for students on the ground to sit in, which ensured that other students walking through that shared space had guidance on where not to step. *Dilyn* also used the electronic guardian within the Oculus Quest device so that students would know when they are out of bounds within the experience. *Sydney* and *Marley* also spoke on using spaces outside the regular classroom, be it in a gym or meeting room.

> *"So actually, the eighth-grade classroom, at that point, happened to be right next to a room, and it was all windows. [For viewing the final projects], I would [have] used like a hallway space or a gym to set all of that up. What I did for the VR club is we use the music room, which had no tables and, we're able to spread across there to use VR; space is the other challenge… I think there's potential to use gyms if you can have like a gym space, I think it's fine."* **(Sydney)**

> *"what we did was we push the tables and desks against the wall when possible…But also, we try to book rooms with rolling chairs, like a meeting room if we could so that the kids could move around."* **(Marley)**

For *Lezli*, the use of the older VR technology, the first Samsung headsets, meant that students have to sit and could not move around as they were tethered to the PC. Newer headsets allow for electronically marking space, the guardian, in which one could move around. This upgrade in technological features was leveraged by *Dilyn,* as shared above.

Space used and its layout mattered to teachers when using immersive VR headsets, with some having to find alternative spaces to give students the proper structure for the experience.

***Stations, Rotations, and Partnering Students.*** Five pioneer teachers implemented stations and/or the rotation of students through activities in smaller groups/pairs; this was where some students engaged in different activities while others experienced immersive VR through the headset.

> *"what if you don't have devices for every student? you set up different stations. So maybe in one station students are using Nearpod, or maybe they're working in a group on one CoSpaces project."* **(Ari)**

> *"setting up our sit stations, and you know, ready for the students to come in. So, it's really all just [like a] pop up."* **(Drew)**

> *"What I had typically done for propaganda is I would do like the whole class altogether, I wouldn't break them up into like the stations like I did for this one…we only had - we didn't have [all] the headsets set up yet."* **(Ryan)**

The use of rotation stations was a strategy pioneer teachers incorporated when all students could not use a VR headset at the same time. Another strategy seen in some of these examples was the partnering/the paring of students. For *Sydney*, having a space adjacent to the classroom that was open for the teacher to be able to see into was necessary; in that space, students were paired to work on projects. *Ryan* leveraged the same strategy of pairing students, and in this case, one student was in the experience, and the other was the onlooker.

> *"So, they had partners, but they could go in, and I could see them across the window [from the classroom]."* **(Sydney)**

> *"we paired them, but it was like if you weren't using the headsets like you were in your seat, you weren't moving around. So, it really didn't change anything; like that desk would be there, even if the kid wasn't there."* **(Ryan)**

*Ryan* provided another example where students were placed into a group where, after a pair of students had experienced immersive VR, onlooker students participated by trying to depict the descriptions provided by those who experienced VR.

> *"two kids would get to view a scene from this guided tour, and then they would have a minute to just look around and view everything while I'm reading them kind of the prompt as like the tour guide, and then they would - then when that time was up, they had to describe what they saw to the other two people in their group who had to draw it on like poster board with colored pencils."* **(Ryan)**

In this example, engaging the onlooker had to happen after the VR experience was completed. The issue of the idle onlooker was also highlighted by *Sydney,* who suggested the benefit of a game-like design of experiences similar to "*Keep Talking And No Body Explodes,"* where students outside the VR experience also get an opportunity to participate as the experience unfolds.

> *"if we can get those students who are…observing…involved in what's going on in the headset, that'd become really valuable because you still have that challenge, especially for me right now".* **(Sydney)**

The problem of the onlooker student underscores the importance of aligning the design of the experience within VR with activities outside the experience.

***Adults in the Classroom.*** Another strategic classroom management option pioneer teachers leveraged, where possible, was having at least one other adult in the classroom. *Drew* spoke of having multiple teachers in the room due to the age and attention span of pre-kindergarten students, whereas *Ryan* spoke of wishing for the second adult.

> *"we tend to have like two or three teachers, and so all will have like three different activities because with was Pre-K you cannot pass a minute."* **(Drew)**

> *"classroom management becomes difficult. If you have a co-teacher in the room, then obviously it becomes much easier…where like the one class was a little bit late, like I'm getting them cleaned up and then the next class is coming in and I've got to like rush to get everything set up."* **(Ryan)**

For *Sydney*, there was a second adult in the classroom most of the time - the school's Technology Director - to troubleshoot technical issues; this will be discussed further within this review of findings. This provided *Sydney* with the opportunity to focus on the lesson.

> *"you need one person kind of manage the lesson and another troubleshooting problems."* **(Sydney)**

*Ryan* and *Marley* articulated an underlying element of fear on the part of teachers when headsets were being used, given that the technology did not always work as expected.

> *"[Teachers are] never ever alone with the goggles, which makes a huge difference. So, I don't think - you have that fear factor…I don't think anybody would use them because it scary."* **(Marley)**

> *"some teachers didn't want to use the cart [of VR headsets] without having the tech person there to help."* **(Ryan)**

Those who did not have two adults in the classroom wished they did.

***Device Management – Set up, Collection, Upkeep, Failures.*** Above, *Ryan* shared an instance during which cleaning headsets and setting up to be ready for the next class coming in was delayed, keeping students in waiting. *Marley* also shared experiences with respect to cleaning devices in between classes until it was noted that using wipes caused makeup to stick to the devices even more.

> *"The girls got makeup on it, but we had a box of Clorox wipes in the past year, so I would [clean] in between classes. [After that], I did not clean them in between classes because what we found that when it was wet from Clorox, the makeup stuck even more… Again, this is way before COVID…If I saw one that had a lot of makeup, we always had two or three extras so I would clean the makeup off; let it dry for the following class."* **(Marley)**

Handing out and cleaning headsets was a complex operation when *Ryan* and another teacher brought two classrooms together pre-pandemic.

> *"[before the pandemic], we had this whole plan, and we were like, very strict about like, you're going to use the headset, and then you're going to return it to the teachers who are going to wipe down and sanitize the whole thing. And then we'll give it to the next person."* **(Ryan)**

With just one classroom of students, *Ryan* spoke on how the process of handing out and collecting devices had to be factored into classroom time management.

> *"The time that it takes to, like, handout, the devices has to be factored in…Okay, everybody come up, grab your headset; it was like I'm putting the headset on your desk, you are not to touch it until I tell you to. And then like at the end of the lesson, it's like, okay, I'm going to give them an activity while I run around and pick up these headsets. And then it's my next period is coming in, and now and I've got to clean all these headsets."* **(Ryan)**

It should also be noted that from *Marley* and *Ryan's* example, the COVID-19 pandemic adds another layer of impact in maintaining the VR headsets. Accounting for time to set up is a point also echoed by *Sydney* with the recognition that setting up the newer VR headsets such as the Oculus Quest was less cumbersome than setting up the tethered Oculus Rift, which was a "*huge* *process*." The stand-alone design of the Quest, per *Sydney*, would allow the technology to be "*more accessible*" to classrooms.

***Failures and Triumphs – The Technology, The Lesson and Backup Plans.*** In addition to preparing and collecting VR headsets during lessons, in some instances, the technology did not always work as expected, requiring backup plans or real-time changes to the learning experience. *Ryan* shared how at times, the headsets simply would not connect via Bluetooth/Wifi.

> *"if you got 25 devices with three of them are having trouble connecting, just because of Bluetooth and WiFi and whatever, you know, that's something that we had to consider as well, and if you're not that comfortable being able to troubleshoot things when it goes wrong [that is an issue]."* **(Ryan)**

For *Dilyn*, technology failures were also commonplace where the headset would "*crash for no reason,"* or "*reboot in the middle of a lesson,*" or "*the batteries run out on the handset."* With the use of a different space for immersive VR experiences and not having a second adult in the classroom, *Dilyn* was left "*bouncing around from managing [the] regular classroom to the VR [space]"* while trying to keep all students on track. According to *Marley*, the Oculus Go headset's battery life was better than expected, but like *Dilyn*, it was the handsets that ran out of battery life quickly.

With some technology obstacles at play, long-term backup plans, juxtaposed next to *in-the-moment* backup options, had to be implemented when using this ecosystem. These backup plans included having a second adult in the classroom, ensuring students were aware of what to do should the technology not work according to plan, having extra units on hand where possible, to shifting gears in the middle of the lesson to the next task. To provide a long-term solution to the battery life challenge, *Marley's* school purchased rechargeable sets as a backup plan for *Marley* so that there was "always a set charging." For *Ari*, backup plans involved extra devices when possible or alternative ways for students to access learning – videos – which students seemed not to prefer.

> *"My backup plans involve having extra devices, having video examples if I was planning to do a demo, also having other options available if a specific tool does not work for some reason or if students cannot access it on a device."* **(Ari)**

Sometimes, backup plans had to be as simple as students taking ownership and pulling on patience; this was the case for *Dilyn* when the technology would shut down during experiences.

> *"So, I just have them sit down, I'm like, let it reboot, just like you would if you were sitting in front of a computer, you have to sit down and wait, you have to be patient for a minute."* **(Dilyn)**

*Sydney*, like *Ari*, also spoke about having alternatives, but more in the guise of moving the lesson forward to the next activity, and when possible, coming back to the VR experience.

> *"I would say, it only worked well 25% of the time…I think being okay with things failing…Alright, we're going to pause this…whether you have a planned backup, or you already know what they're doing next, so you can get started on that and come back to it. What I ended up doing is getting them started on other things. And then I did the experience in smaller groups…even when I was alone, I'm going to figure it out, and next class period, we're going to come back to it. I think that's where if you know what your goal is, and you do like the backwards planning, then no matter what happens, then you have the freedom, even if something fails, you know what, what we're trying to get to, so you can kind of move over here, even if you're going to end up like kind of over here."* **(Sydney)**

*Sydney* also expressed concern that VR may be a "shinny" tool and that it might not provide a truly more profound level of student learning given its current state, a concern that was perceived as potentially slowing down further VR adoption.

> *"but also, in the design is, are we designing things that are one better than a video? Or are we designing just to make it shiny because my feeling right now, as VR is typically used in classrooms, is it's a shiny thing. And that's what I see at Ed Tech conferences a lot which made me a little nervous, once it's really ready to be pushed out further that hopefully, people buy it".* **(Sydney)**

Even with some trials and tribulations of using the VR headsets, there were triumphs. *Ryan*, in contrast to *Sydney*, shared how not using immersive VR would have been a detriment to a learning experience and would have meant potentially interrupting other classrooms.

> *"if I hadn't had the VR and I still wanted to kind of give them that like same experience of like getting to see the propaganda in their school I would probably just have just like kind of did a walk through the school or did something [but]…the problem of okay now am I interrupting other classes parading my kids throughout the hallway and then I can do much less in the period because, I can't do the other stations; it's like now, I'm just taking the whole class and like, instead of being a 10-minute, five-minute thing in VR, like, that's it, that's everything."* **(Ryan)**

*Ryan* also goes on to explain that with all that teachers and students have to cover during the school year, sometimes, giving students these novel experiences was simply worth it and may very well enhance student engagement throughout the unit of learning.

> *"And when you do a VR lesson, what I found is it is very much like - it's a bonus lesson like you don't need to do it, you can easily cut it and still cover the information; and - but like, when you do the lesson like it just makes the learning that much more enriched… it's a highlight for the kids."* **(Ryan)**

At times, it was learning that other students were using VR/AR that prompted students to request involvement.

> *"I didn't do anything beyond the Nearpod in my Spanish classes until they saw some of the kids in my STEAM class using CoSpaces. And they said, how come we don't get to do any of that cool AR VR stuff?"* **(Ari)**

Conversely, during some integrations of immersive VR, it was the students who did not want to participate. *Ari* shared that some students simply did not like the immersive VR experience, while *Lezli* pointed out that for the older versions of the VR headset, students felt dizzy and thus did not always want to engage.

> *"there are some that just it doesn't matter what it is, they just don't like it [the VR headset]."* **(Ari)**

> *"when it was just the beginning of VR, and the headsets were clunky, and students weren't able to use for long; you know, 10 minutes or so, and that's about it. After that, you know, they would start getting woozy."* **(Lezli)**

Even with newer technology on hand, *Dilyn* and *Sydney* also spoke about students feeling seasick, dizzy. Both spoke to providing students with options should that feeling arise.

> *"I do have sometimes kids, because of the age level, who are afraid of virtual reality; they're afraid of being immersed into an environment that they're unfamiliar with, which is completely understandable. And so, I obviously tell them, of course, you don't have to do anything if at any point you feel uncomfortable take off the headset...Sometimes I'll have them not wear the headsets…The other thing is I found that occasionally; it rarely happens, but occasionally some kids get like, seasick or feel sick? The movement disorients them a bit."* **(Dilyn)**

> *"you really have to teach them, one how to use the device on their own so they can get it so that they're not dizzy, but also teach how important it is to set it down that if they are feeling dizzy…how to switch it so they can just look at it on their phones. [Some students say] I don't like VR. I already know that - so I'm just going to use it that way."* **(Sydney)**

These examples can be summed up in *Dilyn's* words that *"technology isn't always our friend,"* and this makes the role of the pioneer teacher during immersive VR experiences complex.

***Role of the Teacher in Immersive VR Experiences.*** Teachers who spoke directly of their role during immersive VR experiences were aligned; teachers during such experiences were observers and, as said by *Lezli*, *"facilitator[s]"* of the learning experiences. Pioneer teachers using VR to support content learning became the virtual tour guides pointing out areas of focus for students or ensured students were safe during the experience or troubleshot technical issues.

> *"I'm more or less trying to just be like the coach the facilitator…But I'm not ever teaching during these times, it's them self-directing their own learning at those points...So, it's always just more of a management position for me, rather than a teaching role at that point".* **(Dilyn)**

> *"So, my role…a lot of it was just managing the classroom and the headsets in the space and trying to get them to spread out."* **(Ryan)**

It was *Ari* who specifically spoke about observing students to learn about their inclinations and to learn alongside them.

> *"it helps me because I see the things that they notice…I've tried to get away from being the one who's just standing and talking at them the whole time and learn right along with them."* **(Ari)**

Facilitating learning also meant that pioneer teachers had to ensure expectations were defined for students regarding what to do when devices were not working, to try to spread out to maintain student safety, etc. Another sub-theme connected to implementation was what can be regarded as the prerequisites and/or policies needed for using immersive VR.

***Prerequisites and Policies.*** With concern about student's safety, how they felt, and what to do when using a VR headset, pioneer teacher's guidance to students prior to their use of a VR headset, as well as setting rules/expectations, are what *Ryan* and *Dilyn* spoke to below. These can be thought of as the enabling prerequisites to ready students for immersive VR.

> *"you have to realize [that] you have to really prep the kids beforehand, establish this clear - get ground rules and then like, once the kid violates those rules, I'm just like, I'm sorry, you're, you're out."* **(Ryan)**

> *"So, we all start together [with] the expectations, and then I sit with each group, okay, this is your task, and then this is what you're gonna be working on. Next, you're going to go here, and then we sit together, and we talk about the expectations for each of these groups."* **(Dilyn)**

Additionally, before putting students into an immersive VR environment, other teachers spoke of different types of prerequisites and policies. *Ari* and *Sydney* speak to having students learn the basics about VR/AR.

> *"I just said to my students, this is what - I explained the concepts of AR/VR and the differences."* **(Ari)**

> *"I think safety…Even if I was teaching another subject [I would] teach them how VR works very briefly. Like how those things are coming together, so they understand how it works. And then I set the expectations."* **(Sydney)**

*Blake* shared a detailed explanation of the process used to provide students with in-depth background on VR and having students experience the "how to use" modules prior to having students use the headset. During the course of this study, *Blake* provided the researcher with the introductory presentation on VR, which was extensive.

> *"So, I had this whole presentation, that's pretty long…So, the actual applications, then we talked about the science behind it, then we talked about the art, there's a really great clip about how virtual reality, how it's an engine of empathy and how you turn your mind inside out…and then I have them check out other students' projects."* **(Blake)**

This idea of informing students about the technology itself was similar to what can be seen in the lesson plan (Appendix VI) provided by *Marley* on a Grade 8 Chemistry lesson where MEL Chemistry was used. "Intro to the VR goggles" was the first activity on the lesson plan. For *Dilyn*, having students learn about the immersive VR headset early on was so that they could be more independent during its use.

> *"So, before they - I ever put them in an experience. I always make them do the first steps, which is the…introduction lesson through Oculus. So, it's like, this is how Oculus works. This is your guardian. This is your remote control, and then it introduces it to them slowly. And then it has them play a few games, learn how to throw things and catch things, and whatnot…And so, I kind of showed them how to do all these things, so they're more or less independent after the first couple of experiences."* **(Dilyn)**

*Sydney* and *Drew* spoke to a different type of student-related prerequisite having to do with students creating in the ecosystem; this can be tied to the developmentally appropriate use of the tools. In their experience, students struggled with three-dimensional (3D) thinking and creating. Ensuring that students who are asked to create in VR/AR have this background skill was found to be necessary.

> *"up until you get access to an AR, or VR world, you're looking at things in one dimension…So, the obstacle initially is getting our students to think beyond that one*

*dimension, and we almost have to jumpstart it by engaging them - we might do an exercise together to get out of that the world-is-flat mode, to get them to move beyond 1-D… So, we introduce [for example] our [pre-kindergarten] students to the - you know, the techniques of paper folding to create three dimensions, you know, make your house in three dimensional and create these wonderful paper forms."* **(Drew)**

For *Sydney*, getting to a point where students can create three-dimensionally in VR meant including new ideas into the learning expectations for students in the school according to developmental levels; this echoed *Drew's* example where the idea of supporting 3D thinking also included students from as early as pre-kindergarten.

*"we didn't previously have 3D modeling as one of our kind of [criterion] of things we want students to learn. But I'm working on bringing that into and creating those standards so that each year we're growing. So, I have it right now down to fourth, I think at fourth grade, or actually no third grade, they start models with volcanoes in 3D and just designing and how do I work in that 3D space".* **(Sydney)**

In *Marley's* school, policies were set up to ensure student safety; only students from Grade 6 and up could use the VR headsets and only for a few minutes which dictated the content selected.

*"I think we're all kind of cautious…I'm waiting for more data to come out with brain development… they weren't in it for more than five or six minutes…We also didn't allow the younger kids to use them….so grade four and five were not allowed to use them."* **(Marley)**

This concept of putting parameters around the use of immersive VR was also shared by *Ryan* but from a different vantage point. For *Ryan*, the frequency of use of immersive VR must be monitored; the novelty this technology brings to the classroom may very well be what excites students, and thus it might be beneficial not to overuse.

*"I think I only want to do it when - and this is something that we talked about, like as a cohort, me and some of the other teachers who are using it - like we want to be very selective about when we use VR because we don't want it to be like, you know, just Oh, it's another VR lesson, or I think that novelty, like I think it helps to build excitement and to make sure that anything we do in it is, really worth it."* **(Ryan)**

Pioneer teachers, in hindsight, provided examples of the prerequisites needed to implement immersive VR in the classroom; school/district-wide policies were also an essential factor to plan for to ensure student health and safety.

***Feature Limitations and Technological Evolution.*** Even while navigating the challenges associated with integrating immersive VR by employing backup plans and having specific rules in place to integrate VR/AR into the classroom, pioneer teachers noted how the technology continues to evolve. They also spoke about limitations with the technology, which impacted their intentions for learning experiences and integration.

In discussing the introduction to VR/AR, *Ari* provided an anchoring statement regarding the continued technological evolution within this ecosystem.

> *"[Regarding Nearpod], they didn't have all of the same features that they have now, I mean, all of these keep adding."* **(Ari)**

For *Ryan*, an original intention to use AR via posters for a lesson on propaganda was altered to the use of VR as *Ryan* could not find an appropriate app that matched the preferred design of the learning experience in AR.

> *"I had an idea for AR to put posters of like teachers in the hallway and just have the picture be like a picture of them, of the teacher, nothing special about it, but like, the idea was like, if you could hold the phone over it, then it would transition to the propaganda poster…Couldn't get the technology for that one…We did some research for it… but a lot of the companies that kind of create the software for that, like it's not designed for schools, it's not free. It's expensive. It's like more for advertising places and big budgets where they charge you like per scan…so then I decided, okay, let's go with VR. So, we scrapped the AR - I thought they were cool, but it just seems like the like the tech isn't there."* **(Ryan)**

*Sydney's* perception of a gap regarding *"where VR is at"* is that *"there haven't been any good game ones yet." Blake* and *Lezli*, whom both used Google Expeditions, shared their disappointment with the scenes being made up of 360 images and not video; *Lezli* showed some optimism regarding tools improving over time and the potential for additional content.

> "*I think it's kind of lame that it's not a video that they could just pivot. It's like a 360 image."* **(Blake)**

> *"It's mostly, you know, panoramic. So, we have, you know, the 3D videos and 3D images, which, [could be created]…but I believe it is yet to come and it [360 video] will come you know, with a lot of application and with wide acceptance."* **(Lezli)**

*Ryan* also spoke about the need for headphones when using the VR headset so students could hear sound.

> *"I think the one thing we didn't have was sound for them. So, I think the kids could bring in their own headphones."* **(Ryan)**

*Dilyn* took note that some of the tools did not allow for student collaboration.

> *"[For Gadgeteer], the only thing I wish about that one is that it was more collaborative. I wish that I could get a group of kids in there to build together…I'm hoping that that will come soon".* **(Dilyn)**

Similar to *Ryan* and *Dilyn's* perceptions that the technological ecosystem lacked certain features, *Sydney* also encountered that potential options for discontinued apps did not yet have certain features built-in. The changing technology landscape where products are discontinued will be discussed further.

> *"with AR, there's this app that doesn't exist...they've stopped their education [product]…they quickly got rid of it. You can't even get the app anymore. It's like not just unsupported, it's gone…. I've asked [other technology companies], like, so I've used this thing, and you can merge them together. [They are] like, yeah, our thing can't do that yet."* **(Sydney)**

Similar to *Marley's* prior discussion about content lacking options for diverse populations, *Blake* spoke extensively about the lack of access to features within a VR creation tool that allowed for the representation of diverse groups of people; this lack meant that students could not realistically depict historical figures and other characters in their creations and the projects may have had to change.

> *"I had a hard time finding an avatar creator, that like, I needed one with braids - like I had a male student with braids, and so on so many of the Avatar creation tools, like boys couldn't have braids…I had to, I had to find one otherwise I couldn't do the project… So, I've had to be the loud…It's not helpful to the students…So, I'm a little obnoxious…especially through Twitter. One of the examples is…an app creation tool. All of their stickers, which they've had were, there was zero minorities, like the doctor was a white male, the dancer was a white female. And I said you have no minorities, like none like that's outrageous. And so, when my, my Hispanic students are doing a project on Misty Copeland, and they have to pick the white, blonde ballerina, that's outrageous. So I said, I can't ethically use your tool. Also, with [another tool], I went a little crazy…because…when they started with their premium accounts…you [could] change the skin color of the characters only in premium…And I said, wait a minute, you have to pay for diversity…10-year-olds are doing a Martin Luther King project with the white guy like that's outrageous."* **(Blake)**

Like *Sydney*, *Blake* also made an effort to share facts around the lack of access to certain content/features with technology developers. At that point in time, the technology did not include what this pioneer teacher needed. In having students use VR to create, *Sydney* also spoke to the inability, depending on the tool/app, to view student's VR creations in another medium - this idea is somewhat tied to how pioneer teachers may assess student learning and/or have students view the work of peers; this is discussed further in this chapter.

> *"If somebody is in VR, as a teacher, you really can't see like, what are they seeing and experiencing and it's - that's a challenge...; if they create something in VR, like say they do something in Tiltbrush - Tiltbrush is okay for pulling stuff out, but other tools where they're creating things in VR, it's not really easy to take what you create in VR and pull it out so that I can see it anywhere else but in that VR."* **(Sydney)**

It was *Lezli* and *Sydney* who also spoke of the inaccessibility of the various technology platforms that allow for the use of VR/AR. For *Sydney*, the changing technology meant that shifting from an older headset to a newer one meant the older information could not be transferred easily to the new; the systems were incompatible. For *Lezli*, accessing a Desktop VR application was complex to set up.

*"I'm currently trying to figure out how to put things that I've created from [Oculus] Rift to the Quest because Quest runs on Android. The [Oculus] Rift, it is great for development because you can just pop the headset on and like pretty much live, see what you're impacting, whereas like right now, I'm fighting with my Oculus Quest to figure out how to get it sent…[it is] completely different because it's a different platform."* **(Sydney)**

*"Because even the Web VR kind of technology is - uh, I could not find it accessible, so easily accessible…Even yesterday, I was trying to do something…but it makes us go to a whole lot of installations and the API installation, I said, man, I do not know if I am going to do all of that. But if it's possible, you know, maybe at some point that this will become easier."* **(Lezli)**

The concept of compatibility with current systems was reiterated by *Sydney* and *Marley*. Per discussion with other teachers and Influencers, *Sydney*'s perception was that many teachers who may now be operating within a hybrid/virtual model due to the pandemic may expect certain features that may not be available to them yet; this, *Sydney* enunciated, was the ability for teachers to push content to various devices and have some level of control.

*"teachers right now because of like Google Classroom, all these teachers, are used to having all these features just send out information to all the devices and have that control. But there's an expectation that that's available now, it's going to transfer to VR as well...I think it's a really good point thinking about like educators coming [to potentially use these technologies]."* **(Sydney)**

*Sydney* also raised a point not raised by other participants; that of integration with the learning management systems within the school given the multidisciplinary approach leveraged for teaching and learning.

*"when I was teaching all the subjects, there's not a learning management system set up for that. I had an assignment where I had students working on four different deliverables, one in Minecraft, a song, um somebody writing an essay because they prefer the traditional method… somebody building something out of Legos… I would have art competencies that needed to be attached, but the rest [of the competencies] wouldn't. And even if I had them all doing the art assignment that was also an English and history assignment, I would have to create three separate assignments in each of those grade categories to check off the competencies."* **(Sydney)**

Ensuring that VR/AR could be easily integrated into the school technology environment was what drove *Marley's* school to purchase the Oculus Go VR headsets. *Marley* shared that because the school used only Apple products, choices at that time were limited. The school chose the Oculus Go headsets as their use is agnostic of the type of technology used in the school; they were standalone headsets.

Another sub-theme that pioneer teachers discussed was that some VR/AR technology was complex because they are still developing, and thus some devices and apps are being obsoleted after teachers and students have invested the time in learning how to use them.

> *"[our school only has Apple products and] I said, okay, Oculus Go goggles, and they were very reasonable, which now I realized they don't make anymore."* **(Marley)**

*Ari* also commented on the recent purchase of the Oculus Go for the classroom but also shared the caveat that "*they're not going to be supported after December"* 2020. *Sydney,* in the example above, spoke to a company no longer offering education-related apps. *Blake* also experienced particular technologies also going off the market.

> *"So, I used HP Reveal, which is normally Aurasma, for years and now…they dropped it like a hot potato, and so now it's like completely pulled…They said, you can't upload, and then a year later, they pulled other projects."* **(Blake)**

> *"During remote learning, due to a lack of equity among my students at home, I am using simpler tools to ensure all can participate. We're using Google Tour Creator (far from [immersive] VR... but it's something) and recently, I am disappointed to hear that this tool will be discontinued starting in June 2021."* **(Blake)**

These examples of the complexities, limitations, and discontinuance of different types of technology in this ecosystem also signal how the technology is still evolving.

*Sydney* brought additional attention to some of the limitations of the technology thus far (i.e., not many educational experiences that leverage six degrees of freedom (6DoF) or gaming). Within this discussion, *Sydney* also raised an element that *"there has to be a lot of intentionality on the [part of the person] who designs the experience"* and also that the *"educator has to be very intentional in how they are using it and how they're using it as a way to bring discussion* *and help students gain a better understand of whatever the topic is."* In this extensive discussion, *Sydney* also points out that the guides that support teachers in leading tours are helpful; however, for some experiences, teachers cannot select the scene they want to go to directly. *Sydney* also raises the issue of ensuring ease-of-use for students and teachers; with the descriptions for fearfulness on the part of teachers shared by others above, there seems to be some level of discomfort with using at least immersive VR in the classroom. *Sydney's* suggestion is to have support to *"get educators and developers and designers together"* to create solutions specifically for education. From *Sydney's* perspective, intentionality and collaboration must lead the way forward.

***Student Demonstration of Learning – On Assessments.*** From how teachers used the technology, to challenges encountered in integrating this ecosystem into that classroom, albeit a deeper focus on immersive VR, to strategies put in place to combat those challenges, another area pioneer teachers discussed was on how students demonstrated knowledge and were assessed when VR/AR was embedded into learning experiences.

Some of the learning platforms that incorporated VR/AR capabilities came with built-in assessments like Nearpod.

> *"Nearpod I use, I mean, if I'm going in the chapters of the book, or following the content of the book, I mean, every chapter, I use it just because I like the assessment piece of it."* **(Ari)**

For *Drew*, preparing students for tests could now be orchestrated differently with VR/AR, and this would account for various student learning styles.

> *"even if I am preparing my students for the test, for those who are auditory and visual learners, a virtual reality segment to teach a concept would be key, you know, as opposed to having that student use a workbook, or text on a worksheet to learn."* **(Drew)**

For *Blake*, with "*over 150 students*" on an *"80-day schedule,"* providing students with tools to create, as mentioned above by *Drew*, was what was important; students could then select the tools they wanted for the projects. In addition, *Blake* chose not to grade open but provided "*detailed feedback and then follow up." Blake's* perspective on grading aligned with *Ari's,* who was focused at the beginning on Pass/Fail grades for students with an additional focus on students learning new tools and skills.

> *"for the first couple of years, the grades were just Pass/Fail. And so, I didn't want - with that course, it wasn't like I was giving them things like a traditional course where they were getting graded, and there were assessments. I mean, I wanted them to build skills, and I wanted them to understand it [VR/AR]."* **(Ari)**

When grading and providing students with feedback, *Blake* chose to use a self-grading rubric to support that assessment process. In line with the goal of individualistic student projects, *Blake* was focused on having students become reflective and own their progress through the concept of *"failing forward."*

> *"I always do a rubric. And I always do a self-grading rubric. So, students grade themselves. And then I review - I find, if any - I review, and I'll adjust if needed. For the most part, students are pretty spot on with honestly grading…And so…I said, if you're not failing forward once, like, you're not gonna fail this project; but if you're not facing one hiccup that you have to figure it out, then you got to up it, you got to make it harder. And so, I have a line in the rubric on mindset…And then I do have one short answer as a question is, how did you fail forward in this project?"* **(Blake)**

*Ari* also leveraged a rubric that provided students with guidelines on expectations around their storying telling projects. *Ari* also relied on standard checks for student understanding, such as discussions and quick online assessments, as did *Ryan*.

> *"if the purpose of using some of these tools is to have students create like as in digital storytelling, then those would have their own rubric to use for assessment. Other times just simply engaging students in conversations or using something for a quick check -*

*whether it's a Google form or some other digital assessment, can be helpful for that."* **(Ari)**

*"So, at the end of it, they when they were done with that station, they had to go into Google Classroom, and there was a question about it. I think it was the same prompt that I had them talk about, like as a group, and then I had them, I had them discuss it as a group, and then they answered it individually on their own."* **(Ryan)**

*Marley* spoke on having students capture reflections in journals to show their learning as they would in non-VR/AR lessons, whereas, *Dilyn* had students combine analog and digital assets to demonstrate learning.

*"So basically, [after MEL Chemistry experience], the style of the class stayed the same, because they use journals that they normally do when they're doing class activities."* **(Marley)**

*"And after the experience, then I have them on a blank piece of paper, I'll have them draw one of the scenes that they saw…And then they will create an augmented reality Flip Grid QR code, so they'll do a video about their, what they saw, how they saw it differently. And then they will print the QR code, and that becomes one of their displays for sharing their learning for their parents."* **(Dilyn)**

*Sydney* shared the use of a more competency-based assessment process; tests and quizzes were used infrequently.

*"I've never done traditional grading. So, my first school I worked in was competency-based, and we very rarely gave out tests and quizzes, mostly the tests and quizzes were so they can still have practice being prepared for tests and quizzes in the future because they'll have them. So, because it was competency-based students did a lot of creation and other forms, whether it's discussion…I still utilize a lot of those methods of assessing because to me, they're a lot more valuable."* **(Sydney)**

*Ryan* spoke of not assessing the accuracy of student recall from their immersive VR experiences but rather that the learnings from those experiences were infused into a project of which the overall output was assessed. It should be noted that students in *Ryan's* class were not creating immersive VR.

Whether related to reflecting on learning, retelling a story, or creating based on learning, an underlying theme for pioneer teachers assessing students' understanding was grounded in storytelling. *Lezli* articulates this through a juxtaposition of learning in a 2D world with standard assessments and a 3D VR world where storytelling becomes paramount. For *Dilyn,* the use of AR through the Merge Cube focused was on having students show their learning by creating characters and places; for example, students showed their learning by writing a book and recreating elements of that story in AR.

> *"But [the] VR experience is more like storytelling. So, I am all for non-traditional assessment of VR experiences, in which alright, you got this simulated experience, now these are the tools, can you rebuild, what you just saw in real [time]. So, it means it will be a rebuilding or retelling of the experiences. That's what is the assessment [is] for VR".* **(Lezli)**

> *"for AR, we've been using it more for constructing worlds and stories. So, I use a lot of like Merge Cubes…they are reading all different stories, and all different genres and whatnot. And so, it's a way of reflection and showing characters and settings and places. So, they'll design their Cubes with different locations and settings, and the people will tell different stories from their perspectives."* **(Dilyn)**

Albeit being complex, *Sydney* had students share their knowledge by completing a biology-related storyline based on where the immersive VR experience left off.

> *"They were kind of finishing the story as part of their final, so their output was [that they] were supposed to continue that, [the VR experience], in kind of a cartoon form incorporating certain content pieces that we've discussed outside."* **(Sydney)**

Having students create in VR/AR to demonstrate learning in an open-ended manner is what *Ari* and *Drew* also engaged students in.

> *"Also, giving students the opportunity to be the creators more with a tool and say, Okay, so we just read this book, instead of a book report..leveling it up and building some other skills that they definitely need. So, pick a tool and have them do even like flipgrid; flipgrid has augmented reality where you could pop up in the space…And they're using [it] to cover their book, and they can put a character on and they tell the story of like, what their takeaway was or what their summary was".* **(Ari)**

> *"on the flip side, having students create products that demonstrate what they know about something can also be a great tool for assessment, to enable the teacher to see where they are in their level, and then fill in the holes as needed for additional things."* **(Drew)**

Whereas for *Dilyn*, the use of VR/AR was a way for students to share the story of their own learning journey and their own work with their families during parent-teacher conferences.

> *"I actually use CoSpaces for student-led conferences. So, I have the kids create their virtual worlds, whatever they see fits their worlds and they design them for the [parent-teacher] conferences, and then they have to put a gallery of their work displays, so videos, pictures, writing pieces, like their artifacts, whatever they like, as part of their display. And then they take their parents through a virtual tour of their student conference."* **(Dilyn)**

All in all, Sydney raises the point that to even use VR/AR as a tool for assessment, one would need to see the process of what students are doing and/or creating in VR/AR and the creation itself; this point of being able to access these elements is most important in immersive VR where students are seeing or doing within the confines of a headset-handset combination. This sentiment is captured by *Sydney,* who shared above, that for an art project using Google's Tiltbrush *(another tool that is shifting to become an open-source platform and would no longer be managed by Google),* the teacher could view the creation in another medium, but this was tool-dependent; not all tools provide that capability.

Regardless of the methods used, students were able to show learning from their VR experiences, express learning in AR as well as in VR, using these tools to have their voices heard.

***Teacher Perception of VR/AR and Impact on Practice.*** Discussing how VR/AR adoption and integration affected teacher's practice provides additional insights into their perception of this process. For *Blake* and *Drew*, the perception was that integrating VR/AR had a neutral impact on their teaching practice; there was no fundamental shift to pedagogy, but, per *Drew*, there was an impact on the knowledge acquisition process for students.

> *"in terms of my teaching practices, I'm pretty much teaching the same*." **(Blake)**

*"I'm not using AR as a teaching tool to inform the remainder of my pedagogical practices…it doesn't necessarily impact from a teaching perspective…we're using our teaching to use AR VR as a tool to enable students to possibly learn in a different way. It's really impacting their learning, as opposed to impacting our teaching…we're only giving them the knowledge of how to use the tool and then giving them free rein to be what they want"*. **(Drew)**

For *Lezli* and *Dilyn*, the impact was related to their perception of the result of the VR/AR integration; there was a shift in the teaching and learning process but not necessarily to pedagogical practice.

*"it has helped me develop a better relationship with my students…[the teachers] also, find out after some time that the traditional ways of teaching, unfortunately, are not suited for this environment…so now there is more and more alignment, you know, with the psychology of human learning, and the pedagogy of learning and teaching; that's what you know, is making this technology more relevant."* **(Lezli)**

*"it has definitely shifted my teaching and learning for sure. Um, because it's taking it to another dimension…It's turned into this collaborative effort, this, like sharing of ideas, it's turned into a community-building, it's turned into different perspectives and strengths of intelligence coming together and creating something as a unity, not a singular unit. It's changed from being two dimensional to three dimensional, it's turned from real world to virtual world and combining the two worlds together. It's, yeah, it's made things that - it's given kids a voice where they didn't have a voice of their own."* **(Dilyn)**

Here, *Lezli* and *Dilyn* share how using VR in the classroom created an environment of collegiality. Like *Drew*, *Dilyn* also spoke of how VR/AR gave students a new way to express their voices; for *Ari*, it was about how VR/AR gave students more ways to access learning, ultimately improving understanding.

*"if I could look at it and say, Okay, I can see the angles or oh, the parts of a volcano or the solar system and see where the planets are, because I'm holding [the Merge Cube] in my hand, it - I mean, it gives you that more of a kind of immersive experience where you're actually connecting with it, but also taking our students out of our classrooms without actually having them to go out of our classrooms."* **(Ari)**

The use of VR/AR had a relatively minimal to neutral effect on teachers' pedagogical practices; the technological ecosystem, however, offered new ways of accessing content and constructing knowledge; and provided students new tools through which to share their voice.

### *Emergent Themes Providing Additional Indications on VR/AR Trajectory*

The research methods utilized in this study, with a semi-structured interview guide and an open stance, allowed the researcher to follow the lead pioneer teachers in terms of where they put an emphasis during discussions. This allowed for the emergence of two (2) themes not directly related to answering the two (2) research questions. These themes offer some potential insights into other factors that may impact the adoption and integration of virtual and/or augmented reality in PK-12 education. These themes were related to (i) the COVID-19 pandemic and (ii) teachers' self-perception, history, and perspectives, and contexts surrounding teaching and learning.

**Theme 6: Impact of COVID-19 on adoption and integration of VR/AR.** Regardless of location or circumstance, all teachers spoke of the impact the COVID-19 pandemic has on their VR/AR adoption and integration journey; this is evident in the stream of excerpts from pioneer teacher interviews shared throughout this chapter. For one, it was clear that classrooms had been affected by the pandemic, with all teachers having experienced school closures at some point in 2020, with some teachers still contemplating what the future would hold for them and their students.

*"So right now, when remote learning, it's, it's challenging."* **(Blake)**

*"I don't know what I'm going to do this year [2020-21]."* **(Sydney)**

From the Interest and Demographic Survey, one potential participant shared that "*if not for the coronavirus pandemic, I think that I would use VR technology much more than I will in the coming school year. I will not be able to use the VR headsets but may be able to guide students through 360 tours on their Chromebooks*." *Ari* spoke about the limitations of the use of VR/AR because of the pandemic; this was echoed by others.

> *"And again, like those things are great, but what does that look like now when we can't be in the same kind of spaces, right - at a distance and teaching my same class, it did limit what I was able to do with them. Fortunately, we had done a lot of this a little bit earlier in the year and then also right before schools closed."* **(Ari)**

Even when classrooms opened up, or there was debate about opening, it was clear that not all students would physically be in the classroom and that there was still going to be a group of students engaged remotely; and if students were in the classroom, it may have very well been the teacher who could be working remotely with another adult in the classroom instead.

During school closures, the use of immersive VR with a headset was stopped, and there was uncertainty if it would be used during the 2020-2021 school year even if students returned.

> *"we're not using [the VR headsets] this year [2020-21]. We're not even using iPads this year".* **(Marley)**

> *"So, this year, [2020-21], like, probably not going to be able to use the VR headsets".* **(Ryan)**

> *"as far as the VR program, my guess would be it's not going to happen…My suspicion is I'm not going to be allowed to use the headsets [for the 2020-21 school year]".* **(Sydney)**

A key factor for the integration of VR headsets into learning experiences, should students return to the classroom, is the issue of cleanliness as enunciated by *Lezli* below.

> *"Maybe [in the new year, 2021, it would be] very much possible [to use the headsets] if we, you know, if there was no concern about the cleanliness and hygiene of the headsets because now I think we'll be in some kind of direction about not using these devices interchangeably".* **(Lezli)**

For the headsets, given that most teachers did not have a complete class set and they had to be shared amongst students, ensuring they are hygienically safe for students to use becomes even more critical. Pioneer teachers spoke to cleaning headsets prior to the pandemic, but there was a sense that what was done in the past would no longer suffice. The increased time to ensure cleanliness would need to be factored into classroom time per *Ryan* and *Dilyn*, and as shared by *Dilyn*, this would impact the scheduling of experiences given the 72-hour wait if disinfectants are not heavily applied.

> *"even like before COVID, it was still like - we're still going to clean them [the headsets]. Um, so - and I had no idea at the time, now I do, that when you wipe something down with like a Lysol wipe, you're supposed to let it dry. And so, I thought I was just like, you know, okay, just get a good wipe and you know, and we're good. You know, I didn't know you need 10 minutes to let it air dry and stuff like that. So that's definitely something that I'm gonna have to consider now going forward".* **(Ryan)**

> *"I researched all the different ways of cleaning, disinfecting…I find that most of the chemicals that are used on the glasses wears out the material faster. And so, I just find - I'm just gonna wait the 72 hours, and I have other things that kids can do in the meantime and reflect, and then we just -yeah, especially the inquiry, you just go in through rotation. So, it's fine".* **(Dilyn)**

The COVID-19 pandemic did not only impact the integration of immersive VR but also affected some AR usage. Pioneer teachers who had relied on the Merge Cube, for example, also discussed the complexities of continuing its use during the pandemic. With students at home, unless the family had access to a printer or could purchase one, the Merge Cube could no longer be used for student learning and expression.

> *"I don't see [continuing] unless each student had their own. I mean, the headsets are not required, but if each student had their own - this is, assuming that families have a printer because you don't know that…And so, students could if they had the app, they could do that at home. Now teaching remotely, I can use my iPad, and I actually did a presentation probably two months ago on AR VR, and I was live demoing in this live session, and some parts of it kept kicking out."* **(Ari)**

Some pioneer teachers began to look for alternatives to meet the challenges of the impacts of the COVID-19 pandemic.

> *"everyone has tech issues, and the kids who have a hotspot, there's a max of data. So, at the end of the month, they can't do anything…I'm trying to do unplugged projects because I want them off the screen; so, I'm trying to design projects that use common household supplies for them to build and for them to get off the screen."* **(Blake)**

> *"During Remote Learning, due to a lack of equity among my students at home, I am using simpler tools to ensure all can participate. We're using Google Tour Creator (far from immersive VR... but it's something), and recently I am disappointed to hear that this tool will be discontinued starting in June 2021".* **(Blake)**

Similar to the last example from *Blake* of using Tour Creator due to the pandemic, others who used immersive VR seemed to be increasing reliance on and/or shifting to Desktop VR and/or AR.

> *"What I'm going to do this year is, because like when you create something with like the Google Tour Creator, you get like a Google polylink…So, you don't get full VR, but you know, it's still it's enough for me to do the activity, especially the propaganda one. You know, I think it's sufficient for that…. even if I've got some kids in the classroom and some kids at home like it'll be the same thing for them."* **(Ryan)**

For *Dilyn*, there was more reliance on tools such as CoSpaces which allowed for the design of virtual spaces that could be seen via Desktop VR as well. *Dilyn* was clear that students were resourced with iPads whereas, for *Blake*, student inequities in internet access caused a shift to *"off the screen"* methods.

> *"I wasn't doing two different things; we were all still doing the same thing. it's just that some were in actual physical space, and some were in a virtual space, and that way, and when it came to building virtual worlds [in CoSpaces], like, that was easy because they all had their own iPads, we were lucky enough that our kids have their own iPads."* **(Dilyn)**

> *"right now, it's most mostly in the web [Desktop VR]… even it was last week, I took them on a field trip, virtual college field trip, you know, that's what we used."* **(Lezli)**

While *Ryan, Lezli,* and *Blake* shifted more to Desktop VR for learning experiences during the pandemic, *Sydney's* was focused on maintaining students' 3D creation skills.

> *"as far as AR with the 3D modeling side of things, I'm not convinced on the Merge Cubes - that they're useful. We have some at school, but since I'm going to do some 3D modeling things with students…when we do get back in person, I might try to do a little with AR because those I have a few more of, and I can clean in between and all…I mean, on the development and creation side, I'm probably going to do a little more with 3D games, because that's still going to teach that same - because it's really about the logic of designing in that three-dimensional space…My guess is that intro to Unity might be games, and we might do something more video related. So that's kind of the direction I'm looking at is keep the modeling side, or maybe we'll do more with 3D printers this year".* **(Sydney)**

For *Dilyn*, long gone were the days when families got to experience student's creations in the classroom.

> *"Typically, without COVID, we have parents come in, and everything and so they will have a published book and they will have their author summary and then they will show their Merge Cube to actually show their three-dimensional worlds and how they portrayed them."* **(Dilyn)**

The question about what the long-term effects of the COVID-19 pandemic would have on the further adoption and integration of VR/AR in PK-12 education remains. When the use and sharing of headsets are allowed again with the appropriate cleaning protocols remains uncertain.

**Theme 7: Teacher Self-Perception, Philosophy, and Educational Context.** One of the other themes that was evident through the discussions with pioneer teachers was their perception of self. This self-perception is seen through their description of self, their history and perspective on teaching and learning, as well as and the educational philosophical context in which they operated. Pioneer teachers often spoke of themselves as being the "techie," different, with interest in digital technology, the ones to keep a pulse on the research and to keep ahead. Some of this was seen in their propensity, as described in the theme on Channels of Learning, to be self-taught and to experiment when they began to learn about and use VR/AR. *Drew* continuously kept abreast of research -

> *"I stay on top of it, so I'm always doing the R&D to see what's the latest out there because I'm a techie and then what can be ported down and layered down as a tool to teach students, and then we can design the lessons and curriculum from it.*" **(Drew)**

*Blake* and *Sydney* viewed themselves as different from other educators around them; for *Blake,* it was being a "trendsetter."

> *"I've always been very techie, so I'm like the go-to person…in every role…I am a trendsetter."* **(Blake)**

For *Sydney*, it was being an "outlier."

> *"so even though the school was starting to bring in those things, I was still a bit of an outlier because people…they're like cool with how it was ran and their vision of themselves was to keep doing it the way they saw".* **(Sydney)**

*Ari's* echoed similar sentiments of being different from other educators in terms of going beyond what would be expected if one was not explicitly teaching technology to students.

> *"And I just didn't think like many teachers – [they] think that, oh, I don't teach a technology course I'm teaching English or math or whatever. And I can't use that. But the reality is, you absolutely can. And when you do use something like that, it really takes it to a new level."* **(Ari)**

For *Ryan*, VR brought many technology interests together.

*"I like to listen to like, podcasts about technology and do different creative things. And you know, I like coding and things like that and so I think for me, VR was kind of like bringing together many of those different things that I enjoy doing and the opportunity kind of to do that."* **(Ryan)**

For *Lezli*, it was acknowledging an aptitude and family environment for early adoption of new technology.

*"In fact, we are, in our - you can say a family of Oculus adopters, early adopters."* **(Lezli)**

*"I always had a knack for, you know, early adoption of any technology. So, sometimes [even when] it's still in the beta version, I need to go for it."* **(Lezli)**

*Lezli* here began here to expand how the self-perception of being an early adopter of technology was linked to personal interest and history. For some pioneer teachers, this interest in technology was tied into their own personal and educational histories of exposure to technology, its use in teaching and learning, and various educational philosophies. For *Drew*, there was an early introduction to the sciences and technology as a child.

*"Informal science was what I did at home from first grade on, so my dad would buy me science kits and different kits…And then, when I was 11, he introduced me to computer science. So, I learned how to code and learned my first computer programming language, and that kind of went from there. So, in high school, I took computer science classes in the summer I took - I was in a program that had coding. And I majored in computer science at school in college."* **(Drew)**

For *Sydney*, this interest in technology and non-traditional practices blossomed in college while still being the "weirdo."

*"so, science and project-based learning is kind of where it's started for me…And that kind of led me to start exploring technology more in college…We actually had iPads instead of content textbooks for our final year, that was really valuable. So, we started learning how to, like reach for resources and develop skills in lots of different areas rather than the traditional, like, here's your textbook…I was kind of a weirdo who was like, wow, like, this is amazing."* **(Sydney)**

Juxtaposed next to ideas around pioneer teachers' self-perception was the context surrounding the school and/or subject matter taught and how it was taught, as well as what might be considered as educational philosophy. Many teachers were provided with flexibility and got the opportunity, with leadership support, to chart new territory in what they taught and how they taught. This open environment may very well have been the fertile ground to allow for new technologies to be seeded.

> *"[My Principal] asked me, what do you want to teach? And I named a lot of different topics. And I mean the basics about tech…but then things that I was curious about what I was learning about. And that is where the AR VR came in, also artificial intelligence, coding, gaming, you name it…So, my course then became what's next and emerging tech…but the AR VR and the AI are big components throughout the year."* **(Ari)**

> *"I said, if you don't like the grade that you earned, you can redo it, as many times they say, do you average? No, I don't average because if that's where your learning is, um, and so a lot of students are taken aback by that. And I say, like, if you're unhappy with your grade, and you want to do better, redo it, and resubmit it as many times until you're happy with it, and I will give you the grade that reflects with your learning."* **(Blake)**

> *"each school chooses their own units of inquiry where they feel that they fit best…you use all of your transdisciplinary skills and learner profiles and stuff and show what you've learned as a student, [in] an exhibition, which is a self-led student inquiry, 12-week research-based project……our school, at least our school is a lot about action…I really, really try to like let go of that power a little bit. And just like let's just see what we can do."* **(Dilyn)**

> *"I was teaching third grade that year, and I had complete freedom to teach very interdisciplinary lessons. I could incorporate computer science into math; I could teach, spend an entire afternoon doing a blended history science stem. And that was really encouraged; very experiential."* **(Sydney)**

Pioneer teachers' perception of self, their histories of taking a keen interest in technology, and the flexibility around developing interdisciplinary/multidisciplinary learning experiences for students, for some, was a backdrop to their adoption and integration of virtual and/or augmented reality in the classroom.

**Findings Conclusion**

In this chapter, the data from the Interest and Demographic Survey that interested participants had to fill out was shared. With a mix of subject matters, ages, and years of teaching experience, next was a description of the findings of the interviews of the nine volunteer participants.

Three (3) key themes rose to support answering Research Question 1 on teachers' experiences adopting and building knowledge about this technological ecosystem. It can be noted that the adoption and integration of virtual and/or augmented reality into PK-12 education by pioneer teachers is a multifaceted and complex process. The introductory and early experiences pioneer teachers had of virtual and/or augmented reality were viewed positively and thus marked the start of the trajectory of adoption into their teaching practice. Pioneer teachers looked to groups, influencers, and social media to build their new knowledge about how these technologies worked as well as what options they had to infuse them into learning experiences for students. Tinkering and experimenting with the technology were how some pioneer teachers continued to build their knowledge base, with some including students in the learning process. An influencing force for pioneer teachers in their adoption and integration process was that of school/district leaders; it was support from these leaders that allowed teachers to have access to the technologies.

When it came to using this technological ecosystem in the classroom, two themes were evident. First, pioneer teachers had to select the tools, apps, content, and experiences to bring into the classroom. Given the nascency of the use of VR/AR in PK-12 education, study participants felt there was at times a lack of content to suit their needs; pioneer teachers did not create new lesson simply because they were leveraging VR and/or AR but instead used these tools to enhance learning experiences and to further engage students. With content/tools selected, implementation in the classroom ensued; this the second theme in which the complexities and the benefits of using these technologies can be seen. At times, pioneer teachers had to find new space in which to use immersive VR headsets, and at times, two adults were needed in the classroom to support classroom management and troubleshooting if devices did not work.  Pioneer teachers had to factor in the time for device management and the fact that most did not have complete classroom sets of Merge Cubes for AR or headsets for immersive VR; with that said, teachers had to plan lessons accordingly.  The impact of VR/AR on teachers' pedagogical practices, inclusive of uncovering student learning through assessments, positive for some and neutral for others.

Other themes emerged through this study, namely around the COVID-19 pandemic and a backdrop for furthering adoption and integration – teachers' self-perceptions, histories, philosophies, and the context in which they practiced their craft.  The COVID-19 pandemic, with school closures and concerns about student health, put an end to the use of VR headsets and other tools that needed to be shared amongst students.  Also, with the school closures, pioneer teachers in this study had to find alternatives to support student learning.  Regarding the backdrop that may have fueled adoption and integration, most pioneer teachers saw themselves are being on the cutting edge, being open to engaging in teaching and learning in new ways, some due to their histories and interests, and some also were given more flexibility in what and how to teach.

The findings from this study will be discussed further in Chapter V with connections made to the literature shared in Chapter II, where it may be further explained by the theories or not.

# CHAPTER V - DISCUSSION

The purpose of this qualitative study was to uncover and understand PK-12 pioneer teacher experiences and perceptions of the adoption and integration of virtual and augmented reality into practice. This chapter includes a discussion of the study's key findings and their connections to the literature on VR/AR, as well as the theories on innovation diffusion and the development of new knowledge. Also included in this chapter is a discussion of the implications for practice, the limitations of the study, and ideas for future research.

This study was focused on answering the following research questions primarily through data captured from nine volunteer participants, pioneer teachers, who had used VR and/or AR technologies with students:

**Research Question 1 (RQ1):** What are the experiences and perceptions of these experiences of pioneer teachers regarding the adoption and integration of virtual and/or augmented reality in teaching and learning for PK-12 students?

- How do pioneer teachers build new knowledge (e.g., TPACK) within the context of the innovation adoption and integration process?

**Research Question 2 (RQ2):** How do teachers integrate virtual and/or augmented reality into learning experiences, and how does this integration impact their teaching practice?

- How does this integration affect the planning of learning experiences, classroom structures/management, pedagogical practices, methods of assessing learning, and/or other areas?

The adoption and integration of VR/AR into teaching and learning begins with teachers' first/early introduction to this technological ecosystem and their perceptions of that particular experience as well as of the technologies in and of themselves. These first/early experiences instigated more learning about VR/AR with considerations on how best to bring this ecosystem into the classroom. District/school leaders played a role in the process of adoption with a positive impact. With a specific lesson in mind, one that might have been used in the past, pioneer teachers embarked on a search for relevant and meaningful content and apps for students; this began the classroom integration process, which was reliant on ensuring critical structures and processes were in place to allow teacher and student readiness for VR/AR's infusion into teaching and learning.

## Interpretation of the Findings

Pioneer teachers' experiences and perceptions regarding the process of adoption and integration of VR/AR technologies into PK-12 classrooms varied, and yet, there were common threads that ran through their experiences and the meanings given to them. These threads, these themes, are each discussed below with a connection to theory and the literature where relevant.

### *Awareness Paves the Road to Discovery and Adoption (Diffusion Stage 1-3)*

Understanding PK-12 pioneer teachers' experiences and perceptions regarding the adoption and integration of VR/AR into teaching and learning starts with their first/early experiences of the technological ecosystem. In Rogers' (2003) Diffusion of Innovations theory, this is the first step of the five-stage process of information gathering and decision-making related to innovation; this is the awareness stage.

***Awareness of VR/AR***

Pioneer teachers' first/early encounters of VR/AR opened the door to the possibilities of what this technological ecosystem could offer to teaching and learning. These introductory experiences mostly came through gatherings, conferences, and courses offered through institutions of higher education. For some, the early memory and experience of VR/AR came through a knowing that was based on keeping a pulse on research about technology. Pioneer teachers perceived these first/early encounters in a positive light, whether a specific incident was remembered or not; this can be heard in the words they used to describe these introductory experiences (i.e., "amazing," "neat," "captivated," "excited," "invigorated," "I was hooked"). For some teachers, finding VR/AR was motivating and meant a reinvigoration of teaching and learning, giving some a sense of newfound "freedom."

An attribution of novelty regarding the technologies came through these early descriptions; according to Rogers (2003), an object or idea being perceived as novel is one of the four defining elements of an innovation. Pioneer teachers recognized that these innovative emerging technologies had the potential of benefiting student learning (Desai et al., 2008; Wartella & Robb, 2007) as, to start, they offered new options for students to access content. This sentiment of benefit came through teachers' assessment of the ecosystems' perceived relative advantage (Rogers, 2003) when compared to other modes of learning. This perceived usefulness of VR/AR for themselves and their students is a second-order intrinsic factor (Blackwell et al., 2014; Buabeng-Andoh; 2012, Makki et al., 2018) which influences the intention to use an innovation, akin to Venkatesh et al.'s (2003) performance expectations concept which is an influencer of the acceptance of new technology.

For some pioneer teachers, there was a sense that VR/AR was going to be in students' futures, and thus, there was also benefit in exposing them to the ecosystem now, allowing them to further meet 21st Century skills and learning expectations (Scott, 2015; International Society for Technology in Education (ISTE), 2017). For others, certain first-order extrinsic factors (Makki et al., 2018), namely student/community characteristics, drove interest in adoption – that student in urban districts/schools characterized by lower socioeconomic status (i.e., Title I districts/schools) may never be exposed to emerging technologies unless the pioneer teacher made a concerted effort. This is in alignment with sentiments that VR/AR may promote equity for all learners regardless of location.

***Discovery – Building New Knowledge (Diffusion Stage 2)***

The introduction to VR/AR triggered Rogers' (2003) second stage of diffusion, the persuasion stage, during which motivated pioneer teachers gathered information about the ecosystem through (i) online searches, (ii) social media, (iii) groups, (iv) collaborators and influencers, and (v) experimentation and co-learning with students. During this stage, they navigated what Badilescu-Buga (2013) termed the knowledge gap to innovation adoption, moving from limited knowledge about an innovation to a level of knowledge that allows for its use. The build of new knowledge to support innovation use is a third-order factor that influences adoption (Tsai and Chai, 2012).

Pioneer teachers spoke of starting the learning process through personal research and harnessed the power of "for-you" pages and social media platform suggestions, with Twitter explorations being the most mentioned source for social media. Learning about VR/AR also happened in groups, whether with other educators or those generally interested in VR/AR; these groups are part of the social system Rogers (2003) deems critical in enabling the diffusion of an innovation.

Within the context of the social system, pioneer teachers' learning also came from influencers and collaborators who had already adopted VR/AR; one could suggest that these influencers are the Innovators Rogers (2003) described as being the first of the five groups of innovation adopters. These Innovators, with some level of proof of effectiveness in hand, ushered the next group, pioneer teachers (some of whom may have very well been Innovators themselves), into Rogers' (2003) third stage of diffusion, the decision stage. It is in this third stage, after weighing the pros and cons, that the decision to integrate VR/AR into the classroom was made. Pioneer teachers also became influencers for other Early Adopters, sharing subject matter-relevant VR/AR experiences with colleagues who were yet to adopt the technologies, some beginning to speak at conferences and teach about VR/AR. Invariably, pioneer teachers became Rogers's (2003) spokespersons for the innovation, those who are more impactful on the rate of diffusion than the Innovators. During this COVID-19 pandemic, the use of parts of the ecosystem has been halted; this means that the spokesperson impact participants began to have on the rate of diffusion may have very well been curtailed.

Experimentation was quite an important mode of learning about and starting to use VR/AR in the classroom. Experimentation, trial and error, was rife during VR/AR lesson implementation process as well. Some pioneer teachers spoke of self-learning through tutorials and tinkering with the technologies as well as co-learning with students who, in turn, taught each other and the teacher. Teachers and students took explicit knowledge from the tutorials and tinkering to build tacit knowledge and vice versa (Nonaka and Konno, 1998). Per Nonaka and Konno (1998), this interplay of explicit and tacit knowledge is how knowledge is created.

According to Rogers (2003), these learning behaviors and knowledge transfer within the social system are cornerstones for enabling innovation diffusion. This new knowledge gained and transferred focused on what the technologies were and how they worked, what they were optimal for, when to use them, and what content was available for pioneer teachers. These types of knowledge are what Zack (1999) coined as causal, conditional, and procedural knowledge; they show pioneer teachers' start in developing the "T" within the TPACK framework (Mishra and Koehler, 2006).

### *The Patronage Factor – An Enabler of Adoption*

Whether in a district/school-wide initiative context or not, pioneer teachers discussed the role educational leaders played in their VR/AR adoption; this role is what Alone (2017) termed the "patronage factor," a first-order extrinsic factor that influences teacher's intention to adopt and use new technologies. Within this study, the patronage factor appears in two ways: (i) the provision of access to resources, namely funding, and (ii) the support of the new knowledge discovery process and the promotion of adoption.

Per the findings of this study, except for in one instance, district/school leaders enabled patronage factors (Alone, 2017) by establishing facilitating conditions (i.e., providing funding to access the technology) and structures for social influence (i.e., group discussions) theorized as determinants of user acceptance and usage behavior in the UTAUT2 framework (Venkatesh et al., 2012). The experience a pioneer teacher had of a school leader halting further use of Desktop VR may very well be a signal of the importance of district/school leader buy-in for adoption.

## The Processes and Structures of Integration – The Implementation Phase

To understand how pioneer teachers integrated VR/AR into learning experiences and the impact that had on practice, it is paramount to view how they used VR/AR and then to look at the processes, systems, and structures leveraged to enable implementation in the classroom.

### *VR/AR in Teaching and Learning*

Shortly after the introductory experience, pioneer teachers moved VR/AR into the classroom once the technology was purchased. They moved from Rogers' (2003) first stage of diffusion, awareness, to the third stage, decision-making, while still navigating the second stage, persuasion, where discovery continued. Armed with information and VR/AR options, pioneer teachers entered the fourth stage of diffusion, the implementation phase, where they began to use the ecosystem in practice. Study findings show that the use of VR/AR in the classroom could be placed into two categories; for the purposes of discussing study findings the following terminology will be used: (i) The Exalted Journey and (ii) The Expression. It must be noted that study participants did not use this ecosystem for students to practice tasks congruent with situated learning (Brown et al.,1989).

The Exalted Journey is where teachers capitalized on the affordances of these technologies (i.e., experiential learning, contextualization, etc. (Delgarno & Lee, 2010)) and took students on trips that fell within a continuum of internal spaces to faraway places; internal spaces such as the human body or atomic structures, and faraway places (Markowitz et al., 2018) such as universities and outer space. The Exalted Journey was used by pioneer teachers to introduce concepts and provide students with direct experience of inaccessible places/spaces; this was aligned with the findings of Mundy et al.'s (2019) on the use of AR in the classroom.

In contrast to The Exalted Journey was The Expression, whose cornerstone was storytelling; this was a way in which teachers had students created with VR/AR tools/apps to tell stories and to share knowledge, similar to Bower et al.'s study involving the creation of AR guides by students to enhance visitor experiences in a sculpture park. Embedded in The Expression are two sub-concepts that are non-exhaustive on the list of ideas within this sub-theme: (i) students creating to demonstrate knowledge of information and/or ideas obtained from non-VR/AR modes of learning (i.e., from a book read) and (ii) students creating to express original ideas not tied to the content of a specific lesson per se but rather as a way to showcase their original research and project work (i.e., creating a virtual museum on a social justice topic of choice). Puentedura (2006) may agree that pioneer teachers' use of VR/AR for The Expression may have indeed reached the highest level of SAMR, the R-level, which is a redefinition of tasks by creating tasks that would not have been possible without the technology.

As articulated by one pioneer teacher, the VR/AR ecosystem is important where students are asked to imagine. Whether for The Exalted Journey or The Expression, VR/AR was used in conjunction with analog and other digital modes of learning. It was suggested by one pioneer teacher that the use of immersive VR was indeed the bonus lesson that kept students intrigued, motivated, and engaged (Georgiou & Kyza, 2018; Lorusso et al., 2018; Metcalf et al., 2013) - factors said to improve student learning outcomes as per the various meta-analyses and study results previously shared. To maintain this level of curiosity and engagement, a suggestion from a pioneer teacher was to temper how often immersive VR, specifically, was used so as to preserve a semblance of novelty; this aligns with Oprean and Balakrishnan's (2020) statement that using VR/AR mixed with other media could very well maintain a level of newness which may support keeping learners engaged over time.

It must be noted that there was a third potential use-case of VR/AR which pioneer teachers within this study were not engaged in, but some spoke to; this was the use of VR/AR for therapeutic purposes to improve transitions, thus potentially minimizing challenging behaviors or to allow students an alternative way to express themselves during restorative justice circles. This is congruent to the works published on the use of this ecosystem for therapies (Baus & Bouchard, 2014) related to phobias or anxiety (Parrish et al., 2016) and to support students with autism (Maskey et al., 2019).

### *Considerations for VR/AR Learning Experiences*

The process of integrating VR/AR into learning experiences started with the search for content, followed by the implementation of learning experiences enabled by structural elements. In this segment of the discussion, immersive VR featured more prominently than AR or other forms of VR (i.e., Desktop VR).

**The Content Experience: A Precursor to Integration.** The integration process began with the search for content – experiences, apps, and tools – to infuse into student learning and creation. From the viewpoint of Lyytinen and Damsgaard (2001), VR/AR content could be considered the complementary technology to the VR/AR hardware (i.e., VR headset, Desktop VR, AR via Merge Cube, etc.) that is critical for adoption; without content, the hardware would be rendered useless.

VR/AR content is found, by pioneer teachers, using the same channels of learning discussed above. Regardless of whether pioneer teachers were having students create with

VR/AR or not, similar themes arose in conjunction with the content experience - the finding, accessing, and engaging content. For pioneer teachers, VR/AR content – tools, apps, and experiences – was deemed as, at times to be (i) limited in number, (ii) inappropriate, and for a few (iii) lacked diversity.

First, the notion of limited content for pioneer teachers was related to immersive VR experiences for The Exalted Journey. These VR experiences were said to be growing in number, as echoed by Hussein and Natterdal (2015) and yet they were still deemed as being inadequate; this limitation was also echoed by participants in Mundy et al.'s (2019) study of AR usage. An example to illustrate this point was that even if there was enough content for the overarching subject-matter of chemistry, a pioneer teacher might need a specific VR experience related to a certain chemical reaction that is designed for students aged 14 to 15; at that level of granularity, finding experiences may be akin to finding a needle in a haystack.

Second, VR/AR content being inappropriate spanned uses for The Expression and The Exalted Journey. Per study findings, pioneer teachers considered the available creative tools/apps to not match the needed level of usability for their student age group. For the Expression, tool/app interface and user experience were reckoned as being too complex and thus required a steep learning curve for students; this learning curve also applied to teachers, in their estimation, for certain tools/apps. Immersive VR experiences were the focus of discussion around inappropriateness for The Exalted Journey. There was concern here about the length of the experience and how the topic was depicted within it - that the experiences were not necessarily created with the levels of development of this age group (usually middle school age) in mind, rendering some experiences as potentially harmful. Questions arose about the effects of immersive VR experiences on young children, similar to Segovia and Bailenson's (2009) caution on the potential for false memory in the developing brains of young children.

Third, the statement of a lack of diverse options spanned both uses of VR/AR. Some of the tools/apps for creation were said to lack features that allowed the depiction of diverse groups of people. In parallel, for The Exalted Journey, it was shared that experiences that included and/or focused on certain populations (i.e., people of color) were limited.

The complexities surrounding immersive VR experiences prompted some pioneer teachers to consider creating their own 360-degree videos, for example. The desire to create content was somewhat tempered by the perceived ease of use (PEOU, Makki, et al., 2018) of creation tools and access to locations. For those teachers who specialized in subjects that required experiences, say, within the human body, for example, it would be impossible to capture related experiences; these teachers could potentially create experiences using computer-generated imagery (CGI), but the tools needed for creation (i.e., Unity) were seen as having a steep learning curve. Only one pioneer teacher spoke directly to having a policy within the school whereby teachers had to review content before using it in the classroom, and that content quality had to be vetted. The concept of content quality was not specifically defined; the teacher used early VR experiences, for example, as the barometer for quality.

**The Processes, Structures, and Impact of VR/AR Integration.** There were various factors cited by pioneer teachers which affected the implementation of VR/AR learning experiences; the starting factor, outside of content, was access to the technology - how many devices, such as Merge Cubes, VR headsets, etc. were available for the classroom. The discussion on device availability was centered primarily on the VR headset. Five of the pioneer teachers did not have a VR headset for each student in the classroom; thus, all students could not view experiences at the same time; this affected the integration of immersive VR specifically. In addition, certain classroom-related processes, routines, and structures enabled or were impacted by the integration of immersive VR learning experiences; at times, these processes and structures were amplified by the lack of one-device-per-student. These were: (i) lesson planning and the structure of lessons, (ii) device management, (iii) classroom structure in terms of physical space, and (iv) classroom management and resources.

***Lesson Planning.*** Pioneer teachers within this study did not necessarily create brand new lessons for which to use VR/AR for The Exalted Journey. In addition, the process of planning learning experiences did not change when VR/AR was infused into a lesson, neither were the intentions of already established lessons to be used; VR/AR was used to strengthen the lesson. On the other hand, the choice of which specific part of the VR/AR ecosystem to include in a lesson and/or how to structure a lesson was impacted by the number of devices a pioneer teacher had access to. The often-used strategy to rotate small groups of students through one immersive VR experience meant that for one teacher, 3 hours of a multi-week unit of study had to be allocated to this one experience; this was to ensure that all students had an opportunity to engage with it at some point.

***Device Management.*** The management of devices was another factor that affected teacher routines and the use of time in the classroom. Device management included charging, storing, cleaning, setting up, handing out, and collecting devices from students only to ready them for the next class. There were variations in cleaning routines as some pioneer teachers, pre-pandemic, cleaned devices in between classes while others cleaned at the end of the day. Device management also included troubleshooting when the technology was unreliable, this further affecting teachers' use of time and thus a potential barrier to adoption per Shaban (2017). Pioneer teachers established routines and backup plans for when devices did not function as expected, for when students felt dizzy using a VR headset, and/or for when students did not want to use the VR headset at all.

***Classroom Structure - Space and Layout.*** Structuring lessons into segments for student-pairs to rotate through or giving students space to move in order to engage in the fully immersive VR experience meant that the space used and the physical layout of the space had to be aligned to the experience. Some pioneer teachers had classrooms with station-type layouts already in place, not initiated by the integration of immersive VR. For others, alternative spaces needed to be used for immersive VR experiences (e.g., conference rooms with swivel chairs to allow for a seated 360-degree viewing). Integrated electronic guardians in new headsets became the new classroom space and allowed students to know when they were out of bounds.

***Classroom Management and Resources.*** Whether in the classroom or in an alternative space for immersive VR, the role of the pioneer teachers during the experience was that of a facilitator; this is parallel to Lorusso et al.'s (2018) AR study with teachers being the supporter and guide during AR-infused learning. Some pioneer teachers expressed a preference for additional resources in the room, specifically, at least a second adult. Some expressed that without additional support in the classroom, the adoption and integration of VR/AR may have been minimal. The role of the second adult was twofold – (i) troubleshooting technical issues and/or (ii) supporting students with special needs. With a second adult, the teacher could then focus on classroom management (i.e., ensuring that students were not bumping into each other, ensuring groups not within the immersive VR experience were on task, etc.) and The Exalted Journey itself (i.e., guiding students through a tour).

Pioneer teachers' sentiments of integrating the ecosystem into teaching and learning align with Shaban's (2017) discovery that some of the challenges and thus barriers to the adoption of VR/AR for teachers are related to time, resources, and the unreliability of technology. Establishing operational routines, managing time, and designing alternative plans for learning were important prerequisites for teachers within the VR/AR integration process.

**Prerequisites and Policies for Implementation.** Outside of establishing these operational routines, pioneer teachers also discussed what could be considered as prerequisites for the use of VR/AR: (i) immersive VR use policies, (ii) student pre-learning about all things VR/AR, and (iii) student readiness to create in three dimensions.

***Use Policies.*** New educational technology policies, discussed for one school, had to be added due to concerns related to the health and safety of students (Blackwell et al., 2014; Georgiou & Kyza, 2018; Jensen & Konradsen, 2018). The policies adopted were that (i) students below Grade 6 were not to use immersive VR, (ii) that students would not be in immersive experiences for more than a few minutes (i.e., approximately 5 minutes limit), (iii) that teachers would experience the content prior to integrating it into the classroom, and (iv) that a check on experience quality would be included in that process. Such additional educational technology policies specific to the use of this new ecosystem are first-order extrinsic factors (Makki et al., 2018) that support adoption and thus further integration.

***Prerequisite – Student Learning About the Technology.*** Some pioneer teachers provided students with opportunities to understand key features of and differences between VR/AR and the affordances of the ecosystem (i.e., immersion allows for the development of empathy). In addition, some had students experience the basics of how to use the technology (i.e., using tutorials within the system, experimentation) to build their confidence and self-efficacy, especially for the use of VR headsets, for example.

***Prerequisite – About 3D Skills.*** Specific to the use of the ecosystem for The Expression, a few pioneer teachers took note that students struggled to create because they did not yet possess the ability to design in 3D. To support students in this skill acquisition, it was suggested that students be provided with specific developmentally appropriate activities before The Expression process (i.e., designing and implementing analog 3D lessons for students such as paper folding for younger students, etc.).

**Assessment Practices.** A review by Hamilton et al. (2020) addresses a gap in the literature related to evaluating the assessment methods used in technology effectiveness studies. With a review of 29 immersive VR studies, 25 of which took place in higher education settings, Hamilton et al. took note the critical detriment of the studies was "the validity of the evaluation instrument to assess learning outcomes." The VR/AR education-related studies reviewed and shared within this study were mostly focused on use cases where VR/AR could be of benefit to teaching and learning. Many of these studies thus assessed the effectiveness of VR/AR through the use of pre/post or a control group-type methods with a view on student learning outcomes for The Exalted Journey, with few having students use VR/AR for The Expression. This focus on the effectiveness of the ecosystem that researchers pursued was different from what teachers practiced in the classroom when assessing student learning and/or having student use VR/AR to demonstrate learning; however, the instruments used for assessments were similar (i.e., journaling, quizzes, etc.). First, it was noted that the assessment methods teachers implemented in the classroom were not dependent on whether students were using VR/AR for The Exalted Journey or The Expression. One might have hypothesized that for The Exalted Journey, assessment would have been focused on the end product, but for The Expression, the focus would have been on the end product as well as the process of creation; no such clear pattern was realized in the study findings. Generally, pioneer teachers used standard methods of student assessment to have students describe, explain and interpret the learning within lessons infused with VR/AR. The instruments pioneer teachers used were short online quizzes, student reflection journals, rubrics for students to understand how their work will be assessed, and small group discussions, for example. What potentially makes assessing creations in immersive VR a complex undertaking is that what is created in that medium, as shared by one pioneer teacher, could only be viewed in that medium depending on the creation tool/app used.

**Evolving Technology and Feature Limitations.** Pioneer teachers took note that the VR/AR ecosystem was still evolving, with new features continuously being added and some products removed. It can be said that VR/AR in education is continuing its trajectory through the Gartner Hype Cycle (William, 2018), where rapid development is coupled with obsolescence in the "trough of disillusionment" (Blosch, M. & Fenn, J., 2018). For some pioneer teachers, even with technological improvements, challenges were still faced during integration regarding (i) the perceived ease of use, and the associated learning curve, (ii) feature limitations, and (iii) the need to consider how to align the ecosystem with school/district IT infrastructure, and (iv) the longevity of the products (i.e., hardware, and apps).

For teachers inclined to create their own content and/or have students create within VR/AR, there were concerns regarding the potentially steep learning curve related to creation tools/apps. Perceived ease of use (PEOU, Makki, et al., 2018) mirrors one of the five factors Rogers' (2003) suggests impacts innovation adoption, that of the actual level of complexity during use; should the innovation require high levels of complexity, the adopter may halt the adoption process, and this is what transpired for a teacher who chose not to consider VR experience creation tools, for example.

Feature limitations also played a role in the adoption process; limitations lead teachers to choose alternatives when available (i.e., using immersive VR because a preferred appropriate AR app could not be found). On a few occasions, some pioneer teachers contacted technology developers to request additional features; it was noted that some of the features requested were now available.

Given that all teachers experienced school closures during the COVID-19 pandemic, one teacher lamented being used to pushing content to student devices during remote learning, a feature which was perceived as not being possible with the VR/AR ecosystem; teachers not being able to scene-select during experiences was also a concern raised. Another took note that the purchase of VR headsets was strategically accomplished with an understanding that the school only used Apple products; thus, VR headsets requiring a PC would have stopped all adoption efforts.

Pioneer teachers also spoke to a key factor that may very well impact the rate of adoption of VR/AR; the longevity of products in a changing landscape. After investing time and effort in certain tools/apps and hardware, some of these technologies were being removed from the market, no longer supported by technology firms. The question remained as to whether schools would purchase anew to keep up with the latest and greatest technology in the ecosystem.

Keeping a pulse on this still-evolving technology for teaching and learning becomes important, as well as understanding the district/school/classroom-level technology infrastructure in which this ecosystem would be embedded.

### *Perception of Impact on Teacher Practice*

New technologies may drive new pedagogies, which could lead to technology-enhanced pedagogical innovation (Law, 2018). Per this study, pioneer teachers' perception of the positive effect of VR/AR was centered on the impact on student acquisition of knowledge and not so much pedagogy.

Variations in levels of immersion within this VR/AR ecosystem provided students with new, more relevant, and creative options to access and construct knowledge, as well as to share their voices. This active process of learning, per pioneer teachers, was better aligned with the science on how students learn; VR/AR allowed for contextualized and personalized learning which was still anchored in collaboration between students and teachers. For teachers, student ownership of the learning experience was heightened, and the use of VR/AR provided students a way to connect on a deeper level with the content (i.e., where they could begin to assimilate the vocabulary used during The Exalted Journey). The ideas of collaborative, yet personal, contextual, and student ownership of learning are echoed in the literature (Antonioli et al., 2014; Martín-Gutiérrez et al., 2017; Jowallah et al., 2018; Rizzoto, 2017; Winn, 1993). For a few pioneer teachers, the integration of VR/AR into the classroom allowed for stronger relationships with students. Ultimately, teachers' perception was that allowing students to be more engaged and to access learning in different ways suitable to their learning style – visual, kinesthetic, auditory (Winn, 1993) – meant student understanding improved.

## Emergent Themes Influencing Integration - The Pandemic and Self-Perception

The challenge all pioneer teachers spoke of that affected the use of this ecosystem was the impact of the COVID-19 pandemic. This and another emergent theme will be discussed below.

### *Impact of the COVID-19 Pandemic*

The COVID-19 pandemic had a resounding impact on the adoption and integration of VR/AR into PK-12 education in two ways: (i) devices were no longer used with school closures and may not be used in the near future due to health and safety concerns, and (ii) with remote learning during the pandemic, teachers shifted their lessons to use other parts of the ecosystem and/or stopped using it altogether. The school closures broke the momentum for the use of VR/AR, raising questions on whether the concept of "embeddedness" (Reinhardt & Gurtner, 2018) would eventually prevail for diffusion to take hold. It was evident that for the 2020-21 school year, VR headsets and other student-shared devices were not going to be used even if students returned. Teachers researched various VR headset cleaning methods, but there was still uncertainty about the best method of cleaning to prevent damage.

Given internet access inequities in the community served, one pioneer teacher, for example, chose to reduce the use of Desktop VR, purposely opting from more analog learning experiences for students at home. Pioneer teachers who had used immersive VR began to shift to using more Desktop VR applications (i.e., Google Expeditions) with remote students, understanding that not all of them would have access to even print a Merge Cube at home for AR. Pioneer teachers who had already incorporated tools such as CoSpaces continued to leverage them where students had ready access to computers and the internet.

### *Teacher Self-Perception, Characteristics, Philosophy and Educational Context*

The findings of this study revealed another emergent theme, that of pioneer teachers' self-perception and characteristics, as well as their educational philosophy and the context in which they worked (Mishra, 2019). Pioneer teachers' self-perception can be seen in the words used to describe themselves; some saw themselves as the "techie" who kept up with the trends and research in technology while also having a sense of being different from other teachers. This characteristic of technophilia, an enthusiasm for technology, per Ortt et al. (2017), can lead to technological innovation adoption. Pioneer teacher characteristics can also be seen in how pioneer teachers approached learning about VR/AR through self-learning and experimentation; they were self-starters. Personal and professional histories affected teachers' interest in educational technology. For one, it was the influence of a parent that led them down a path of science and technology; another described themselves and their family unit as being an "early adopter" of technology. Pioneer teachers were motivated and exuded passion for learning about and using VR/AR with students.

It must be noted that most of the study participants, per the Interest and Demographic Survey results, used VR personally, which is tied to the concept of hedonic motivation (Venkatesh et al. (2012) that increases the propensity to adopt the technology. It could potentially be hypothesized that pioneer teachers' characteristics, self-perception, and increased hedonic motivation heightened their inclination to view the ecosystem favorably and to adopt.

Self-perception and characteristics, coupled with subject-matter taught and/or educational perspective, may have also allowed a more open stance to accept VR/AR. Some pioneer teachers, when provided an opportunity to select what to teach, tended to gravitate to subjects that included technology (i.e., STEM). For others, the educational philosophy of the school and/or of themselves was more linked to interdisciplinary, inquiry and/or project-based approaches where student-centered learning was at the forefront. These constructivist approaches are aligned with the VR/AR ecosystem, which allows for tangible student-centered (Antonioli et al., 2014) personalized and experiential learning (Rizzotto, 2017). Lyytinen and Damsgaard (2001) may agree that pioneer teacher self-perception and potentially their educational perspective or context could very well be considered the “soft” complementary technology to VR/AR adoption in PK-12 education.

**Implications for Practice**

Educators wanting to learn more about VR/AR, outside of the growing peer-reviewed research, may wish to scour Twitter feeds to capture ideas on use in practice. Having leaders and/or teachers participate in educational technology MeetUp groups and/or online groups would offer an insight into how other teachers may be using this technology and options for bringing VR/AR into the classroom.

Regardless of how a district, school and/or teacher becomes aware of the VR/AR technological ecosystem, findings in this study show that leadership buy-in and support is critical to driving adoption given the investment (i.e., funds, human resources, IT infrastructure) needed for integration. A teacher wanting to embark on using VR/AR outside of it being part of a district/school initiative would be served by reflecting on their contextual knowledge (Mishra, 2019) related to the classroom environment and the climate of the district/school in which integration would need to occur. Processes such as stakeholder analysis could be beneficial for such contextual reviews. Should the initiator of VR/AR adoption be a district/school leader, a similar stakeholder-type analysis could also be beneficial. Districts/schools that want to adopt VR/AR may want to embark on this journey through the development of a pilot program where potentially two to four teachers can trial parts of the ecosystem. Per the findings of this study, a suggestion for schools/districts developing VR/AR pilot initiatives would be to approach VR/AR as an ecosystem for eventual adoption (from desktop VR to immersive VR through a headset) given that each component has different sets of affordances and thus different benefit to students. All components of the ecosystem may not be adopted at once; however, it should be noted that when one part of the continuum cannot be used (i.e., VR headsets during a pandemic), there are other options to leverage. It may also be advantageous to amplify successes throughout the district/school community, which may further excite other teachers and students, inciting the potential need for additional adoption.

Given the emergent theme found in this study regarding teacher characteristics, self-perception, and educational perspective, district/school leaders may have to triangulate various data points to determine how best to roll out a pilot program (i.e., context, teacher characteristics, educational philosophy). An understanding of teacher characteristics, by grade-level, with a focus on potential willingness to adopt would be critical; the goal would be to determine which teachers would be included in the pilot based, maybe, on who would be considered an Early Adopter of technology and/or which teachers may have higher hedonic motivation due to personal use of VR and/or AR. According to Daher et al.'s (2018) study on ICT adoption, in-service teachers had a more complex trajectory to adopting new technology given that they had to unlearn/learn anew when compared with pre-service teachers; this must be considered when VR/AR adoption is being planned. Providing pre-service/student teachers with an opportunity to engage with VR/AR in higher education settings might be supportive of further VR/AR adoption in PK-12 as pre-service teachers transition into the PK-12 classroom and out of higher education. Districts/schools may be served to assess their educational philosophy to understand if expectations are congruent with constructivism which this ecosystem is seemingly aligned.

Regardless of the impetus to adopt VR/AR, a district/school leader must be involved, have buy-in, and be the sponsor for the pilot. The district/school technology team would be a critical stakeholder for any pilot as there would need to be an evaluation of how this ecosystem could best be embedded with the IT infrastructure. Sponsoring leaders may find benefit in establishing a Professional Learning Community (PLC) structure.  This PLC would include, at least, teachers and technology staff in the development of a pilot implementation plan inclusive of rollout timelines, measures of success to determine criteria for a wider rollout - replication, staffing plans (i.e., how could a second adult be available during immersive VR experiences for troubleshooting and support), and potential source of funding (i.e., use of discretionary funds, use of grants, etc.). Time and space would need to be made available for PLC members to congregate with regular cadence; this would need to be coupled with a standing facilitator, set ground rules for collaboration, specific agendas, etc., and inclusion of the best practices of action research.

Findings in this study suggest that districts/schools looking to adopt VR/AR should review the standing educational technology policies and protocols to ensure that they are aligned with this emerging technology.  Pioneer teachers within this study spoke of policies, protocols, prerequisites, and rules related to the use of this ecosystem by teachers and students with a focus on immersive VR with a headset. For example, having clear guidance on what grade levels would be able to access the VR headset, how long immersive experiences would need to be for the various age groups, how often should students engage with this ecosystem, what students should do if concerns arise, what options do students have should they not want to engage with the technology, what pre-learning is needed for students to understand the technology within their own context, what onlooker students should be engaged in, whether there would be an appropriate dedicated space for immersive VR experiences, and what family engagement processes would be needed to obtain family buy-in, especially for younger learners given the general concerns about health and safety.

Per study findings, integration of VR/AR directly into the classroom is complex, especially when it comes to finding the right content – tools, apps, and experiences - for specific learning expectations and/or for diverse populations. For districts/schools that would have students create in VR/AR, understanding the trajectory of building student capacity to create in three dimensions grade-by-grade would be of benefit. Criteria would also need to be developed regarding how content quality would be assessed before integration in the classroom; this can be done at the district/school level or with the support of child development experts and technology developers. This may be something needed industry-wide; this is inclusive of best practices related to assessing learning that may be better linked to the affordances of the parts of this ecosystem.

As shown in this study, the number of devices (i.e., VR headsets and other hardware) a teacher has access to is a determinant of integration. As shared above, understanding potential sources of funding is part and parcel of this process to ensure that there is an adequate number of devices in the classroom. Should there not be an opportunity for one-headset-per-student, for example, additional resources (i.e., time, people) would need to be specified for classroom integration. Protocols for storing, charging, and cleaning hardware must also be established and followed, especially post-pandemic; methods of cleaning should not bring harm to students/teachers and/or damage the devices.

Given that the technology is still evolving, districts, schools, and/or teachers looking to adopt and integrate VR/AR into teaching and learning would need to recognize that the cycles of technological innovations could very well mean that technologies that have been invested in may not have longevity. Being an Early Adopter may be less risky than being an Innovator. Potential adopters would be served by assessing tolerance for risk with an understanding of where in the

Gartner Hype cycle the technology currently sits. It could be that the diffusion of Desktop VR and AR may become the focus for PK-12 education given the complexities the COVID-19 pandemic posed for immersive VR. Either way, there would seemingly need to be an increase in VR/AR educational game options for students.

Even with growing content for VR/AR for PK-12 students, it is still limited for specific learning intentions; improvisation and experimentation on the part of teachers would be needed. In addition, it may very well be that teachers would prefer to create their own content; resourcing teachers to embark on such endeavors could be beneficial to increasing relevancy to student learning. Having a virtual space where teachers could store and securely share self-created content could be useful. In addition, having students not only view content in VR/AR (The Exalted Journey) but create in VR/AR (The Expression) would be needed to further develop their VR/AR 21$^{st}$ Century skills. Districts, schools and/or teachers looking to adopt and integrate VR/AR have a myriad of considerations to ponder; a pilot program, to start, would be advantageous.

**Research Limitations**

The limitations associated with this study are twofold, related to (i) the research method and (ii) the participant pool. This was a phenomenological study that used teacher interviews as the primary data collection process to understand teacher experiences and perceptions. Using a case study approach may have allowed the research questions to be answered through a triangulation of data from other stakeholders involved in the adoption and integration process, such as school leaders, technology staff, and even students. This could have brought more visibility in which to contextualize the teacher experience. In addition, using a mixed-method approach where the qualitative is mirror by the quantitative may have further strengthened the study. For example, a Likert scaled survey could have been leveraged to understand teacher's perception of the ease of integration followed up with an interview to clarify the why behind the rating. This could have made the interviews more target.

Additionally, given that this study was conducted during the COVID-19 pandemic, all participants had experienced school closures; their use of the ecosystem, especially immersive VR, had happened months before the interview, and thus teachers were going on memory. In addition, due to the pandemic, the number of participants was lower than expected as schools were grappling with how best to cope; this may make it complex to generalize the findings to all school situations. Even with these limitations, the methods selected for this study answered the research questions and provided insights into the diffusion of VR/AR into PK-12 education.

**Recommendations for Future Research**

Several areas could benefit from additional research to increase understanding of the diffusion of VR/AR in PK-12 education. First, as shared above in the research limitations, gaining a more holistic view of VR/AR diffusion to potentially better predict future trajectories would warrant inclusion of the perspectives of educational leaders, students, technology staff, and even families. Even though study participants had students with special needs in their classrooms, it would be valuable to examine diffusion specifically in the context of therapeutic and special education services given the benefits VR/AR is showing to have on supports for special populations due to the ecosystems' affordances; this more specific context research could also be extended to bilingual education services, Career and Technical Education (CTE) and even for specific grade-bands (i.e., Pre-Kindergarten to Grade 2, Grade 3 -5, etc.).

Generally, this study could be replicated with a larger participant pool post-pandemic or specifically with teachers who adopted VR/AR during the pandemic; comparing various teacher populations could also shed light on the process of diffusion. Follow-up with participants of this study post-pandemic could also bring light whether the pandemic changed perceptions and the operating of VR/AR and its use in the classroom. For teachers who have adopted VR/AR, it could also be advantageous to understand how their prior adoption of digital technologies compares that of VR/AR and whether prior experiences may have influenced VR/AR adoption. Another critical population for further study would be teachers who used VR/AR and decided to abandon adoption; it would be critical to understand the experiences of this population, especially if the decisions were made pre-pandemic – the researcher was anecdotally made aware of at least one such case. With the pandemic came school closures and remote learning; understanding the expectations teachers may now have of the ecosystem or even parts of the ecosystem post-remote/hybrid learning models would also provide insights into future adoption. Further understanding of the use of VR/AR in informal settings such as afterschool programs, museums, etc., could be of benefit to determining how those settings can provide non-committal exposure to VR/AR for teachers and students.

Most study participants used some form of VR coupled with AR except for what may be considered "Web VR" or even "augmented virtuality" where, with special see-through glasses, images come out of the computer screen for students to interact with using a special pen, for example (i.e., zSpace); understanding the diffusion and usage of this type of VR may provide additional insights. Additionally, testing of attributes that impact adoption and integration of technologies (i.e., age, gender, etc., as per UTAUT2 (Venkatesh et al., 2012)) could provide further insights into the potential path and pace of VR/AR diffusion in PK-12 education. An area that would support further diffusion of immersive VR, post-pandemic, would be studies to determine the most effective and efficient methods of cleaning devices.

Given concerns raised by participants around the lack of certain features within the VR/AR ecosystem, including the lack of options that mirror diverse populations globally, further research on understanding the extent of these gaps would support continuous improvement and inclusivity. This study focused on how teachers used VR/AR with students; research could also be conducted on the impact VR/AR technologies may have in supporting teacher quality initiatives that promote increase teacher efficacy. Lastly, additional research on the impact of VR/AR on child development (i.e., those under age 12), especially concerning immersive VR, would be impactful; this may also illuminate guidelines on the needed levels of quality and parameters regarding the design of experiences for younger students inclusive of the critical instruments that leverage the affordances of the ecosystem for the assessment of student learning.

## Conclusion

In this study, the diffusion of virtual and augmented reality into PK-12 education was unearthed with the use of a phenomenological methodology that looked to understand the lived experiences and perceptions of pioneer teachers who had used VR/AR with students. The first/early experiences pioneer teachers had with this ecosystem, which all viewed in a positive light, became a gateway for their development of new knowledge about VR/AR, as well as their adoption and integration into their teaching practice. In following pioneer teachers' trajectory from the beginning to implementation in the classroom, it is clear that the stages of innovation diffusion codified in Rogers' (2003) Diffusion of Innovation theory were indeed the path traveled by teachers, even if not in lockstep.  Integration of VR/AR into the classroom, with support from leadership, was a multifaceted endeavor that involved not just the ecosystem but impacted classroom structures and resources (use of human capital, space, and time). It is not so much that the use of VR/AR radically shifted pedagogy but instead, it impacted student acquisition of learning. Continued collaboration between educators and technology developers would be critical to ensure content is relevant, appropriate, and beneficial for student learning.

Per Rogers' theory, early adopter spokespersons will be critical to the rate of diffusion; in alignment with this idea, pioneer teachers set off on that path to be the spokespersons within the social system of educators. Pioneer teachers influence on diffusion within their community was abridged due to the COVID-19 pandemic. In addition, the COVID-19 pandemic also thwarted further use of immersive VR through a headset for participants, and thus further diffusion into the social system of PK-12 educators has been decelerated. The question remains as to whether AR and/or Desktop/Web VR may fill the gap until immersive VR diffusion accelerates again. The diffusion of VR/AR into PK-12 education in the midst of a pandemic is an unfinished tale.

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**APPENDICES**

**Appendix I – Interest and Demographic Survey**

**Interest Survey - VR/AR in PK-12 Education**

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**Start of Block: Default Question Block**

Thank you very much for choosing to share your interest in participating in this dissertation research study.

Your completion of this survey will provide the researcher with information about you and your use of Virtual and/or Augmented Reality (VR/AR) with your students.

For additional information regarding this study and your potential role as a volunteering participant, please refer to the Consent Form. This Form will need to be completed should you agree to participate in this study. The Consent Form can be found here: https://tinyurl.com/soklbyl

Q1 First Name/Preferred Name

________________________________________________________________

Q2 Email Address

○ Email Address (1) ________________________________________________

Q3 Best Telephone Number

○ Telephone Number (1) ________________________________________________

Q4 Gender

○ Male (1)

○ Female (2)

○ Do Not Wish to Specify (3)

Q5
What is your preferred method of communication with the researcher regarding discussion about the study (i.e. to set up interview, to clarify questions, etc.)? (Please Rank)
_______ Email (1)
_______ Phone (2)
_______ Text (3)

Q6 Age

○ 22 - 34 (1)

○ 35 - 44 (2)

○ 45 - 54 (3)

○ 55 - 65 (4)

Q7 How did you learn about this research study opportunity?

▢ ISTE Professional Learning Community/Communications (1)

▢ KDP Community/Communications (7)

▢ NAEYC Online Community/Communications (2)

▢ District/School Leader (3)

▢ General EdTech MeetUp Group (5)

▢ AR/VR-Specific MeetUp Group (6)

▢ VR/AR Association (VRARA) (16)

▢ National Science Teaching Association (NSTA) (17)

▢ Immersive Learning Research Network (iLRN) (18)

▢ Other (15) ________________________________________________

Q8 In which city and state is your school located?

- ○ City (5) ________________________________________________

- ○ State (6) ________________________________________________

Q9 What school- and grade-level(s) are you currently teaching/did you teach where you used VR and/or AR? (Select all that apply)

- ▢ Pre-Kindergarten (Age 3 and/or 4) (23)
- ▢ Kindergarten (24)
- ▢ 1st Grade (25)
- ▢ 2nd Grade (26)
- ▢ 3rd Grade (27)
- ▢ 4th Grade (28)
- ▢ 5th Grade (29)
- ▢ 6th Grade (30)
- ▢ 7th Grade (31)
- ▢ 8th Grade (32)
- ▢ 9th Grade (33)
- ▢ 10th Grade (34)
- ▢ 11th Grade (35)

☐ 12th Grade (36)

☐ Other (37) ________________________________________________

Q10 Are you currently student teaching/a pre-service teacher?

○ Yes (1)

○ No (2)

Q11 For how many years have you been teaching?

0 5 10 15 20 25 30 35 40 45 50

| | |
|---|---|
| Number of Years Teaching () | |

Q12 Please select the option which applies to you.

- ○ I use/have used Virtual Reality with my students (1)
- ○ I use/have used Augmented Reality with my students (2)
- ○ I use/have used both Virtual and Augmented Reality with my students (3)

Q13 What subject(s) are you teaching/have you taught using VR and/or AR?

- ▢ Algebra (24)
- ▢ Art (25)
- ▢ Biology (26)
- ▢ Business Studies (27)
- ▢ Calculus (28)
- ▢ Chemistry (29)
- ▢ Computer Science/Programming (30)
- ▢ Economics (31)
- ▢ English Language Arts (32)
- ▢ Foreign Language/Non-English Language (33)
- ▢ Government (34)
- ▢ History (35)

- ☐ Mathematics (36)
- ☐ Music (37)
- ☐ Other (38)
- ☐ Other (39)
- ☐ Physical Education (40)
- ☐ Physics (41)
- ☐ Science (42)
- ☐ Social Studies (43)
- ☐ Other (44) ________________________________________________
- ☐ Other (45) ________________________________________________
- ☐ Other (46) ________________________________________________
- ☐ Other (47) ________________________________________________

Q14 What special populations are you currently teaching/have you taught using VR and/or AR? (please answer if applicable)

- ☐ Gifted & Talented (4)
- ☐ English Language Learners/Dual Language Learners (5)
- ☐ Special Education - Autism Spectrum Disorder (ASD) (6)

☐ Special Education - non-ASD (8)

☐ Other (9) ________________________________________________

Q15 Are you using/did you use VR and/or AR during regular school hours or during after-school program hours?

◯ Regular school hours only (1)

◯ After-School program hours only (2)

◯ During BOTH regular and after-school hours (3)

Q16 How often do you/did you use VR and/or AR with your students?

| | Always (daily) (1) | Often (2-3 times a week) (2) | Sometimes (2-4 times a month) (3) | Rarely (1-2 times a month) (4) | Never (5) |
|---|---|---|---|---|---|
| Virtual Reality (1) | ◯ | ◯ | ◯ | ◯ | ◯ |
| Augmented Reality (2) | ◯ | ◯ | ◯ | ◯ | ◯ |

Q17 For approximately how many MONTHS have you been using VR and/or AR for teaching and learning?

| | 0 8 16 24 32 40 48 56 64 72 80 |
|---|---|
| Virtual Reality () | |
| Augmented Reality () | |

Q18 What VR and/or AR technology do you use/have you used with your students (i.e. hardware, apps, etc.)?

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

Q19 Has your use of VR and/or AR been part of a school/district-wide initiative?

- ○ Yes (1)
- ○ No (2)

Q20 Do you plan to use VR and/or AR in the foreseeable future (i.e. during the next school year)?

| | To a Great Extent (1) | Somewhat (2) | Very Little (3) | Not At All (4) |
|---|---|---|---|---|
| Virtual Reality (1) | ○ | ○ | ○ | ○ |
| Augmented Reality (2) | ○ | ○ | ○ | ○ |

Q21 Do you use VR and/or AR personally (outside of using it for teaching and learning purposes)?

- ○ Yes (1)
- ○ No (2)

Q22 Is there any other information you would wish to share at this time? If yes, please include your additional thoughts below.

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

**End of Block: Default Question Block**

**Appendix II – Criteria for Selecting Participants**

- Participants must be teachers who plan/have planned and implement/have implemented virtual and/or augmented reality-infused learning experiences for students Pre-K to Grade 12
- Participants must be based in the U.S.A. or in a school outside the U.S.A. that may be similar to what would be found in the U.S.A. (i.e., American Schools, International Schools, etc.)
- Participants may be in a public district, public charter, private, parochial, or independent school
- Participants must be using/have used VR and/or AR during regular instructional hours; interviews will be focused on learning experiences during regular school hours and not afterschool program hours
- Participants must be in-service teachers and not pre-service/student teachers.
- Participants may use/have used VR and/or AR with different populations within the span of PK-12 (i.e., general education, special education, inclusion classroom, gifted and talented, English Language Learners, etc.)
- Participants may be focused on various disciplines, subject-matters/content areas, classroom contexts and models (i.e., single teacher, co-teaching, transitional grade-levels (e.g., transitional kindergarten), etc.).

**Proposed Target Number of Participants**

| Grade Level | Technology Being Used | Target Number of Participants* |
|---|---|---|
| Pre-K to Grade 2 | Augmented Reality-focused (include VR if used) | 3-4 |
| Grade 3 to Grade 5 | Augmented Reality-focused (include VR if used) | 3-4 |
| Grade 6 to Grade 8 | Augmented Reality and/or Virtual Reality | 3-4 |
| Grade 9 to Grade 12 | Augmented Reality and/or Virtual Reality | 3-4 |

****NOTE:*** *Some teachers may use/may have used both virtual and augmented reality.*

## Appendix III – Interview Recording and Transcription Protocols

### Protocols for Recording Remote Interviews

For remote interviews, Zoom (zoom.us) was used to conduct the interview and to record it. An audio and video file were captured as well as any information shared in chat (i.e., links to documents). Where a participant did not want to be video recorded, the camera was not activated; only the researcher appeared in the video.  This Zoom information was saved to the researcher's external hard drive which was then backed up to another. Information captured via Zoom was not saved to the cloud using that feature in Zoom. The Zoom recording was referenced related to any documents that were shared online between the participant and the researcher (i.e., when the participant wanted to discuss a particular lesson planning document, they could do so by links in Zoom chat if not shared prior to the interview or through screen share). Within that 24-hour period, the recording was transcribed using the web-based application Otter (Otter.ai). The transcribed text was reviewed and matched to the recording to ensure that there were no errors. All found errors were corrected and the transcribed text was uploaded into the web-based computer-aided qualitative data analysis software (CAQDAS), Dedoose (www.dedoose.com), when ready. All transcripts were saved into Dedoose under the participant's pseudonym. The Dedoose system was used as the repository of the transcripts and all data in that system was encrypted.

**Appendix IV – Interview Guide**

The interview guide was developed with, for example, the valid and reliable TPACK Interview Protocol as one starting point (https://activitytypes.wm.edu/Assessments/TPACKInterviewProtocol.pdf) as well as Lauterbach's (2018) insights on the interview in Hermeneutic Phenomenology research methodology.

***General Topics to Cover***

A. Teachers' introduction to VR and/or AR
B. How teachers came to accept and adopt VR and/or AR
C. How teachers develop and implement VR and/or AR learning experiences for their students, inclusive of how they assess learning
D. How the use of VR and/or AR has impacted their teaching practice, including what shifts they may have had to make in integrating VR and/or AR into a learning experience

***The Semi-Structure Interview Guide***

***Interview Introduction.*** *"Thank you for being here today. Over the last few years, a lot has been shared about the use of virtual and augmented reality in education. The purpose of our conversation is to understand your experiences and perceptions of adopting and integrating virtual and/or augmented reality into learning experiences for your students."* ***<<Given the COVID-19 Pandemic, I am aware you very well may have not used VR/AR with your students at the end of the last school year given school closures (or did you find a way to leverage this remotely?>>***

- First, I want to confirm that you are in agreement with having this interview audio recorded.
- This recording is so that I do not miss any critical information you share; it will not be shared with anyone else.
- Please let me know if at any time you would prefer the device to be turned off or paused.
- Do you have any questions before we begin?

**<Device Now On>**

**There are 2 questions I am looking to answer/understand – (i) what has been your experience adopting/integration VR/AR for the classroom (how did you come to start using it, how did you build new knowledge about it, etc.) and (ii) how has this adoption affected your teaching practice (from where you teach, how you assess learning, etc.)**

**Regarding RQ1: What are the experiences and perceptions of these experiences of pioneer teachers regarding the adoption and integration of virtual and/or augmented reality in teaching and learning for PK-12 students?** ***How do pioneer teachers build new knowledge (e.g. TPACK) within the context of the innovation adoption and integration process?***

- How did you come to learn about VR/AR?
    - *Potential Clarifying Question(s):*

        - Where did you first learning about VR/AR?
            - Can you describe that experience?
        - **What did this experience signify for you/mean to you?**
- How did you come to decide to start using it for your teaching practice?
    - *Potential Clarifying Question(s):*
        - Why did you decide to start using VR/AR for learning experiences?
            - Who/What drove you to try VR/AR for your teaching practice?
            - What about your prior experiences drove you to want to use VR/AR for teaching your students?
        - What was your intention when you decided to use VR/AR for teaching?
            - **Was this use based on needs of your students?**
        - **Was this part of a school/district pilot or is this a permanent addition?**
- Can you describe how you came to learn about how to use VR/AR for teaching and learning?
    - *Potential Clarifying Question(s):*
        - Who was important in your learning about VR/AR for teaching?
            - Who supported you in building this new knowledge?
        - What information channels did you look to for this learning?
        - What information did you receive about how to use VR/AR for teaching?
        - **Can you describe the supports you received (& who would continue to provide these supports?)**
            - **(i.e. was it through PD? If yes, how was the PD structured and what was your perception of it? (i.e. how timely, how relevant, sustainable intentional PD model, quality of the PD, etc.)**

**Regarding RQ2: How do teachers integrate virtual and/or augmented reality into learning experiences, and how does this integration impact their teaching practice? *How does this integration affect the planning of learning experiences, classroom structures/management, pedagogical practices, methods of assessing learning, and/or other areas?***

*"For this segment of the interview, I would like to explore a specific learning experience you implemented for your students. If do you have your lesson planning documents, we can use that to discuss the process you used in developing and implementing this learning experience; if you do not have these documents, you make take a few minutes to think about one learning experience to discuss. In discussing this learning experience, I would like you to think aloud a bit so that I may better understand your thought process as your developed and implemented this learning experience."*

- To start, why did you select this particular learning experience to discuss?
    - *Potential Clarifying Question(s):*
        - What came to mind when you were selecting which learning experience to discuss?
- How did you plan this learning experience? Please consider -
    - What your intention/objective was for this learning experience
    - Why you decided to use VR/AR for this learning experience

        - **What was the thinking behind selecting VR/AR for this learning experience?**
    - What you were thinking about as you planned
    - What decisions you had to make while planning and what they were about
        - **How did you plan for obstacles?**
            - **What were the potential obstacles you anticipated as you planned?**
- After planning, how did you implement this learning experience with your students? Please consider -
    - How you introduced the learning experience?
    - Why you selected this way of introduction?
    - **Where you inserted VR/AR into the learning experience?**
    - *How your students received this experience**? <<not as critical a question as the focus is not on students>>***
    - How much time was spent in this learning session in VR/AR?
    - **What your role was as the teacher (or that of teaching assistants) when students were engaged using VR/AR?**
        - **What were some of the complexities regarding your role during VR/AR implementation?**
    - How you checked for understanding/assess student learning during this experience?
- What have been some of the barriers to integrating VR/AR into planning and/or implementing learning experiences?
- What **did you have to** change in your practice when you have decided to leverage VR/AR for a learning experience?
    - **How you many have implemented this lesson without VR/AR?**
    - Please consider -
        - Your classroom (physical structure, classroom management, use of lab instead, etc.),
        - Your planning process, your pedagogical practices,
        - **Your implementation,** and/or
        - Your assessment of student learning?
    - **How may your practices shift as the next school year begins with the COVID-19 pandemic looming still?**

**Closing to include this question with a thank you a confirmation of next steps:**

- Are there any other critical experiences you would like to share that we have not discussed yet?

**Appendix V – Interest and Demographic Survey Results**

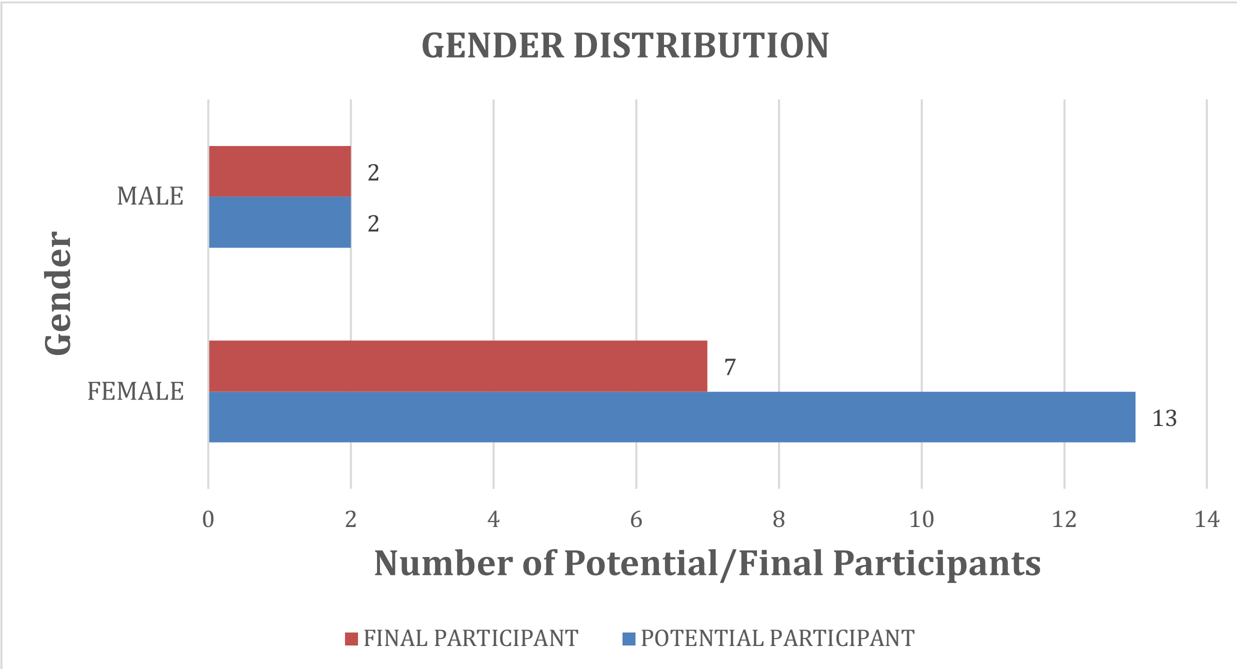


**Fig. 1: Two of the nine final participants were male; the rest female.**

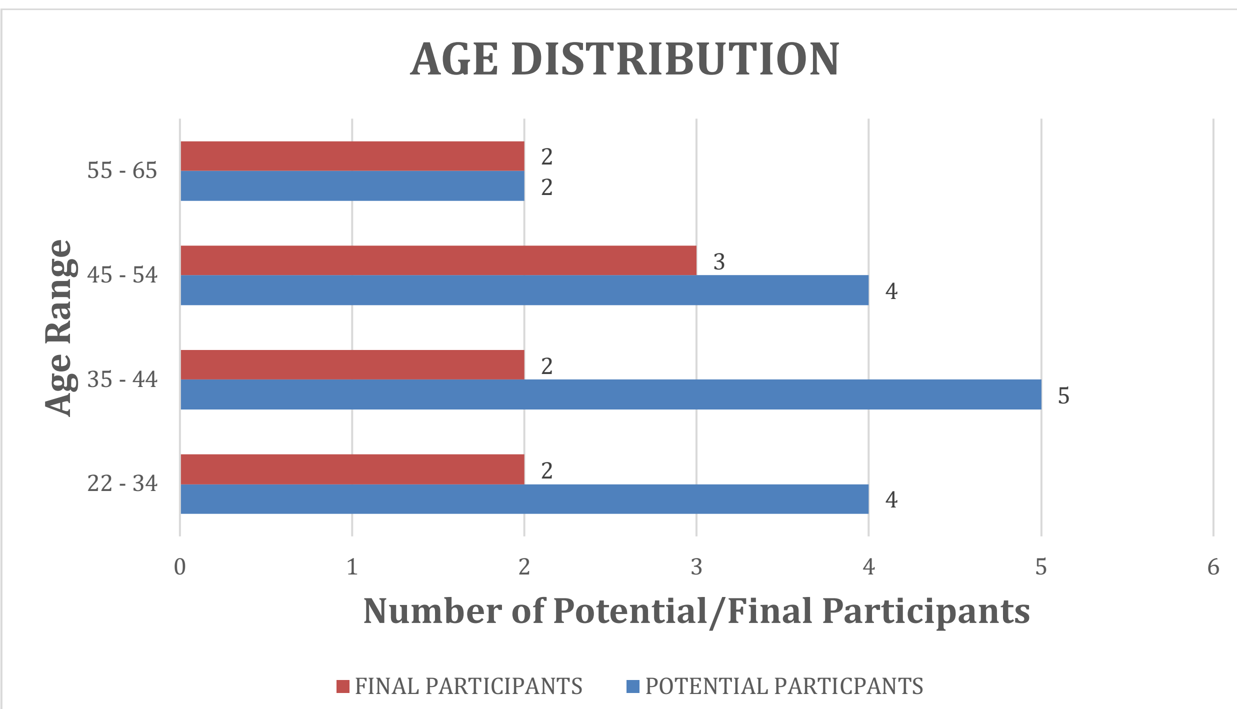


**Fig. 2: Final participants were distributed across all defined age ranges.**

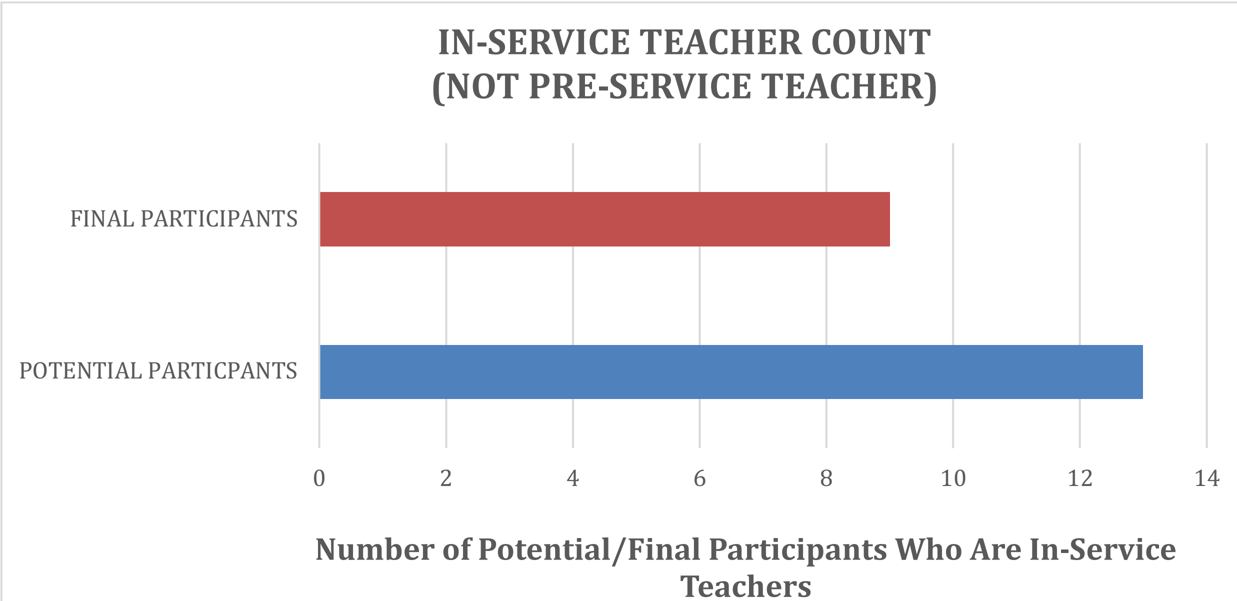


**Fig. 3: Most potential participants, and all final participants were not pre-service/student teachers; they were in-service teachers.**

| | **YEARS OF TEACHING EXPERIENCE** | |
|---|---|---|
| | **POTENTIAL PARTICIPANTS** | **FINAL PARTICIPANTS** |
| **AVERAGE** | 13.25 | 16.125 |
| **MEDIAN** | 11.5 | 13.5 |
| **SPAN** | 2 to 33 | 5 to 33 |
| **RANGE** | 31 | 28 |

**Fig 4: Years of teaching experience for potential participants and final participants**

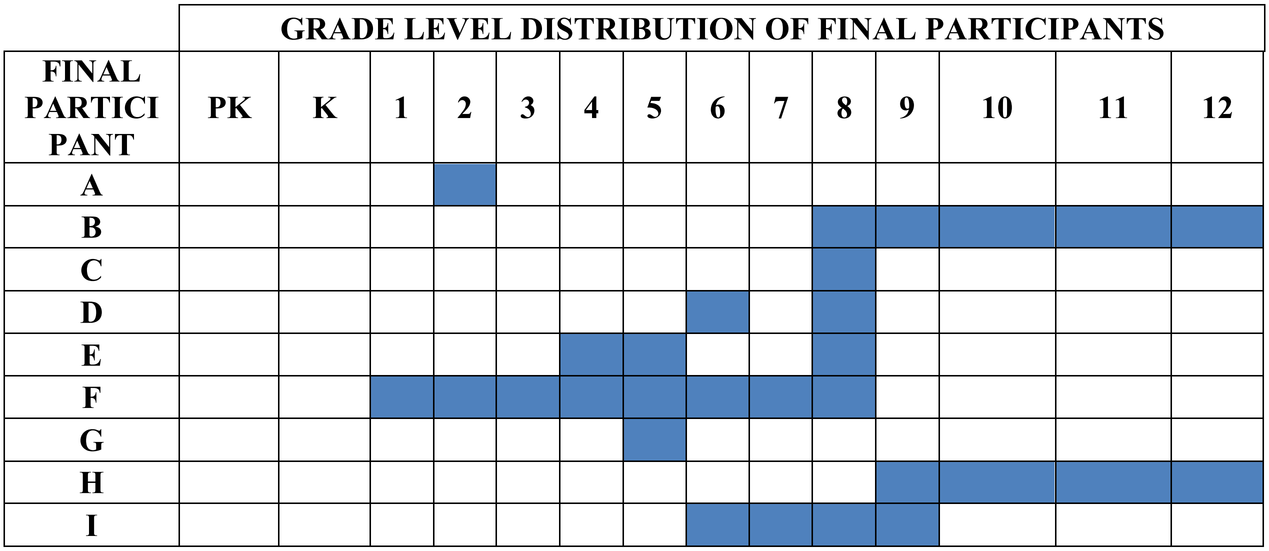


**Fig. 5: Grade-levels taught by Final Study Participants**

| FINAL PARTICIPANT | SUBJECT-MATTER/COURSE TAUGHT |
|---|---|
| A | English Language Arts |
| B | STEAM |
| C | History,Social Studies |
| D | Technology |
| E | Art,Music,Science, Technology |
| F | Computer Science/Programming, Engineering & Design, Creative Technologies |
| G | Integrated Subjects (English Language Arts, Math, Science, Social Studies, etc.) |
| H | Computer Science/Programming,English Language Arts |
| I | STEAM |

**Fig. 6: Subjects taught by Final Participants**

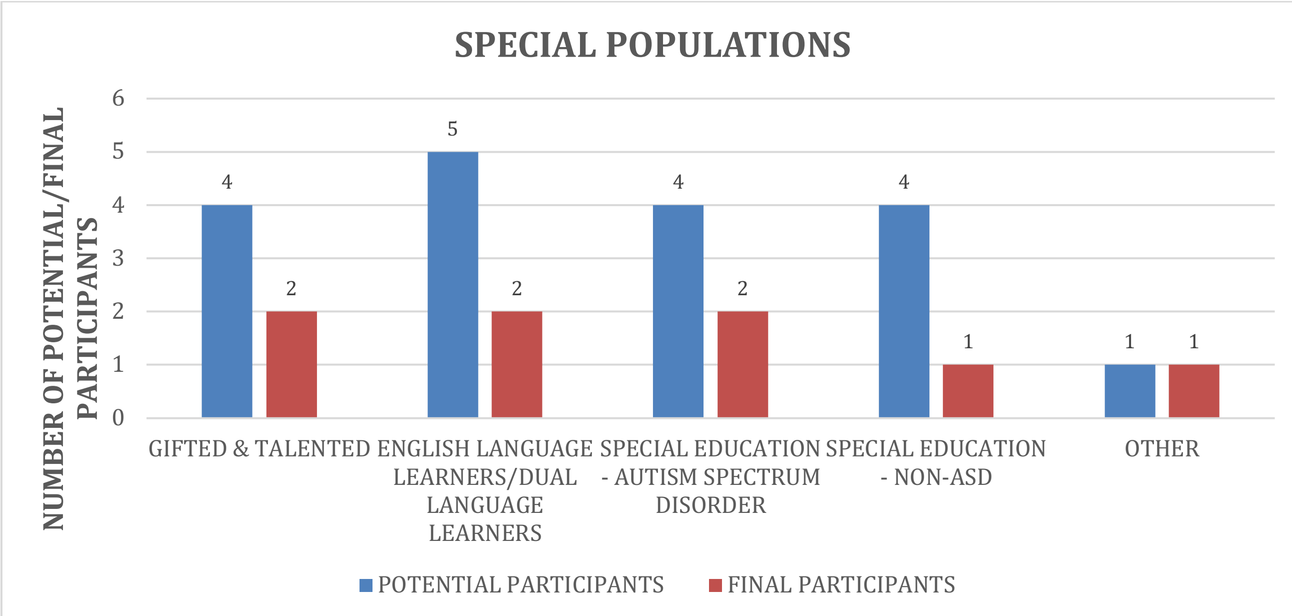


**Fig. 7: Special populations within the classroom**

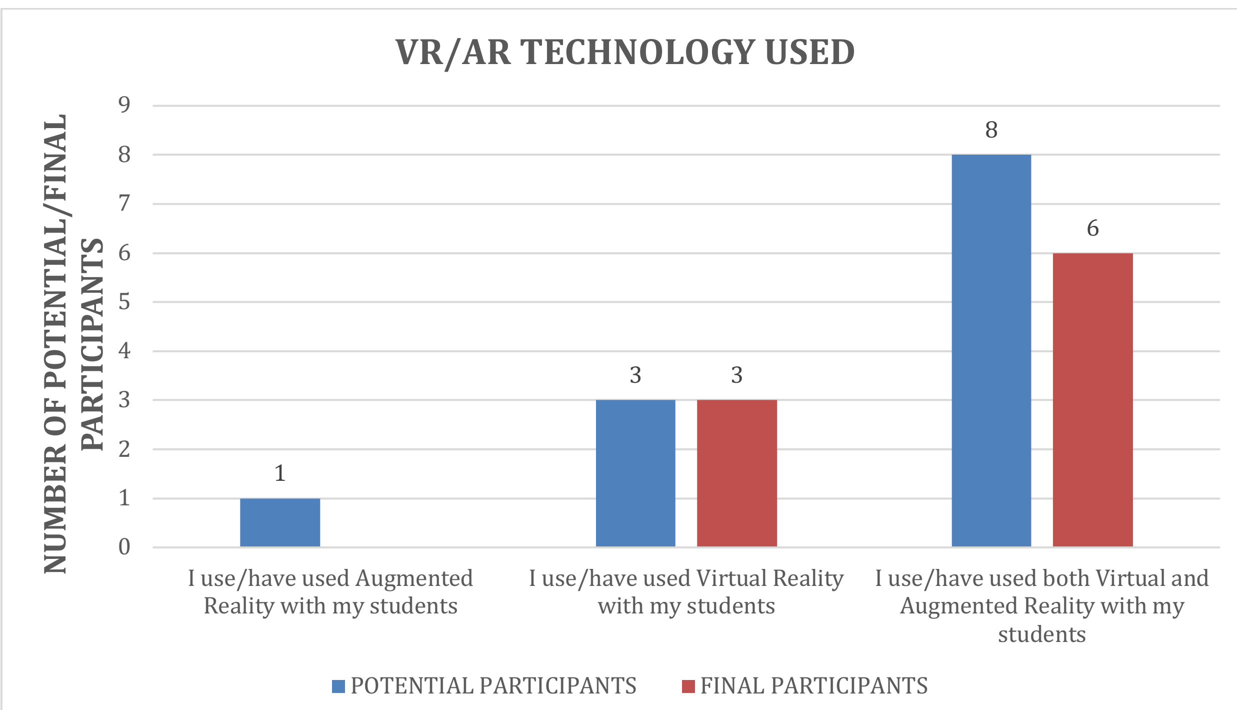


**Fig. 8: VR and/or AR Technology used for Teaching & Learning**

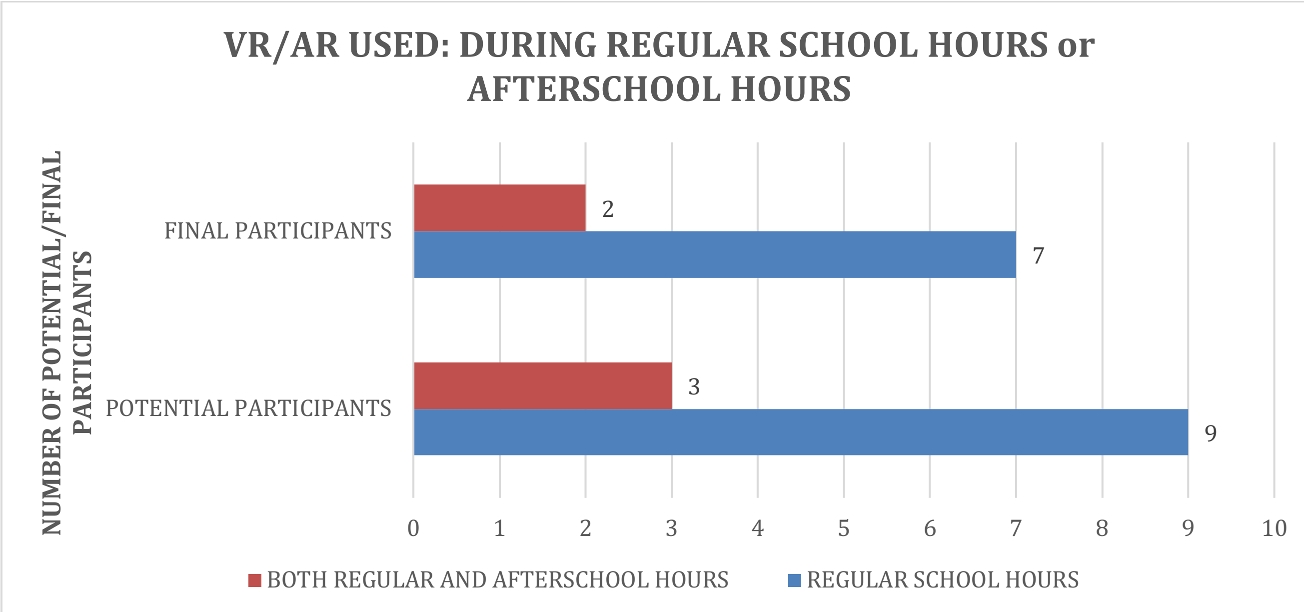


**Fig. 9: Number of Potential/Final Participants who used VR/AR Usage in Regular School Hours and/or Afterschool Hours**

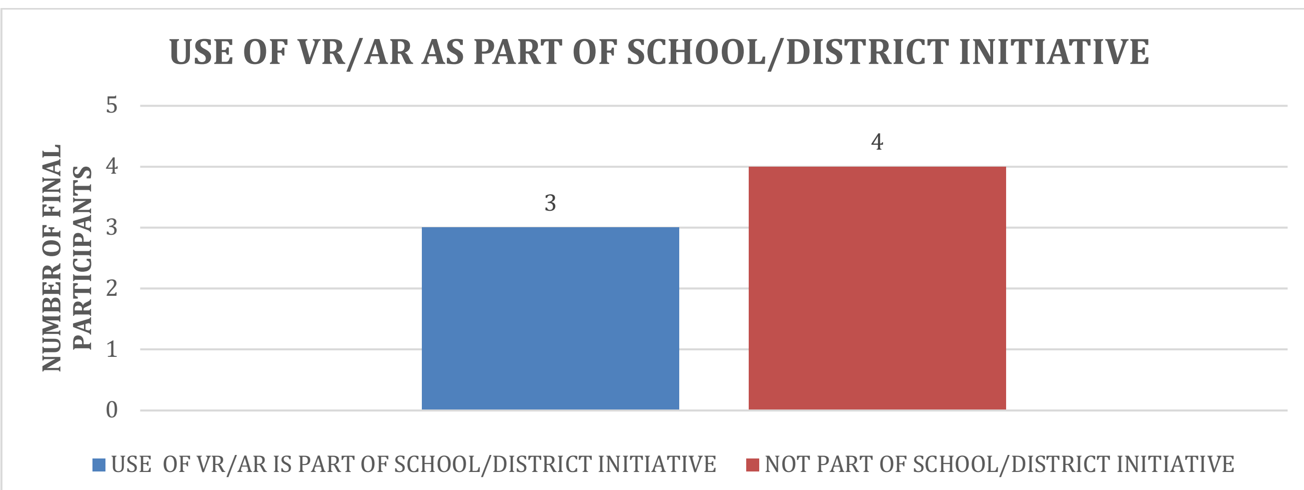


**Fig. 10: Number of Final Participants using VR/AR is part of a School/District Initiative**

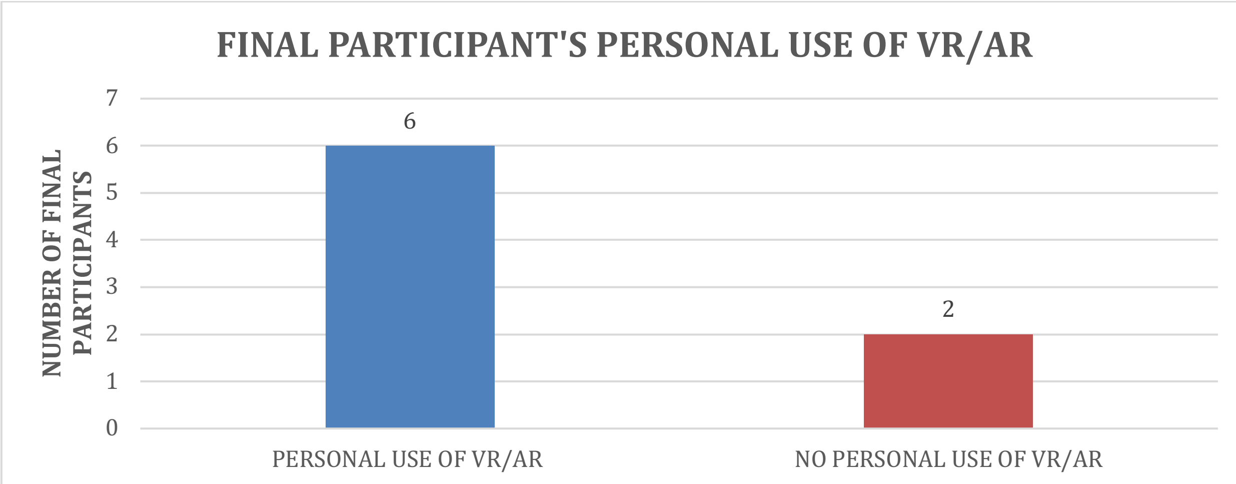


**Fig. 11: Number of Final Participants who indicated a personal use of VR/AR**

| | MONTHS USING VR | | MONTHS USING AR | |
|---|---|---|---|---|
| | **POTENTIAL PARTICIPANTS** | **FINAL PARTICIPANTS** | **POTENTIAL PARTICIPANTS** | **FINAL PARTICIPANTS** |
| **AVERAGE** | 30.33 | 36.22 | 27 | 40.2 |
| **MEDIAN** | 32 | 32 | 20 | 36 |
| **MONTH SPAN** | 2 to 80 months | 3 to 80 months | 1 to 80 months | 15 to 80 months |

**Fig 12: Months Potential/Final Participants have used VR or AR**
**Note: Interest and Demographic Survey options did not go beyond 80 months.**

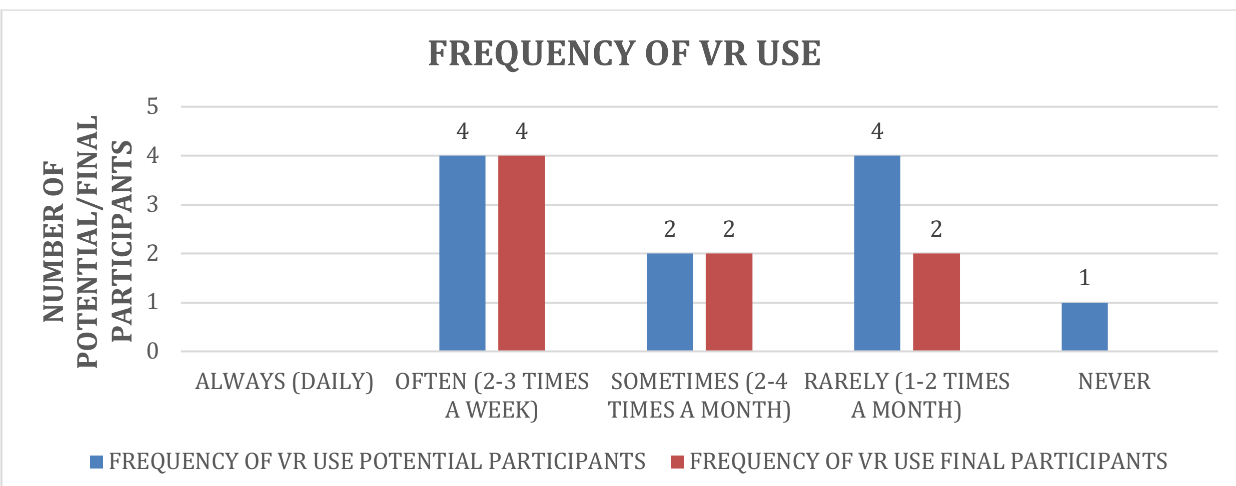


**Fig 13A: Frequency of VR Usage**

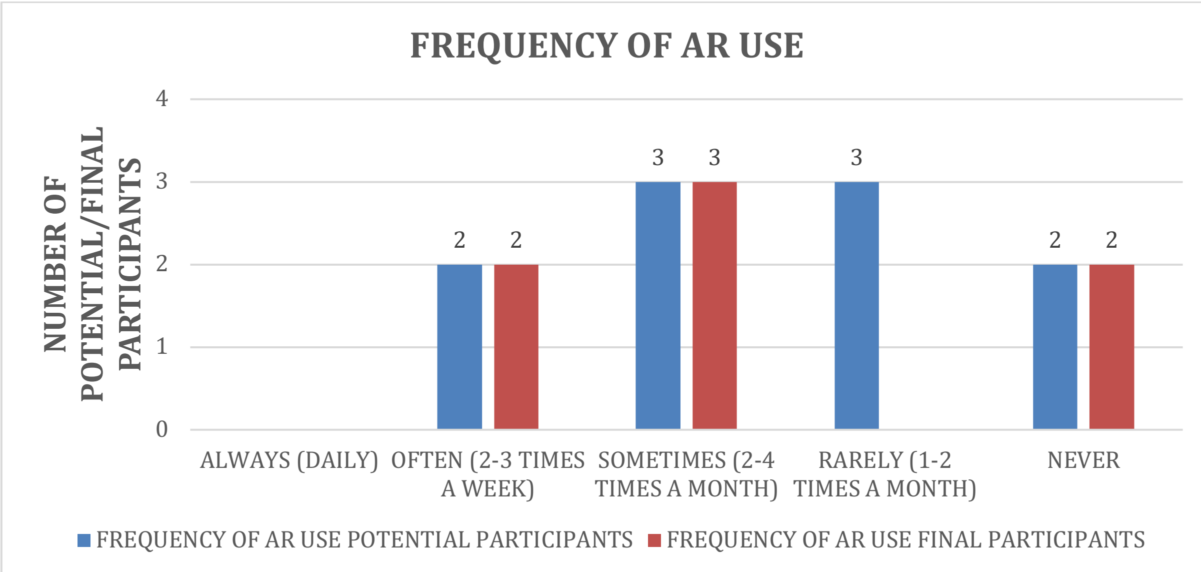


**Fig 13B: Frequency of AR Usage**

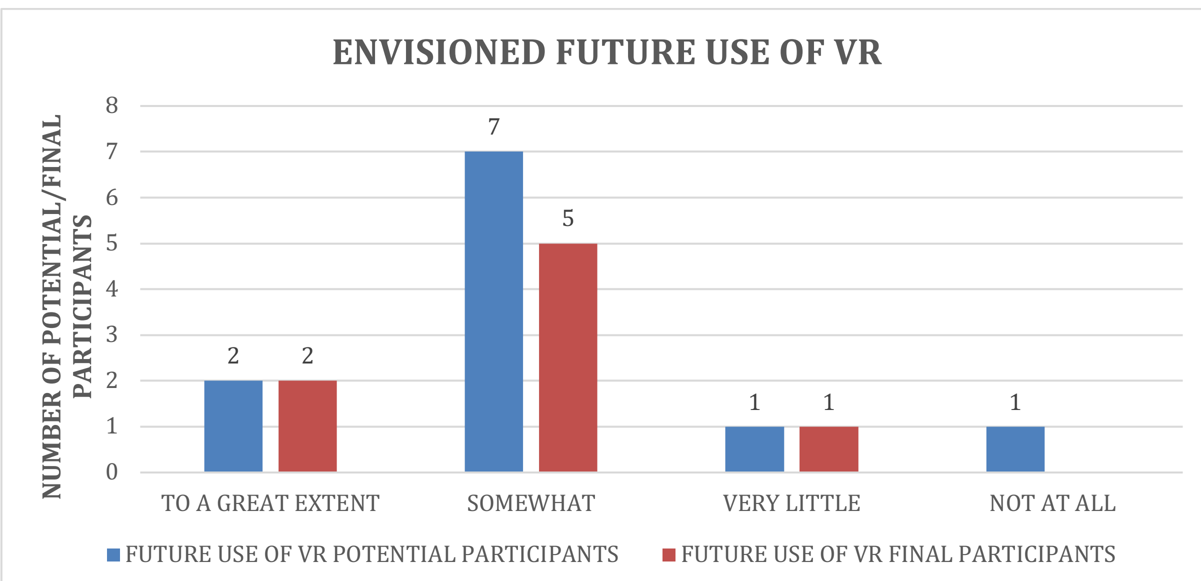


**Fig 14A: Envisioned Future Use of VR**

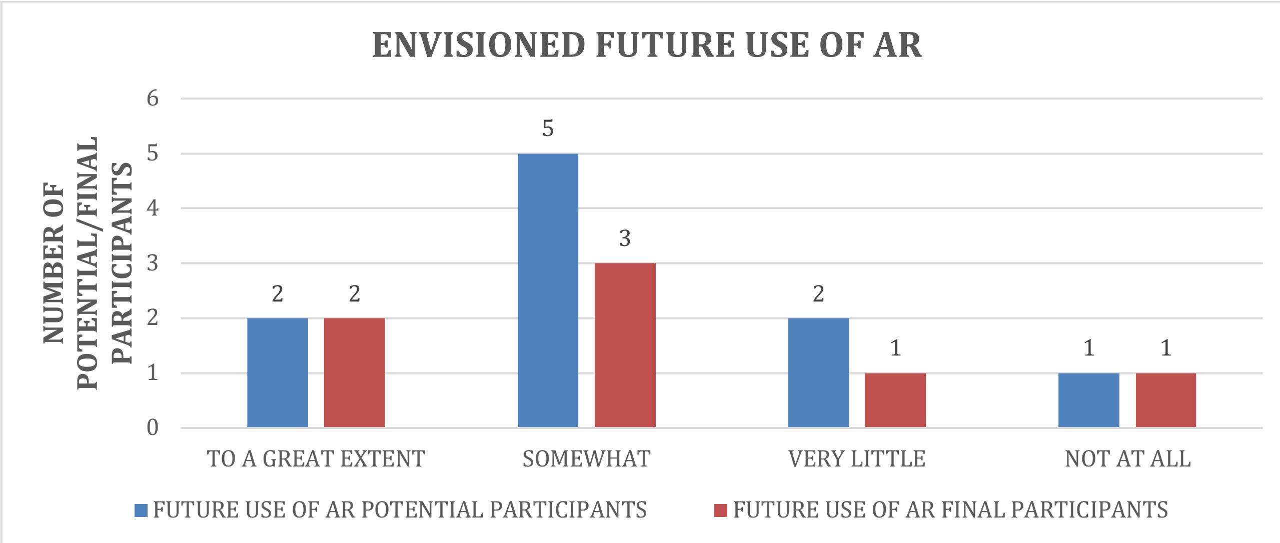


**Fig 14B: Envisioned Future Use of AR**

**Open-Ended Question on VR/AR Used**

| | |
|---|---|
| *What VR and/or AR technology do you use/have you used with your students (i.e., hardware, apps, etc.)?* | • Nearpod and Google<br>• Virtual Reality is a great tool to be used in the classroom environment. I beleive it's a great way to allevate certain behaviors that arouse within the classroom setting. I have used this tool for approximately 2-3 months but, learned that it was not acceptable by the Administrators. I actually was trying this Virtual Reality tool out and to see if it would make a difference in the classroom settings. And it did.<br>• Nearpod, cospaces, metaverse, merge cube, 3d bear, Google expeditions, Google tour creator<br>• Mostly Google Expeditions but also 360 video on YouTube, Quiver, and a couple of QR apps.<br>• Mostly Google Expeditions but also 360 video on YouTube, Quiver, and a couple of QR apps.<br>• Oculus Go Goggles:<br>Our Solar System (Used by all 6th graders)<br>Gala (Used by Chinese WL class)<br>MEL Chemistry (Used by all 8th graders)<br>• IPad apps:<br>Insight Heart (used by health classes)<br>Night Sky (used by 5th grade SS classes)<br>Living Lung (used by health classes)<br>Shapes 3D (used by 8th-grade geometry classes)<br>• HTC Vive, Rift, 3DOF devices, CoSpaces, Ipads and phones for AR, HoloLens (only once) Apps: CoSPaces, Melody, TheBody, google expeditions, Unity, TiltBrush, Minecraft for VR |

| | |
|---|---|
| | • HTC Vive, Rift, 3DOF devices, CoSpaces, Ipads and phones for AR, HoloLens (only once) Apps: CoSPaces, Melody, TheBody, google expeditions, Unity, TiltBrush, Minecraft for VR<br>• Oculus Rift<br>Oculus Quest<br>Samsung Gear VR<br>• CoSpaces, Google Expeditions |

**Open-Ended Question – Additional Information**

| | |
|---|---|
| *Is there any other information you would wish to share at this time? If yes, please include your additional thoughts below.* | • There are a lot of different augmented and virtual reality apps and tools that I use. Continue to find more to try and learn more about with my students<br>• If not for the coronavirus pandemic, I think that I would use VR technology much more than I will in the coming school year. I will not be able to use the VR headsets but may be able to guide students through 360 tours on their Chromebooks.<br>• COVID 19: we will NOT be using the VR goggles or iPads this coming year due to the spread of COVID 19. We hope to resume in 2021.<br>• Some of the questions have been challenging to answer because Covid will likely pause a lot VR use for the year. :( Also, There was a question about how often I use VR, and I use it within certain Units, so it is not a consistent pattern of Use. I am also studying Human Centered Design and Engineering and have recently interviewed other educators about there use of VR in the classroom as part of VR design project for one of my classes.<br>• School leaders are not yet convinced as to the impact of AR/VR for classroom use. |

## Appendix VI – Sample Lesson Plan A

***Marley's Lesson Plan for 8<sup>th</sup> Grade Chemistry***

*<u>Lesson Plan for 8th-grade Chemistry</u>*
*1. Intro to the VR goggles*
*2. Complete Atoms in solids (https://melscience.com/US-en/vr/lessons/atoms-in-solids/)*
*a. Discuss with your table- what did you notice inside the pencil?*
*b. In your notes-how were the atoms arranged and what were they doing?*
*c. Predict- how will the atoms in a gas differ from those in a solid (arrangement and motion)?*

## Appendix VII – Sample Lesson Plan B

***Ryan's Lesson Plan for Propaganda Lesson***

*<u>Social Studies Propaganda Lesson Plan</u>*
*1) View these images (excluding slides 22-25) and discuss the following questions in a small group.*

- *Which posters have you seen before? Why do you think it became so famous?*
- *What do the posters have in common?*
- *What emotions are you supposed to feel when you see the posters?*
- *If the time allowed, they created their own propaganda about Peppa Pig.*

*2) Read this Wapo article about propaganda in the digital age and discuss as a group: Do you agree with the author? How influential do you believe memes are at shaping your opinions on political issues? Then, create memes that serve as propaganda.*

*3) View slides 22-25 from these images, which are of our principal. Discuss as a group: Are any of these examples? What makes something propaganda? Is there a clear line between what is and isn't propaganda?*

*4) Students would use the VR headsets to view this tour of our school, with the [principal's] propaganda added in. Then, students would discuss as a group: What do you think it takes for a cult of personality to develop about a country's leader? Can it happen anywhere? What do you think it would be like to live there?*

**Appendix VIII – Themes and Their Definitions**

| Questions/Topics | Themes* Uncovered | Defined |
|---|---|---|
| ***Regarding the experience of adoption and integration of VR and/or AR into teaching and learning inclusive of knowledge building about VR/AR*** | *First/Early Experiences of VR/AR* | A description of pioneer teachers' introduction to VR and/or AR |
| | *Building New Knowledge about VR/AR* | Learning about VR and/or AR (the technology and how to leverage it for teaching & learning) through various channels of learning. Experimentation played a significant role in new knowledge building. |
| | *District/School Leader Role* | District/School leader role in the VR/AR adoption and integration process. |
| ***Regarding integration of VR and/or AR and its impact*** | *The Search for Content/Tools/Apps/Experiences* | The process of searching for and finding VR and/or AR tools and experiences to bring into the classroom |
| | *Implementation* | How using VR and/or AR, and the considerations, processes, and structures surrounding implementing VR/AR-infused learning experiences<br><br>Sub-Themes:<br>• How VR/AR used (type of lesson, where infused in the lesson)<br>• Availability of Tech (# of devices)<br>• Classroom structure & management<br>• Device management<br>• Policies/Rules/Prerequisites to using the technology<br>• Evolving technology/Feature limitation impact<br>• Assessment practices |
| | | |
| ***Other*** | *The COVID-19 Pandemic* | The COVID-19 pandemic's effect on the adoption and integration of VR and/or AR |
| | *About the Pioneer Teacher and/or the Context of the School/District* | Pioneer teacher characteristics - history, interest, educational philosophy, etc. and/or the educational philosophy of the district/school has a role in the adoption/integration of VR and/or AR |

**Appendix IX – University Institutional Review Board Approval**

SETON HALL UNIVERSITY
1856

June 17, 2020

Frances Nana Ofosu-Amaah
[redacted]

Re: Study ID# 2020-075

Dear Ms. Ofosu-Amaah,

The Research Ethics Committee of the Seton Hall University Institutional Review Board reviewed and approved your research proposal entitled "Diffusion of Virtual and Augmented Reality in Pre-K to 12 Education: Experiences and Perceptions of Pioneer Teachers" as resubmitted. This memo serves as official notice of the aforementioned study's approval as exempt. Enclosed for your records are the stamped original Consent Form and recruitment flyer. You can make copies of these forms for your use.

The Institutional Review Board approval of your research is valid for a one-year period from the date of this letter. During this time, any changes to the research protocol, informed consent form or study team must be reviewed and approved by the IRB prior to their implementation.

You will receive a communication from the Institutional Review Board at least 1 month prior to your expiration date requesting that you submit an Annual Progress Report to keep the study active, or a Final Review of Human Subjects Research form to close the study. In all future correspondence with the Institutional Review Board, please reference the ID# listed above.

Thank you for your cooperation.

Sincerely,

Mara Podvey
Mara C. Podvey, PhD, OTR
Associate Professor
Co-Chair, Institutional Review Board

**Office of the Institutional Review Board**
Presidents Hall · 400 South Orange Avenue · South Orange, New Jersey 07079 · Tel: 973.275.4654 · Fax 973.275.2978 ·
*www.shu.edu*

W H A T  G R E A T  M I N D S  C A N  D O