TechTrends (2019) 63:463–469
https://doi.org/10.1007/s11528-019-00401-6

ORIGINAL PAPER

Learning to Teach with Virtual Reality: Lessons from One Elementary Teacher

Timothy Patterson [1] · Insook Han [1]

Published online: 2 May 2019

Abstract
In this article we make recommendations based on our qualitative inquiry into one elementary teacher's iterative processes of designing and implementing technology-enhanced instruction using virtual reality (VR). The use of VR has gained more attention from educational researchers and practitioners but evidence-based demonstrations of how teachers can use this emerging tool effectively in K-12 classroom settings is rare. Therefore, we provide reflections on our observations of and interviews with one teacher, providing a model for how teachers might integrate VR into their own curricula and use emerging technologies to enhance their teaching practices more generally. Some instructional design suggestions include needs assessment for students' prior exposure to VR, communication with parents, modification of existing lessons and selection of VR content to align with learning objectives, plan for alternative experiences as well as physical and technological setup.

Keywords Curriculum design · Elementary teaching · Google Expeditions · Virtual field trips

Introduction

Imagine an elementary teacher planning a series of lessons on the founding of the United States as part of their social studies curriculum. Connecting young children to the past is a challenging task; students will complain that the clothing and customs of several centuries ago feel distant to the point of irrelevancy. What can our teacher do to spark the students' interest and develop historical empathy in their students? Our elementary teacher knows there are a variety of museums and cultural institutes that focus on this particular topic. Museums have long been recognized as sites of productive K-12 learning, as the sights, sounds, images, and artifacts found in museums allow students to experience the past (Marcus et al. 2012). This type of learning would be difficult to replicate in the classroom.

Of course, field trips have logistical challenges that may dissuade or prevent teachers from taking their students out of the school building. Virtual reality (VR) is an increasingly accessible option for teachers who want their students to experience the content of places distant from their schools without leaving their classrooms (Freeman et al. 2017). Just as taking a group of students on a field trip is a daunting task, many teachers are intimidated by VR, especially when it is a novel tool for them as teachers specifically and consumers of technology more generally. Designing from scratch or enhancing one's lessons with any form of technology is a complex process, requiring a great deal of thought about content, context, students, and technology (Matuk et al. 2015). Unfortunately, teachers are unlikely to find meaningful professional development to support their planned-for use of emerging technologies (Liu 2013; Yang and Liu 2004).

In response to these concerns, we explored one teacher's introduction to VR and the changes displayed in his lesson planning and implementation as he grew more comfortable with VR through systematic self-reflection. We were especially interested in the process by which this teacher's knowledge, beliefs, and practices evolved during the iterative process of integrating VR over the course of multiple lessons. Rather than simply inserting a readymade technology lesson into his existing curriculum, this teacher took an active role as the designer of a technology-enhanced curriculum. Observing him in this role allowed us to document two phenomena: the step-by-step process by which VR can be integrated into a curriculum and the process by which teacher-as-

✉ Insook Han
insook.han@temple.edu

Timothy Patterson
tuf79684@temple.edu

[1] Department of Teaching and Learning, Temple University, Ritter Hall 439, 1301 Cecil B. Moore Avenue, Philadelphia, PA 19122, USA

designer lead to professional development for this teacher. In this article we offer reflections from our observations of and interviews with this teacher, providing a model for how other teachers might integrate VR (and other emerging technologies) into their own curricula.

Previous Lessons on VR in K-12 Settings

VR refers to "computer-generated environments that simulate the physical presence of people, objects, and realistic sensory experiences" (Freeman et al. 2017, p 46). With the educational potential of using VR, the 2017 Horizon Report identified virtual reality as one of the emerging technologies that will impact education in the very near future (Freeman et al. 2017). While VR might seem like a recent development, it has been around for some time and has been developed in various forms for educational purposes since the late 1990s with different names – virtual reality, virtual worlds, or virtual learning environments. Many earlier forms of VR used in K-12 and higher education settings were desktop-based virtual learning environments, and included games, simulations, and virtual worlds involving interactivity and 3-dimensional representations (Merchant et al. 2014). These various definitions of VR led to equally varied recommended educational uses, with research highlighting increased learning outcomes (Merchant et al. 2012; Song and Lee 2002; Yoo et al. 2018), learner satisfaction (Dickey 2005), and social interactions in virtual spaces (Ke and Im 2013).

More recent uses of VR include head-mounted devices that can maximize realistic and immersive experiences with 3D images. Furthermore, affordable devices and freely available educational VR content reduce previous concerns and limitations, such as high cost of VR devices (and subsequent maintenance) (Mantovani et al. 2003) and offensive content in virtual spaces (Dickey 2011). One example is Google Cardboard and Google Expeditions. Google launched Google Cardboard in 2015, and since then numerous free classroom-ready VR modules have been developed by NASA and National Geographic. Moreover, Google opened its first virtual field trips to the public in 2017 as a form of stand-alone application downloadable on mobile devices titled Google Expeditions. The application includes over 500 three-dimensional field trips that can be viewed on mobile phones attached to VR headsets as well as lesson plans that go with those field trip modules.

Unlike traditional forms of field trips that oftentimes have budgetary limitations (Lukes 2014), virtual field trips allow teachers to take their students to places far (different countries), in the past (places in history), or not reachable (other planets or the bottom of the ocean) (Morgan 2015). For example, teachers have designed social studies lessons using virtual field trips to allow students to visit historic places such as Ellis Island while learning about immigration, or the beaches of Normandy, France and the Holocaust Museum in Washington, DC for learning about World War II (Thompson 2018). Google Expeditions also provides a variety of VR modules that can be used in science, geography, arts, and many more.

While there is a growing interest in using virtual field trips in education, research-based understandings of the use of VR devices in K-12 classrooms is still immature. In response to this need, we offer a brief exposition on one elementary teacher's journey from novice to skilled-practitioner. We then provide principles teachers might follow when integrating emerging technologies into their own curricula. We conclude with a discussion of the obstacles and benefits of using VR in an elementary classroom based on our observations of this teacher's experiences.

Method

Context and Participants

In this single-case case study, we explored one elementary teacher's use of VR in teaching 4th graders in a private school in South Korea in summer 2017. The teacher, Mr. Park,[1] was a teacher with 28 elementary students (14 boys and 14 girls) and the head of the research department at his school. Mr. Park co-taught this group with a collaborating teacher. For this series of lessons, they opted to divide the class into two groups of 14 students with Mr. Park teaching a lesson on Korean literacy to one group and in a neighboring classroom his partner teaching a lesson to the other. The students then swapped and Mr. Park taught the same lesson to the other group of students. Therefore, Mr. Park taught the same daily lessons to two sections of 14 students consecutively. Since the focus of this study was an in-depth exploration of one teacher's growth during the design and implementation of VR lessons, we worked closely with Mr. Park throughout all phases of data collection.

For this study, we introduced Mr. Park to Google Expeditions, suggesting he incorporate it into his teaching. After the introduction, Mr. Park was mainly responsible for using VR headsets throughout this study and designing two units of VR lessons, one for social studies and one for Korean literacy, each of which was taught to two groups of 14 elementary students. During the process of designing the lessons, Mr. Park developed ideas for how to prepare devices, arrange a classroom setting, and design and support students' activities. After implementing each lesson, Mr. Park made revisions to his instruction based on his systemic reflections.

[1] All names are pseudonyms.

Data Collection and Analysis

Two rounds of design and implementation of VR lessons took about four weeks. During those four weeks, we collected qualitative data in the form of Mr. Park's written reflections, video recordings of his classroom teaching, field notes of observations, and follow-up interviews after each observation. Even though this study focused on the teacher's perspective, a bigger project involved participation of 28 elementary students in the Mr. Park's 4th grade classroom as a part of their regular class activity. Therefore, we received consent forms from both the teacher and his students. Since students were minors, consent forms were signed and returned by parents or legal guardians before any data was collected. The teacher was aware of parents' concerns about students' using cell phones at school. However, parents or legal guardians were clearly informed about the students' use of cell phones along with VR headsets only for learning activities during the class and affirmative in their support of this pedagogical initiative.

For initial planning, we communicated with Mr. Park via emails and in-person meetings and provided curricular resources for using VR in the classroom. After the initial planning, Mr. Park took the lead in designing and teaching the lesson while going through two cycles of planning and implementation. During each cycle, teaching practice was video recorded and field notes were documented. After each lesson, a semi-structured interview was conducted asking Mr. Park to reflect on his experience with the lesson and how he would revise his lesson for future teaching. Once all data was collected, we deductively coded the interviews and observations to generate themes related to Mr. Park's use of VR.

Learning to Teach with VR: One Teacher's Journey

The First Cycle: Researching and Implementing

When designing the initial lesson, Mr. Park spent most of his time gathering information and researching VR and its potential uses in his classroom. Since the use of VR was new to Mr. Park as well as students, he was first worried about informing parents, finding resources, and creating a structured sequence of activities that did not create chaos in using a novel tool in his classroom. He was also skeptical about the effectiveness of VR. Mr. Park began by informally evaluating his students' prior experiences with VR. As he expected, many students had either heard about VR or experienced it for entertainment in settings other than a classroom, but few regarded it as an educational tool. Based on this informal evaluation, Mr. Park decided to design a VR lesson that he hoped would provide immediate, meaningful learning experiences, as opposed to an introductory lesson to VR.

While researching prefabricated VR lessons, Mr. Park found that what was available to him did not completely align with the current curriculum and decided to re-design the materials rather than executing what was provided. For example, an upcoming topic in his social studies curriculum was city life in Korea. He searched for VR content but could not find VR content directly related to the lesson, nor did he anticipate that existing resources would engage his students. So, Mr. Park expanded the search to include cities around the world (e.g., Paris and New York) and modified his lesson topic to compare and contrast cities around the world with life in Korean cities. This choice was predicated on the decision to use existing VR content aligned with the curriculum topic and at the same time motivate his students through a compelling VR experience.

After consulting with us, Mr. Park decided to use a Xiaomi head-mounted display (HMD), one of the more affordable VR headsets available. This headset costs about $25 and is made with a more durable material than cardboard sets. Smartphones from 4.7 to 5.7 in. in size are inserted in front of HMD lenses (Fig. 1). The immersive experience provided by HMDs required Mr. Park design an environment that was responsive to the physical movements and reactions of students while using VR. Mr. Park found a multimedia room that was equipped with a flat TV screen, a reliable Wi-Fi connection, and movable desks and chairs. He then reorganized the classroom setting to accommodate students' movements during the VR experience. He also prepared three extra chairs in one corner of the classroom for students to rest if they felt uncomfortable (Fig. 2). In such a case, students were instructed to raise their hands and take off their headsets. Instead, they could watch the same scene via a TV that was connected to the teacher's device. While a few students felt minor dizziness, no student stopped to take a rest during the class.

During the design of his first VR lesson, Mr. Park developed a deeper understanding of VR's pedagogical potentials. Unguided or minimal guidance rarely results in positive educational outcomes (Kirschner et al. 2006), as students require careful scaffolds in order to understand what they are viewing in virtual spaces and explore VR modules without getting lost.

Fig. 1 Xiaomi head-mounted display

Fig. 2 14 students exploring VR in front of the classroom

Google Expeditions has two modes of exploration: 'Discover' where students can freely explore the module on their own and 'Guide/Join' where a teacher becomes a guide and walks through the virtual space with the students. In this 'Guide/Join' mode, a teacher selects the scene. Simultaneously students see an arrow pointing to the selected scene within the VR module so that they can follow the teacher's lead. Mr. Park applied guided discovery learning to maximize the purpose of VR experiences. As he planned this lesson, Mr. Park conducted a trial run of the guide mode, noting areas where the premade VR content deviated from the goals he created in developing this lesson. He thusly reorganized the sequence of experiences and discussion questions in order to maximize his students' potentials for engaging with desired content in the virtual world. Mr. Park moved between scenes from the VR module with guiding questions so that students could experience the same content within the same sequence.

Mr. Park's Growth Following the First Lesson

Instead of being a one-off experience for his students, Mr. Park decided he would more regularly incorporate VR into his classroom activities. His reflective process began almost immediately: while he taught this lesson Mr. Park continuously made note of the problems that emerged, such as a spotty Wi-Fi connection and battery shortages, and addressed them in planning his second lesson. Instead of having 14 students using VR simultaneously, Mr. Park decided to have seven students use VR at a time. He also set aside a couple of extra sets of devices to be swapped in for malfunctioning VR sets.

Fig. 3 Classroom Settings: Front (left) and Back (right)

He also reorganized the classroom to have ample open space in front of the classroom for seven students (see Fig. 3).

During the design of his second lesson, Mr. Park modified existing learning objectives and textbook readings to be more in-line with VR content. While developing a lesson plan for the topic "The Use of Information," he realized that the textbook only focused on traditional media, such as books, newspapers, internet, and television as information sources. However, Mr. Park developed his knowledge about VR during the design of this lesson and concluded that it can also bring new types of engagement with meaningful information. Thus, Mr. Park designed that particular week's lesson to teach his students both *about* and *with* VR, with a particular focus on how VR compares and contrasts with more traditional platforms for delivering information.

Further, the knowledge Mr. Park gained from his first lesson guided him in redesigning learning activities to better accommodate the constraints of technology and class time. From the first lesson, he realized that it took longer than he planned to set up devices and get them connected to Wi-Fi. So, instead of having a traditional 40 min-lesson, he created a 60 min-block lesson that could give him more time to prepare the equipment as well as cover the compare and contrast activities that he planned for students.

The Second Cycle: Taking Risks and Making Improvements

Mr. Park's second lesson, "The Use of Information," was designed for his Korean Literacy class. His central learning objective was for the students to "experience VR and discuss what information we learned from VR content." Mr. Park selected two VR modules from Google Expeditions: San Diego Zoo and Reef Sharks. Each group participated in one hour-long VR experience. At the beginning of the class, students linked their HMD to the school's Wi-Fi, connected to Mr. Park's HMD for his guided tour, and put their cellular phones into their HMD.

After placing ready-for-use devices on the designated spots on the floor, Mr. Park started the lesson by providing motivational prompts, presenting learning objectives, and a definition and usage of VR. Then, students learned about either an animal at the zoo or sharks in the ocean (depending on the as-

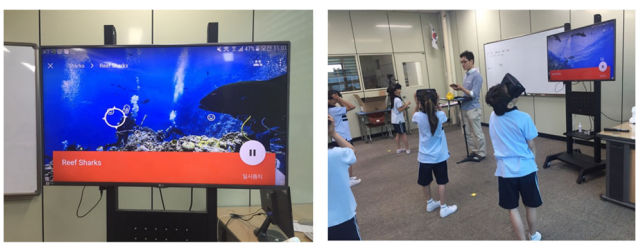

Fig. 4 VR Experiences: Teacher's Monitor (left) and Students with HMDs (right)

signment of their group). While the first group experienced the San Diego Zoo through VR with Mr. Park's guidance and scaffolds, the second group watched the same content through a TV screen while listening to Mr. Park's explanations. Next, the students swapped roles: the second group learned about reef sharks via VR (Fig. 4), while the first group watched the same content on a television screen.

After experiencing two presentations through both VR and a television screen, students completed an activity that required them to construct at least three questions for their counterparts who experienced the same content through a different medium. Once completed, the students paired up and interviewed each other. To conclude the lesson, Mr. Park asked students to write a reflection paper focusing on their overall experiences with VR and their opinion regarding the advantages and disadvantages of using VR in education.

Mr. Park's Growth Following the Second Lesson

At the conclusion of Mr. Park's second lesson, we were able to observe the ways in which the iterative process of designing a VR-infused lesson, teaching that lesson, reflecting on it, and developing a new lesson led to more sophisticated uses of an emerging technology. From a practical standpoint, Mr. Park was able to use the setbacks of the first lesson (primarily time and space constraints) to develop a second lesson that allowed his students to more effectively utilize VR. From a pedagogical standpoint, the question-and-answer strategy assisted the students in reflecting on their own learning and making deeper meanings out of the implications of consuming media through a television as opposed to VR.

In addition to the students' motivational outcomes in the first implementation, Mr. Park also observed cognitive outcomes in students in their acknowledgment of the differences in information delivered by two media. By recognizing students' cognitive outcomes, Mr. Park concluded that the use of VR could not only engage students in learning but also alter the experiences to a greater extent when they were well aligned with his purpose for instruction. More generally, assuming the role of teacher-as-designer allowed Mr. Park to become more proficient with an emerging technology but importantly has encouraged him in taking risks, reflecting on his lesson planning, and adopting unfamiliar tools.

Lessons Learned

Through the implementation of VR in his teaching, Mr. Park noted several opportunities, benefits, and challenges of using VR in the classroom (Table 1). High cost and usability concerns have been factors limiting the of VR in educational spaces (Mantovani 2001). Mr. Park shared those concerns when contemplating using VR in his classroom, but found them eased throughout the process as relatively affordable and easy-to-use VR devices as well as free educational VR content were available to him. Overall, the device was very easy for the elementary students to use and no costs other than VR devices were included in the lesson. However, Mr. Park still perceived technical problems as significant challenges. Students brought their personal devices to use in the classroom after installing the application at home but there were still some issues caused by unique settings across devices as well as an unreliable Wi-Fi connection. Since HMDs produce more motion sickness than desktop-based VR (Sharples et al. 2008), a small number of students felt discomfort during VR experiences. Even though the increased fidelity of modern devices reduces the level of such symptoms, teachers should be aware of students' reactions to VR. Some teachers might opt to minimize these reactions by limiting the time of exploration or having students stay seated while in the virtual world.

While navigating through the opportunities and challenges, Mr. Park designed and implemented VR-infused lessons by modifying existing lessons and accommodating emerging needs of students. There are lessons for teachers interested in using VR in their classrooms based on instructional decisions Mr. Park made during that process. VR can be easily used in

Table 1 Opportunities, challenges, instructional design suggestions, and benefits for VR lessons

Opportunities	Affordable VR headsets
	Free educational VR content
Challenges	Technical problems (e.g., cell phone battery, unreliable Wi-Fi connection)
	Motion sickness
Instructional design suggestions	Needs assessment for students' prior exposures to VR
	Communication with parents and students for setting the expectation of VR lessons
	Modification of existing lessons to align learning objectives with VR content
	Trial run for selecting VR scenes for guided discovery learning
	Plan for alternatives for students feeling motion sickness and technological malfunctions
	Preparation of physical and technological setup
Benefits	Increased students' engagement
	Overcoming the limitation of time, space and budget

most classrooms, but it is new to teachers, parents, and possibly students. Therefore, teachers should conduct an informal needs assessment to gauge students' prior experiences with VR. As many students may already use VR for entertainment, teachers need to introduce VR as a learning tool and explain the purpose of VR lessons to students. Also, teachers should actively communicate with parents before attaining informed consent to alleviate potential concerns about students' use of cell phones during class. In terms of lesson design, Mr. Park viewed free educational content as an opportunity but also acknowledged some modifications were necessary to align the premade content with his learning objectives. Teachers should not only modify existing lessons but also select scenes within VR modules to use for guided discovery learning. The use of VR also involves the rearrangement of the physical setup of the classroom and an evaluation of available technology. In particular, Mr. Park found that mirroring his device on a TV screen in front of the classroom helped him prepare for technological malfunctions and the potential for students to feel discomfort.

Mr. Park also perceived two broad benefits of using VR. One major benefit is an increase in students' engagement by providing immersive learning experiences with HMDs. Mr. Park noticed that compared with a TV, HMDs created a higher level of engagement and immersion among students. He is not alone in noticing this increased engagement, as other researchers have found that the use of immersive VR displays increases the feeling of virtual presence when compared to low immersion displays (Kwon et al. 2018; Makransky and Lilleholt 2018; Makransky et al. 2017). Also, the use of VR content can overcome the limitations of time and place without the burdensome budget of field trips (Lukes 2014) and Mr. Park and his students were particularly excited about the opportunity to explore the ocean and cities in different countries.

Conclusion

Though Mr. Park had always embraced experimentation and innovation in his classroom, taking on the role of teacher-as-designer was elemental in the development of his technological pedagogical content knowledge (Koehler and Mishra 2009). Mr. Park's experiences largely comport with other research that suggests technology is most effectively integrated into the curriculum when teachers are involved in a collaborative process of designing new lessons (Cviko et al. 2014). Mr. Park's research on VR, lesson designs, and reflections was done in part while collaborating with us. We were able to observe a seamless congruence between Mr. Park's pedagogical goals for his students and his use of VR in his lesson. His role as co-designer gave him a sense of ownership and encouraged the sustained implementation of VR-infused lessons. This contrasts with the more common approach of novice teachers' integrating readymade technology-based lessons into the existing curriculum (Grossman and Thompson 2008).

With this advice in mind, we return to our hypothetical elementary teacher. Having decided that a visit to the Museum of the American Revolution in Philadelphia is not a plausible option for their students, this teacher explores the possibility of using Google Cardboard and one of the many Google Expeditions on the American Revolution. Our research leads us to recommend this teacher seek out other colleagues with whom they can collaborate when redesigning their curricula. We also recommend this teacher customize the experience based on stated learning goals, rather than dropping a readymade Google Expedition into their existing curriculum. Finally, and most importantly, this teacher will want to reflect on the planning and implementation of this lesson and make VR and more regular occurrence across the content areas. As we have found, when supported by systematic reflection repeated uses of emerging technologies hold the potential to not only further engage students in powerful learning, but also impact the way teachers thinking of their own planning and instruction.

Funding This study was funded by the Office of the Provost, Temple University (2017 Summer Research Award).

Compliance with Ethical Standards

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Conflict of Interest Timothy Patterson declares that he has no conflict of interest. Insook Han declares that she has no conflict of interest.

References

Cviko, A., McKenney, S., & Voogt, J. (2014). Teacher roles in designing technology-rich learning activities for early literacy: A cross-case analysis. *Computers & Education, 72*, 68–79.

Dickey, M. D. (2005). Three-dimensional virtual worlds and distance learning: two case studies of Active Worlds as a medium for distance education. *British Journal of Educational Technology, 36*(3), 439–451.

Dickey, M. D. (2011). The pragmatics of virtual worlds for K-12 educators: Investigating the affordances and constraints of active worlds and second life with K-12 in-service teachers. *Educational Technology Research and Development, 59*(1), 1–20.

Freeman, A., Adams Becker, S., Cummins, M., Davis, A., & Hall Giesinger, C. (2017). *NMC/CoSN Horizon Report: 2017 K–12 Edition*. Austin: The New Media Consortium.

Grossman, P., & Thompson, C. (2008). Learning from curriculum materials: Scaffolds for new teachers? *Teaching and Teacher Education, 24*(8), 2014–2026.

Ke, F., & Im, T. (2013). Virtual-reality-based social interaction training for children with high-functioning autism. *The Journal of Educational Research, 106*(6), 441–461.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75–86.

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education, 9*(1), 60–70.

Kwon, S.-H., Lee, Y.-J., Choi, S.-Y., & Kwon, Y.-J. (2018). Analysis of components affecting learners in utilization of life science VR contents. *Journal of Learner-Centered Curriculum and Instruction, 18*(6), 585–605.

Liu, S. H. (2013). Teacher professional development for technology integration in a primary school learning community. *Technology, Pedagogy and Education, 22*(1), 37–54.

Lukes, L. (2014). A new take on the field trip. *Science Teacher, 81*(1), 24–29.

Makransky, G., & Lilleholt, L. (2018). A structural equation modeling investigation of the emotional value of immersive virtual reality in education. *Educational Technology Research and Development*, 1–24.

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2017). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. Online first, *Learning and Instruction*.

Mantovani, F. (2001). VR learning: Potential and challenges for the use of 3D environments in education and training. In G. Riva & C. Galimberti (Eds.), *Towards CyberPsychology: Mind, cognitions and Society in the Internet age* (pp. 207–225). Amsterdam: IOS Press.

Mantovani, F., Castelnuovo, G., Gaggioli, A., & Riva, G. (2003). Virtual reality training for health-care professionals. *Cyberpsychology & Behavior, 6*(4), 389–395.

Marcus, A., Stoddard, J. D., & Wooward, W. W. (2012). *Teaching history with museums: Strategies for K-12 social studies*. New York: Routledge.

Matuk, C. F., Linn, M. C., & Eylon, B. S. (2015). Technology to support teachers using evidence from student work to customize technology-enhanced inquiry units. *Instructional Science, 43*(2), 229–257.

Merchant, Z., Goetz, E. T., Keeney-Kennicutt, W., Kwok, O. M., Cifuentes, L., & Davis, T. J. (2012). The learner characteristics, features of desktop 3D virtual reality environments, and college chemistry instruction: A structural equation modeling analysis. *Computers & Education, 59*(2), 551–568.

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education, 70*, 29–40.

Morgan, H. (2015). Focus on technology: Virtual field trips: Going on a journey to learn without leaving school. *Childhood Education, 91*(3), 220–222.

Sharples, S., Cobb, S., Moody, A., & Wilson, J. R. (2008). Virtual reality induced symptoms and effects (VRISE): Comparison of head mounted display (HMD), desktop and projection display systems. *Displays, 29*(2), 58–69.

Song, K. S., & Lee, W. Y. (2002). A virtual reality application for geometry classes. *Journal of Computer Assisted Learning, 18*(2), 149–156.

Thompson, M. (2018). Making virtual reality a reality in Today's classrooms. *THE Journal*. Retrieved on May 17, 2018 from https://thejournal.com/Articles/2018/01/11/Making-Virtual-Reality-a-Reality-in-Todays-Classrooms.aspx?Page=1. Accessed 15 July 2018.

Yang, S. C., & Liu, S. F. (2004). Case study of online workshop for the professional development of teachers. *Computers in Human Behavior, 20*(6), 733–761.

Yoo, M., Kim, J., Koo, Y., & Song, J. H. (2018). A meta-analysis on effects of VR, AR, MR-based learning in Korea. *The Journal of Educational Information and Media, 24*(3), 459–488.