Chapter 10
3D Virtual Reality in K-12 Education: A Thematic Systematic Review

Rebecca Tilhou, Valerie Taylor and Helen Crompton

Abstract With progressive twenty-first-century 3D virtual technologies, the ability to blur the lines between material reality and digital worlds is proliferating in K-12 classrooms across the globe. A thematic systematic review was used to examine three-dimensional (3D) virtual reality (VR) in K-12 education from 2010 to 2019. Findings revealed specific features and capabilities of contemporary 3D VR technologies, how 3D VR technologies are being used in K-12 education, and how 3D VR supports learning experiences. In 3D virtual worlds, students are able to view peripherally through a virtual presence, experience weather, time, and different environments, and virtually touch and examine objects. The current research showed that 3D VR is commonly applied in middle and high school science classrooms and facilitates the pedagogic approach of inquiry-based learning (IBL), a branch of constructivism. The reviewed studies indicated that integrating 3D VR technologies leads to enhanced learning experiences, leading to increased achievement and motivation.

Keywords 3D virtual reality · Immersive environment · Inquiry-based learning · Virtual environment for learning · Virtual field trip

10.1 Introduction

Rapid advancements in technology are challenging humans to reconsider basic categories that make up reality (Brown and Green 2016; Choat 2018). The boundaries between the natural and the technological, human and non-human, and how life is defined are changing in response to human innovation (Choat 2018). A digital model of the material world allows for a reconceptualization of matter, agency (Choat 2018), and how students can learn by experiencing a real versus virtual material world. Children naturally engage in autotelic practices to learn about the world and nature around them (Rautio 2013). For example, the act of picking up and holding

R. Tilhou (✉) · V. Taylor · H. Crompton
Darden College of Education and Professional Studies, Old Dominion University, Norfolk, VA, USA
e-mail: rtilh001@odu.edu

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a stone, feeling its texture, temperature, and shape is both the activity and reward in itself. The learning about nature and matter is intrinsically motivated. Yet, what if this tangible “vibrancy of matter” (Bennett 2010; Tesar and Arndt 2016) could transcend how matter is defined, allowing children to virtually experience and touch stones miles away from where they sit within the walls of a classroom? With progressive twenty-first-century 3D virtual technologies, the ability to blur the lines between material reality and digital worlds is proliferating in K-12 classrooms across the globe (Brown and Green 2016).

Three-dimensional virtual reality (3D VR) is a digital representation of an environment where users can become fully immersed within it (Dalgarno and Lee 2010). In 3D VR environments, humans can create their own presence, move around and see in all directions, and interact with objects, giving students a strong sense of being in the simulated space (Mikropoulos and Natsis 2011; Pederson and Irby 2014). Educators are increasingly interested in incorporating 3D VR into pedagogical practices because of the learning benefits it offers students. Experiential learning opportunities that students may otherwise not be able to access, contextualized and exploratory learning, and increased motivation and engagement are all affordances granted by the use of 3D VR environments (Dalgarno and Lee 2010; Pederson and Irby 2014).

While a growing body of current empirical research reveals the positive impacts that 3D VR applications have on learning in K-12 classrooms (Grotzer et al. 2015; Pederson and Irby 2014; Sun et al. 2010; Tarng et al. 2012), scholars and educators need a more current, holistic understanding of contemporary 3D VR technologies due to its expeditious developments and educational affordances (Brown and Green 2016; Kavanaugh et al. 2017; Minocha et al. 2017).

The purpose of this thematic systematic review is to examine 3D VR technologies being used in K-12 education and how 3D VR supports students’ learning experiences. This chapter begins with a brief overview of 3D VR and a synthesis of extant systematic reviews related to 3D VR’s use in education. Following, a review of empirical studies illustrates current uses of 3D VR specific to K-12 education. This section will give special attention to types and features of 3D VR systems, learning contexts, participants, and outcomes of 3D VR integration. Next, descriptions of the most contemporary 3D VR technologies gained from reports, reviews, and teacher–practitioner articles are offered. Lastly, a conclusion will provide a summary of the findings and provide implications for future research.

10.2 Literature Review

10.2.1 Virtual Reality

Three-dimensional immersive technologies have become a basic component of modern computer games (Dalgarno and Lee 2010), such as with *World of Warcraft, Active Worlds,* and *Second Life* (Dalgarno and Lee 2010; Han 2011). *Second Life,* founded by the Linden Lab in 1999, became one of the most popular computer games in the first decade of the twenty-first century due to the use of 3D technology. In 2010, a reported 1,381,635 users signed into *Second Life* in just one month (Han 2011).

As 3D immersive technologies have gained momentum, so has their potential for uses in K-12 teaching and learning. Richer, more experiential engagement that was never before possible is now viable with the ability to virtually explore places and interact with objects and structures in those environments (Dalgarno and Lee 2010). Thus, with these advancements of 3D VR systems and their union with education, 3D VR has come to assume many sub-categories such as (a) 3D virtual field trip (VFT) (Argles et al. 2015; Tutwiler et al. 2012), (b) 3D virtual worlds (Hew and Cheung 2010), (c) 3D virtual learning environment (3DVLE) (Dalgarno and Lee 2010), (d) 3D virtual environment for learning (VEL) (Pederson and Irby 2014), and (e) 4D VR (Moorefield-Lang 2015). These 3D VR sub-categories include systems whose features range from life-like graphics on a screen without the use of a headset to the use of lightweight headsets that allow users to view 3D VR applications peripherally in more realistic ways. The growth of 3D VR in education is undeniable; however, VR technologies have yet to gain widespread inclusion into educational curricula (Kavanaugh et al. 2017) in the same way gaming 3D VR has infiltrated homes and children's leisure activities.

10.2.2 Extant Systematic Reviews

To date, few systematic reviews of 3D VR in education have been conducted. Hew and Cheung (2010) explored how 3D virtual worlds were being used in education and what research methods and topics were utilized. Mikropoulos and Natsis (2011) examined research with educational virtual environments (EVEs). Following these, Kavanaugh and colleagues (2017) examined 3D VR research in education. These reviews provide scholars with an examination across of empirical work across nearly two decades.

Hew and Cheung's (2010) systematic examination of 3D VRs in education covered research up to 2008. The authors found that 3D virtual worlds were used as communication spaces, simulations of a space, and experiential spaces where users could act on the environment. The majority of the studies reviewed utilized descriptive or experimental research approaches. Additionally, the majority of the samples came from polytechnic and university settings (69%), with secondary schools representing 19% and primary schools 12%. The disciplines where the research was carried out were typically in the arts, health, and environment fields and sought to examine participants' learning outcomes, affective domain, and social interactions (Hew and Cheung 2010).

Mikropoulos and Natsis (2011) sought to discover studies' educational contexts, characteristics of the 3D VR environments, and learning theories applied to 3D VR studies conducted. The review conducted by these authors covered research from 1999 to 2009 and found that 40 of the 53 reviewed articles conducted studies in the context of math and sciences. No specification of participant age and schooling level, other than stating that all of the studies ranged from elementary school pupils to university students and teachers, was provided. Specific characteristics of 3D VR found during this time period were immersion, multisensory interaction channels, and intuitive interactivity with visual representation being the predominate feature (Mikropoulos and Natsis 2011). The authors concluded that the overall features of 3D VR implied the principles of constructivism, which was used as a framework by the majority of studies reviewed. These features were experiential, contextual and collaborative learning, spatial representation, and engagement (Mikropoulos and Natsis 2011).

Kavanaugh and colleagues' (2017) review of research from 2010 to 2017 focused on understanding why, despite the decades-long existence of virtual reality, education has not integrated 3D VR more consistently. Through this analysis, the authors also examined the context in which implementation mostly occurs, as well as a few contemporary 3D VR technologies and systems currently available, such as *Oculus Rift*. Findings indicated that researchers typically employ virtual reality with the purpose of increasing learners' intrinsic motivation, and a framework of constructivist pedagogy, collaboration, and gamification emerged (Kavanaugh et al. 2017). Differing slightly from the previous review, this research indicated that 3D VR was used mainly in health and medicine fields, and 51% of the studies took place in higher education. Lastly, the authors found 3D VR's limitations included insufficient realism, cost and overhead, usability, usefulness, lack of engagement, and even motion sickness. These issues provided insight into why 3D VR has not been more widely embraced by education communities worldwide.

10.2.3 Purpose

These aforementioned reviews of existing empirical research of 3D VR in education provide valuable insights into the progress and future needs of this growing technology. However, little specific knowledge about K-12 populations is provided. While these reviews found that studies typically took place in math and the sciences, little detail was offered about other disciplines where 3D VR was used (Kavanaugh et al. 2017; Mikropoulos and Natsis 2011). Lastly, much is still unknown about the types of current 3D VR systems employed in education and their specific capabilities for teaching and learning (Hew and Cheung 2010; Kavanaugh et al. 2017; Mikropoulos and Natsis 2011).

The purpose of this thematic systematic review is to address these gaps in knowledge about 3D VR's use in K-12 education through examination of most current research (2010–2019). There will be a specific focus on: (a) features and capabilities of current educational 3D VR technologies; (b) disciplines where 3D VR is implemented and how it is applied; and (c) impacts on K-12 students' learning experiences. Thus, the research questions guiding this systematic review of extant research were:

1. What contemporary 3D VR technologies are being utilized in the K-12 educational setting?
2. How is 3D VR currently applied in the K-12 classroom?
3. What are the impacts of 3D VR on learning experiences in the K-12 educational setting?

10.2.4 Method

A thematic synthesis methodology (Gough et al. 2012) was applied to address the three research questions and develop a synthesized knowledge base specific to VR in K-12 education. A thematic synthesis unites findings from different types of research (Thomas and Harden 2008), as it allows for the analyzation of multidisciplinary datasets and creates a platform for common understanding across fields (Boyatzis 1998: xiii). A key activity of thematic synthesis is the translation between studies' results, which allows the researcher to analyze findings from different paradigms (Gough et al. 2012). Employing this method is essential in the case of this systematic review because research covering VR has emerged from a variety of research approaches and several disciplines such as educational technology, science, and mathematics. Additionally, current VR knowledge can be found from technology reviews, reports, and teacher–practitioner articles.

Search strategy. The search for literature took place through EBSCOhost *Academic Search Complete, Education Research Complete,* and *ERIC* databases. Results were limited to: (a) peer-reviewed journals and (b) date selection of 2010–2019. Search keywords were used in several phases. Phase one used the terms *virtual reality, education, elementary and secondary.* In subsequent phases, additional keywords were employed such as *virtual learning, elementary students, virtual environment,* and *affordances.* Articles were selected based on the following criteria: (a) studies involving K-12 students and (b) determination that a 3D VR was actually discussed and employed. In a final keyword search, specific VR technologies, such as *Google Expeditions* and *Google Cardboard*, discussed in a previously included article were used and resulted in additional articles providing current information about 3D VR technologies and their uses.

10.2.5 Findings

These searches yielded seven studies from peer-reviewed publications. Five of the seven's populations included middle or high school students and three populations included upper elementary students. All studies took place in science classrooms. Table 10.1 indicates some key components of these seven studies.

Table 10.1 Population, location, and subject area in relevant studies

Study	Population	Location	Subject area
Grotzer et al. (2015)	Fifth- and sixth-grade students	USA	Ecosystems Weather
Lin et al. (2011)	Tenth-grade students	Taiwan	Earth science Weather systems
Minocha et al. (2017)	Fourth–eleventh-grade students	UK	Geography
Pederson and Irby (2014)	Seventh-grade students	USA	Ecological impacts of natural disasters
Sun et al. (2010)	Fourth-grade students	Taiwan	Space systems
Tarng et al. (2012)	Third-grade students	Taiwan	Agriculture and plants
Tutwiler et al. (2012)	Tenth-grade students	Taiwan	Earth science Geography

The studies included in Table 10.1 were examined to address this review's three research questions. The upcoming sections answer those research questions which provides insights into contemporary 3D VR systems being used, disciplines and fields where 3D VR is commonly applied, and 3D VR's impact on learning experiences in K-12 classrooms. Following these sections will be the further description of the most contemporary 3D VR systems at the time of publication that are emerging in practitioner literature but have not yet been employed in a study.

10.2.6 Contemporary 3D VR Technologies Utilized in the K-12 Setting

Lin and colleagues' (2011) and Tutwiler and colleagues' (2013) subsequent study with Taiwanese students used the 3D virtual field trip (VFT) *Virtools*. *Virtools* is a virtual representation of Hsiaoyukeng Walking Area in Taiwan. Most of the 3D VFT is experienced from a first-person point of view, though there are third-person perspectives when users interact with computer-controlled people within the world. Students had the ability to investigate with classmates rather than in a solitary manner. Weather patterns within the virtual world fluctuate to mirror typical weather patterns of that real-world area. There is a visitor's center with signs pertaining to rock specimens that can be found in Hsiaoyukeng Walking Area. When these rocks are spotted by users, they can be picked up, moved, and viewed from every angle, as well as enlarged to see minute detail.

Minocha and colleagues (2017) integrated physical, real field experiences with *Google Expeditions* (GEs). GEs offer guided field trips on a smartphone using a viewer called *Google Cardboard*. *Google Cardboard,* shown in Fig. 10.1, is a small box equipped with lenses that fit into a smartphone. The GEs' application offers

Fig. 10.1 *Google Cardboard* viewer

more than 500 3D VFT expeditions that allow for 360° photospheres of locations all over the world. Like *Virtools* in Taiwan, GEs enable students to view places such as Great Barrier Reef or Tolbachik Volcano, which would be difficult to visit physically. Additionally, with GEs, students can take biological field trips to see systems such as the human heart, the process of respiration, or to look microscopically at organelles in a cell (Craddock 2018). However, in this particular research, GEs were used to visit a nature preserve.

Through Pederson and Irby's (2014) 3D virtual environment for learning (VEL), *Hurricane Hal,* students were able to traverse a realistic wetland in order to collect data using instruments available in the virtual world. Learners were able to take on the role of a research assistant named Sam who visits four different wetland environments impacted by a hurricane. Students were able to navigate the sites with a virtual airboat and laboratory where they could create and implement investigations. Data was collected most often by sighting and taking counts of animals in the environment.

Grotzer and colleagues' (2015) *EcoMuve* has similar properties to *Hurricane Hal*. Students could test the water quality and study animals living and dying in the environment. With an additional mobile 3D VR application employed, *EcoMOBILE*, students also visited a physical site with their mobile devices and viewed the site using the application, *Virtual Binoculars,* which offered an augmented reality where students could see the physical place along with water monitoring stations distally to gain information about water quality (Grotzer et al. 2015, p. 47).

Sun et al. (2010) utilized a 3D VR model *Sun and Moon System*, created by combining Microsoft Direct3D Library, C++ programming language, and Autodesk 3-D Max for model construction. The system allowed students to view simulation of the earth's movement and orbit, Earth's location, simulation of the moon's movement and phases, and the sun and moon positioning. Students were required to view these components, and the learning activities focused on the moon's phases and location.

The 3D virtual farm in Tarng and colleagues' (2012) study with third graders allowed students to navigate a detailed farm that included a pond, a garden, and buildings. The application allowed students to role play as farmers caring for their animals and crops. Animals moved and grew over time from the students' care.

Students could plant vegetables and observe their growth from seeds. The elementary children had to be actively engaged with the virtual farm's components and, over time, measure the growth of the animals and plants they cared for.

10.2.7 Current Educational Applications of 3D VR in K-12

The findings show that 3D VR was solely used in the sciences at the upper elementary, middle, and high school levels. In several of the studies, different 3D VR systems facilitated VFTs. Virtual field teaching improves accessibility in situations where it is difficult to physically go to an environment due to climate, terrain, or school resources (Tutwiler et al. 2012). Similarly, 3D VFTs introduce the "nature of fieldwork" in a unique way that engages students (Argles et al. 2015). Not only do 3D VFTs build familiarity of fieldwork with students, but with teachers as well, prompting teachers to facilitate physical field trips for their students (Argles et al. 2015; Tutwiler et al. 2012). However, Argles and colleagues (2015) argued that 3D VFTs should be used in conjunction with other resources for best learning.

The study of earth science and geography is among the topics that were paired with a variety of 3D VFTs employed in studies. For example, in Lin and colleagues' (2011) study and Tutwiler and colleagues' (2012) follow-up study with the same population and context, Taiwanese tenth graders used *Virtools* to virtually visit tough terrain at high altitudes to explore geological features of Hsiaoyukeng Walking Area within a remote national park in Taiwan. Students were able to review geological concepts and explore rocks and weather patterns through their virtual experience.

Pederson and Irby (2014) used a 3D virtual environment for learning (VEL) named *Hurricane Hal* and student-directed scientific inquiry, or inquiry-based learning (IBL), to explore the ecological impacts of a natural disaster on a wetland ecosystem. IBL, a component of constructivism (Fowler 2015), requires students to address real-world problems by collecting and interpreting data, and then synthesizing the evidence to come to conclusions, develop curiosity, and ask more questions related to specific learning goals (Minocha et al. 2017; Pederson and Irby 2014). Pederson and Irby's middle school students were given a task using the 3D VEL, prompted to ask questions, design their own investigation, collect and examine data, and report findings. Similarly, *EcoMuve* was employed in Grotzer and colleagues' (2015) study to allow fifth- and sixth-grade students to explore and collect data over time in an ecosystem that offered a pond along with neighborhoods and a golf course. This study's learning focus was on understanding the concepts of causation and change over time in a natural environment rather than explicit IBL, however, the pedagogy behind the exploration echoes inquiry.

Minocha and colleagues (2017) integrated geography, IBL, and the 3D VFT, *Google Expeditions* (GEs), with 4th through eleventh-grade students. The researchers and educators blended real experience with the virtual to teach geography and time-change concepts and also to explore the affordances of the GE's application. Minocha and colleagues took students to a physical field trip site—a nature reserve—to sensitize students to the concept of change in environments being caused by construction and tourism. In this case, a high-speed train track was being hypothetically built in the area. After the physical field trip, using a 3D VFT deepened students' inquiry because they had the physical experience as a foundation of background knowledge. The pairing of the real and virtual experiences stimulated questions they would not have previously known to ask (Minocha et al. 2017).

Sun et al. (2010) utilized a 3D VR model named *Sun and Moon System* to teach space systems to fourth-grade students. Sun and colleagues explicitly positioned their population's learning of space systems within constructivist theory, with a specific focus on using the 3D VR to correct misconceptions about spatial orientation of the planets, moon, and sun, and gain new conceptual understanding of space systems. In another study with elementary students, Tarng et al. (2012) integrated a 3D virtual farm into third-grade science lessons teaching about plants and animals. Students learned about common animals and plants, their features, parts, functions, and needs for living through the use of the 3D VR farm.

These findings indicate that constructivism, the foundation for inquiry learning, is a dominant pedagogic approach paired with 3D VR in K-12 education. Constructivism posits that humans develop knowledge and understanding through a constructive, active process (Dewey 1985; Kavanaugh et al. 2017). In a constructivist learning environment, students actively and iteratively form a personal, subjective model of reality from the fluid dynamic between experiences and ideas (Dewey 1985; Kavanaugh et al. 2017). Constructivist approaches to teaching and learning foster students' ability to access prior knowledge, examine existing ideas, and navigate related experiences in a supportive, interactive manner, allowing students to construct new ideas and apply those ideas to create deeper understanding and skills (Sun et al. 2010). The experimental and experiential are essential to learning (Dewey 1985), and 3D VR technologies in education facilitate constructivist qualities (Kavanaugh et al. 2017).

10.2.8 Affordances of 3D VR on Student Learning

The studies examined show that the use of 3D VR had a direct impact on students' learning experiences, notably, when used in conjunction with or to promote physical fieldwork. *Virtools*, the technology used to facilitate the 3D VFT with Taiwanese tenth graders, led students to increased achievement in content learning and positive attitudes toward the virtual field experience. Furthermore, students had greater engagement when they directed the 3D VFT rather than observing a teacher via projection on a classroom board (Lin et al. 2011). In a later report, Tutwiler et al. (2012) explored how students' ability to visit the national park site with classmates within the virtual realm increased desire to physically explore the site in the future. Other scholars have affirmed the value and importance of pairing 3D VR with real physical field experiences (Argles et al. 2015; Minocha et al. 2017). Field scientists have often criticized the use of 3D VR to teach concepts that need true field experiences because, in essence, it is not possible to replace the learning that happens in physical reality with a 3D VR (Argles et al. 2015). However, when 3D VFTs are implemented to support physical field courses, they supply further background knowledge and experience that promotes more strategic use of students' time while out in the field (Argles et al. 2015). Prior to physical fieldwork situations, 3D VFTs can allow students to practice scientific methods applicable to their field of study, making mistakes in a low-risk environment (Minocha et al. 2017). Furthermore, the nature of scientific fieldwork can be practiced in classroom settings, in an engaging format, which then builds familiarity with fieldwork for both students and teachers. 3D VFTs also provide post-physical fieldwork that reinforces learning, facilitates completion of tasks, and allows for additional observations (Argles et al. 2015; Minocha et al. 2017). The use of 3D VFTs can be a valuable aid in enhancing learning outcomes, motivation, and physical fieldwork at all curriculum levels, and it is best practice that educators use this type of 3D VR to support physical field experiences rather than replacing them.

Researchers and educators' strategic implementation of 3D VR technologies often has a focus on facilitating students' independent scientific inquiry through the IBL approach. The ability to collect and analyze data in the virtual environment promotes scientific inquiry, or IBL, in the classroom (Grotzer et al. 2015; Pederson and Irby 2014). IBL fosters students' development of investigation skills in subjects such as science, history, and geography, leaving plentiful space for problem-solving and critical thinking (Minocha et al. 2017; Pederson and Irby 2014). IBL was employed throughout several of the studies analyzed for this review.

In Pederson and Irby's (2014) study with middle school students, the authors collected data on students' engagement and self-directed inquiry and found that students' self-regulated interest in learning increased significantly, shown, for example, by how students specifically posed many questions at the beginning of the program and later spent much time synthesizing evidence from their collected data. The authors reported further that student engagement throughout the use of the 3D VEL steadily increased as students grew to understand the structure of IBL and the 3D VEL, which led to positive outcomes in learning.

Additionally, students using *EcoMuve* and *EcoMOBILE* showed increased understanding and reasoning about changes over time and the impacts of humans on ecosystems through an IBL approach (Grotzer et al. 2015). The researchers found when students visited the physical site after using *EcoMuve*, and upon viewing the real pond in nature, it was evident that the students were able to transfer aspects of the virtual experience to their observations at the real, material pond. The transfer of learning was apparent with the questions students posed, the information they sought, and how their attention was focused.

Sun et al.'s (2010) findings indicated that students who had access to *Sun and Moon System* 3D VR showed significantly higher learning achievement compared to the group who did not and expressed a willingness and interest to use the technology. The authors deduced that the 3D VR model significantly improved learning because it offered multiple perspectives about space system motion and moon phases rather than a textbook explanation. Additionally, a post-survey indicated that more than two-thirds of the students had desire to use *Sun and Moon System* 3D VR. Similarly, Tarng and colleagues' (2012) virtual farm study with third-grade students found increased learning achievement and willingness and interest in using the 3D VR technology. It is important to note, however, that even though more than two-thirds of Sun and colleagues' students indicated interest in the 3D VR, some students showed a preference to learning the scientific concepts in other ways. This finding supports the point that 3D VR educational technologies are most effective when combined with other resources and avenues of knowledge and experience.

10.2.9 Future Studies on Contemporary 3D VRs in Education

The findings identify a gap in scholarly understanding of various contemporary 3D VR. The following technologies were highlighted in the literature but have not yet been employed in empirical studies. Future research is needed on these 3D VR technologies as they may have the potential to further extend and enhance K-12 learning. Argles and colleagues (2015) presented the 3D VFT *Virtual Skiddaw* to teach geology. *Virtual Skiddaw*, shown in Fig. 10.2, can be accessed via any Web browser and it has a multiuser capability which allows for collaborative group work, even when users are geographically dispersed. Brown and Green (2016) detailed applications such as Google's *Street View* which allows the user to create and view others' photospheres and share them on the internet.

Other applications Brown and Green presented were Mattel's *View-Master*, which is similar to *Google Cardboard*; *Discovery VR* which allows viewers to enter Discovery channel's TV shows; and *VR Immersive Education* which allows users to

Fig. 10.2 *Virtual Skiddaw* 3D VR geology field trip (TheOpenScience Laboratory 2013)

Fig. 10.3 *Oculus Rift* headset (Oculus, n.d.)

create environments in history and science to deepen understanding. Moorefield-Lang (2015) described the most recent version of *Oculus Rift* which offers users an advanced headset and the ability to design 4D VR apps themselves. Users have a “beta share space” to support the sharing and testing of other user-created programs on their headset devices. The *Oculus Rift* headset is shown in Fig. 10.3.

While these descriptions of programs often refer to science teachers, Han (2011) explored how the use of the 3D VR application *Second Life* could be used with art students. As *Second Life* offers the ability to build one’s own 3D virtual environment, Han argued that art students could create 3D art in the virtual world in the same ways a sculptor would in physical reality. Han’s article shows possibility for alternative approaches with the use of 3D VR in education, leading users into subject areas outside the realm of the sciences and data collection. As Brown and Green’s (2016) description of *VR Immersive Education* implies, creating an environment in history could be a powerful tool in increasing students’ motivation to learn history and also understand what an environment in the past may have looked like. Grotzer and colleagues’ (2015) *EcoMuve*, which addressed the concept of time—past, present, future—implies further ability to create environments to simulate the past. Chintiadis et al. (2018) exhibited how environments representing places in the past can be created for educational use with their description of *Trials of the Acropolis*. This 3D VR aligned with third-grade Greek history and Greek mythology allows students to enter Ancient Greece with the purpose of fulfilling an ancient myth. Users engage with avatars, hear background music, and are able to have rich experience with characters and storytelling. These innovative, current 3D VR applications imply a wide range of uses for teaching and learning (Fig. 10.4).

Scholars posit that 3D VR technologies can be beneficial in K-12 teaching and learning; however, further examination of specific 3D VR technologies with empirical methods is needed. It appears from these findings that more research is needed in different K-12 subject areas, such as mathematics, social studies, and literacy. Furthermore, many of the extant studies are in middle and high school and further exploration is needed with younger students.

Fig. 10.4 *VR Immersive Education's* "Apollo 11" represents the historic 1969 NASA space journey (VR Education Holdings 2019)

10.3 Conclusion

The current research examined in this systematic review conveyed the rapid advancements of 3D VR technologies in K-12 education. Educators and learners have options available on the market to use a multitude of realistic applications on mobile devices and laptops/desktops. Some of the VR applications are screen-based and others connect with a variety of headsets that allow users to experience virtual worlds with peripheral vision. It appears from the findings of this thematic systematic review that the grade levels and disciplines where 3D VR is most often applied are middle and high school classrooms narrowed to branches of science. The studies reviewed indicated that 3D VR facilitates the pedagogic approach of constructivism, with a specific focus on inquiry-based learning (IBL) in the sciences. While other systematic reviews identified constructivist learning theory in previous empirical research, this review's findings reveal a specific focus on the iterative process of inquiry to build knowledge and understanding in K-12 settings. This approach conjoined with 3D VR technologies has been found to enhance learning experiences, leading to increased achievement and motivation. More empirical research is needed to explore the affordances of the most contemporary 3D VR systems and how they enhance learning.

With the lack of empirical research exploring the use of 3D VR technologies in disciplines other than the sciences and these findings suggesting that 3D VR enhances students' learning and motivation, there is a further need to examine the affordances of 3D VR in other subject areas. Craddock (2018) argued that using GEs in her library biology lesson-assisted English language learners in better understanding scientific concepts because the visual experience created association with the scientific language. If entering 3D virtual worlds assists students with understanding scientific language, then what could a 3D VR to teach reading or writing add to this preliminary knowledge related to language acquisition? Additionally, using a 3D VR for students to not only enter an environment, but a community of people in a place and time, could offer powerful social and historical learning experiences. In the arts and engineering, affordances of 3D VRs could allow students to build objects and images in an environment. These implications leave much to be explored.

Lastly, this review reveals there is a dearth of research with primary students. Bruner (1960/1977) argued that every child at any stage of development can be effectively taught any subject in an intellectually honest form. Teaching with advanced technologies is no exception to Bruner's philosophy. Though teaching and learning certainly gain complexity as student's age, elementary students, like those in Sun and colleagues' (2010) study, are exposed to intricate concepts that require understanding of a physical, visual, dynamic world. As scholars continue to conduct research in K-12 education utilizing contemporary 3D VR systems, educators and students at a variety of levels and disciplines will be able to experience new, virtual notions of what objects and environment, experience and inquiry can be.

Glossary of Terms

3D VR A digital representation of an environment where users can create their own presence move around and see peripherally, and interact with objects.

Constructivism A learning theory that suggests humans develop knowledge and understanding when in a supportive environment that allows them to construct new ideas and apply those ideas to create deeper understanding and skills.

Google Cardboard A small box equipped with lenses that fits into a smartphone to be paired with 3D VR technology, Google Expeditions.

Google Expeditions A 3D VR technology that offers more than 500 3-D virtual field trip expeditions that allow for 360-degree photospheres of locations all over the world.

Immersive Environment A realistic three-dimensional virtual environment where users have a presence they can control and use to interact with matter in the environment.

Inquiry-Based Learning A component of constructivism that requires students to address real-world problems by developing curiosity through questioning collecting and interpreting data, and synthesizing evidence to come to conclusions.

Virtual Environment for Learning A 3D virtual environment that represents realistic natural environments where users have the ability to interact with objects in the environment collect data, and see change over time.

Virtual Field Trips A 3D virtual environment that can represent real-world locations. Users have the ability to interact with objects in the environment collect data, and collaborate with other users within the environment.

References

Argles, T., Minocha, S., & Burden, D. (2015). Virtual field teaching has evolved: Benefits of a 3D gaming environment. *Geology Today, 31*(6), 222–226.

Bennett, J. (2010). *Vibrant matter*. Durham, UK: Duke University Press.

Boyatzis, R. E. (1998). *Transforming qualitative information*. Cleveland: Sage.

Brown, A., & Green, T. (2016). Virtual reality: Low-cost tools and resources for the classroom. *Tech Trends, 60,* 517–519.

Bruner, J. (1960/1977). *The process of education*. Cambridge, MA: Harvard University Press.

Chintiadis, P., Kazanidis, I., Tsinakos, A. (2018). Trials of the Acropolis: Teaching Greek mythology using virtual reality and game based learning. In M. Auer & T. Tsiatsos (Eds.), *Interactive mobile communication technologies and learning*: *Proceedings of the 11th IMCL conference* (pp. 247–257). Cham, Switzerland: Springer.

Choat, S. (2018). Science, agency, and ontology: A historical materialist response to new materialism. *Political Studies, 66,* 1027–1042.

Craddock, I. M. (2018). Immersive virtual reality, Google Expeditions, and English language learning. *Library Technology Reports, 54*(4), 7–9.

Dalgarno, B., & Lee, M. J. W. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Education Technology, 41*(1), 10–32. https://doi.org/10.1111/j.1467-8535.2009.01038.x.

Dewey, J. (1985). *Democracy and education, 1916*. Il: Southern Illinois University Press Carbondale.

Fowler, C. (2015). Virtual reality and learning: Where is the pedagogy? *British Journal of Educational Technology, 46*(2), 412–422. https://doi.org/10.1111/bjet.12135.

Gough, D., Oliver, S., & Thomas, J. (2012). An introduction to systematic reviews (2nd Ed.). London, UK: Sage.

Grotzer, T. A., Powell, M. M., Derbiszewska, K. M., Courter, C. J., Kamarainen, A. M., Metcalf, S. J., et al. (2015). Turning transfer inside out: The affordances of virtual worlds and mobile devices in real world contexts for teaching about causality across time and distance in ecosystems. *Tech Know Learn, 20,* 43–69. https://doi.org/10.1007/s10758-014-9241-5.

Han, H. (2011). Second Life, a 3-D animated virtual world: An alternative platform for (art) education. *Art Education, 64*(4), 41–46.

Hew, K. F., & Cheung, W. S. (2010). Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research. *British Journal of Educational Technology, 41*(1), 33–55. https://doi.org/10.1111/j.1467-8535.2008.00900.x.

Kavanaugh, S., Luxton-Reilly, A., Wuensche, B., & Plimmer, B. (2017). A systematic review of virtual reality in education. *Themes in Science & Technology in Education, 10*(2), 85–119.

Lin, M., Tutwiler, M. S., & Chang, C. (2011). Exploring the relationship between virtual learning environment preference, use, and learning outcomes in 10th grade earth science students. *Learning, Media & Technology, 36*(4), 399–417.

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

Minocha, S., Tudor, A., & Tilling, S. (2017). Affordances of mobile virtual reality and their role in learning and teaching. In *The 31st British human computer interaction conference*. University of Sunderland's St. Peter's Campus, UK, 2017. Sunderland, UK: BCS Learning and Development Ltd.

Moorefield-Lang, H. (2015). Libraries and the rift. *Knowledge Quest, 43*(5), 76–77.

Oculus. (n.d.). Oculus rift. Retrieved February 4, 2019, from https://immersivevreducation.com/apollo-11-vr/.

Pederson, S., & Irby, T. (2014). The VEL science project: Middle schoolers' engagement in student-directed inquiry within a virtual environment for learning. *Computers & Education, 71,* 33–42.

Rautio, P. (2013). Why children carry stones. *Children's Geographies, 11*(4), 394–408.

Sun, K., Lin, C., & Wang, S. (2010). A 3-D virtual reality model of the sun and the moon for e-learning at elementary school. *International Journal of Science and Mathematics Education, 8,* 689–710.

Tarng, W., Chang, M., Ou, K., Yu, K., & Hsieh, K. (2012). The development of a virtual farm for applications in elementary science education. *International Journal of Distance Education Technologies, 10*(2), 1–16.

Tesar, M., & Arndt, S. (2016). Vibrancy of childhood things: Power, philosophy, and political ecology of matter. *Cultural Studies Critical Methodologies, 16*(2), 193–200.

The OpenScience Laboratory. (2013). Virtual Skiddaw: 3D geology field trip. Retrieved from https://learn5.open.ac.uk/course/format/sciencelab/section.php?name=skiddaw_1.

Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Medical Research Methodology, 8*(45).

Tutwiler, M. S., Lin, M., & Chang, C. (2012). Determining virtual environment "fit": The relationship between navigation style in a virtual field trip, student self-reported desire to visit the field trip site in the real world, and the purposes of science education. *Journal of Science Education and Technology, 22,* 351–361. https://doi.org/10.1007/s10956-012-9398-4.

VR Education Holdings. (2019). Apollo 11 VR. Retrieved from https://immersivevreducation.com/apollo-11-vr/.

Rebecca Tilhou is Graduate Research Assistant and Doctoral Student of Curriculum and Instruction in Darden College of Education and Professional Studies, Old Dominion University, Virginia, USA. Her research interests involve alternative and innovative pedagogies and educational models with a focus on early childhood and elementary education.

Valerie Taylor is Graduate Research and Teaching Assistant in the doctoral program in Curriculum and Instruction in Darden College of Education and Professional Studies, Old Dominion University Virginia USA. Her research interests include digital and disciplinary literacy and the integration of educational technology and digital tools across content areas.

Helen Crompton (Ph.D.) is Associate Professor of Educational Technology at Old Dominion University. She holds a Ph.D. in Educational Technology and Mathematics Education. Her research is primarily focused on educational technology. She has presented at national and international conferences on the topic of educational technology and published over 100 articles, chapters, and white papers in this field.