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ORIGINAL PAPER

Approaches to Integrate Virtual Reality into K-16 Lesson Plans: an Introduction for Teachers

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Abstract
This discourse presents TPACK as a conceptual framework for thinking about the integration of Virtual Reality into the classroom. This content introduces the concept of immersion, explores of the possibilities of VR technology, including the hardware, software, and potential classroom uses. This review also provides heuristics for deciding VR's fit with the learning objectives. Readers also will learn processes for finding resources, overcoming challenges, and addressing tradeoffs to K16 teachers implementing VR. The methodological approach provides a guide to practitioners for supporting both course learning objectives and student engagement. The TPACK framework, considerations of levels of immersion afforded by different hardware, and access to technology frame the planning and analysis of integration of VR technology. The article closes with content to introduce practitioners and administrators to the range of virtual reality (VR) technology and facilitate decisions on integration of VR into classrooms in order to improve the technological competency of K16 teachers and empower them to integrate VR content into their classrooms effectively.

Keywords TPACK · Immersive technology · VR · XR · Virtuality continuum · Implementation

While Virtual Reality (VR) has become an area of mass mainstream interest in the last several years, due to the consumer release of the Oculus Rift Virtual Reality Head Mounted Display, VR is not a new concept. Although many current VR enthusiasts still consider Virtual Reality a technology for games and recreation, some of the earliest uses for VR were for training and education (Seymour et al. 2002; Fast et al. 2004; Zyda 2005). Now that virtual reality has become a popular technology trend, many companies have rejoined the bandwagon, adopting quick and inexpensive implementations of the technology. As a technological tool, virtual reality experiences are limited by access, hardware, and design. This discourse is intended to provide a conceptual framework for thinking about implementing immersive technology in the classroom. In addition to synthesizing research based instructional design models, the article explores the possibilities of virtual reality technology, including the hardware, software, potential classroom uses, and the process for finding significant resources, challenges, strategies, and tradeoffs to K16 teachers.

Virtual Reality experiences have the power to transform a classroom through increased engagement, recall, and learning outcomes (Dede 2009). Experts in the field (Segovia and Bailenson 2009; Dede 2009; Lindgren and Moshell 2011) have led much of the research that demonstrates these positive outcomes of VR for learning and behavior change. Additionally, more recent studies are supporting previous researcher's early findings by presenting further supporting evidence for improved learning outcomes (Durbin 2016; Weng et al. 2019). The potential of widespread adoption and generalizability of these positive outcomes may manifest over time.

The purpose of this paper is to support the technological competency of K16 teachers and empower them to integrate VR content into their classrooms effectively. In addition to the numerous VR hardware options, there is a great deal of software content (VR experiences) available in the VR ecosphere,

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which can leave educators with a great deal of searching in order to find potentially useful and relevant experiences. Since each VR product has different features, we are specifically highlighting a few of the most popular in the marketplace. As of a search on April 24, 2020, there were 5776 VR titles available on the Steam digital distribution platform developed by Valve Corporation, the makers of one of the leading VR platforms, the HTC Vive. Of these, less than 200 were listed as educational.

Similarly, there are thousands of experiences available across Oculus devices (Oculus Rift, Samsung Gear – Powered by Oculus, and Oculus Go) and the standalone VR headset, Oculus Go, launched with over 1000 experiences during the year of this publication (2020). Likewise, Google Play Store offers hundreds of Google Cardboard Experiences in addition to the hundreds of more immersive and interactive Google Daydream experiences. Finally, Google's Expeditions ecosystem is used to power several virtual fieldtrips that are integrated by users from The Smithsonian Magazine to Houghton Mifflin Harcourt. As of May 14, 2020, Google Expeditions, hosts 988 educational VR experiences on their list of available interactivities. To avoid a kind of analysis paralysis, this article explains the key elements of VR in terms of access to hardware, affordances of VR, cost, and effective approaches to implementing VR in the classroom.

What Is Virtual Reality

Virtual Reality (VR) technology has evolved a great deal from the 1960s when Morton Helig's Sensorama prototype and Ivan Sutherland's Sword of Damocles afforded immersion into virtual experiences that replaced the physical world, but required prohibitively expensive hardware that could not be easily transported. Consumers can now experience VR's increasing levels of immersion through portable and evermore affordable technology. Like the hardware, the use of the term Virtual Reality has seen many iterations. While most VR developers refer to experiences in which an individual interacts with a three-dimensional virtual space as VR, some related technology has also been referred to as VR. Researchers often expand Virtual Reality to include 3-dimensional (3D) virtual spaces, even when displayed on flat screen (Modjeska and Chignell 2003). In contrast, 360-degree video provides a sort of immersive experience that allows a user to see a space displayed in 360 degrees around them, similar to a panoramic. While it allows users to turn their head to explore a space in the 360 degrees around them, it does not allow the user to interact with the environment. Although 360 videos are not authentic Virtual Reality, they are often included in the discussion of VR, as they are more easily accessible. In contrast, the highest level of immersion currently available to VR consumers includes users viewing in 360 degrees around them in addition to being able to move around the space freely while interacting with objects in the space. Some of the most highly immersive VR tools even use devices to simulate touch, taste, and smell.

Virtuality Continuum

These varying definitions of Virtual Reality led Milgram and Kishino (1994) to establish a "Virtuality Continuum" (Fig. 1) that distinguishes levels of reality. Their continuum shows a progression from "real environment" to virtual environments. This continuum refers to a three-dimensional experience representing a virtual world on a flat screen as mixed reality, as one is essentially experiencing the real world and virtual world simultaneously. Augmented Reality and Mixed Reality allow the user to engage with virtual objects or entities while still viewing their own physical surroundings by overlaying virtual objects over physical objects.

Levels of Immersion in Learning

In addition to Milgram's continuum of virtuality, it is important to consider the levels of immersion afforded by different implementations of VR. In highly immersive virtual reality, the user wears a head mounted display that closes out the view of the physical environment and replaces it with the sights and sounds of a virtual space. Highly immersive, interactive experiences also integrate controllers that allow users to interact with objects in a virtual space. Some of these highly immersive experiences also include devices to stimulate the user's sense of touch and movement. The most immersive types of virtual reality provide users more than a simple representation of functional knowledge; they provide users with an experience. In some cases, children who have had experiences in virtual reality were later unable to distinguish those experiences from memory (Segovia and Bailenson 2009). Segovia and Bailenson (2009) found that students between four and seven years of age, could not distinguish real memories of visiting Sea World, from a visit using Immersive Virtual Environment technology. This ability to create memories speaks to the powerful nature of immersive tools for education, such as virtual field trips and virtual practice.

John Dewey detailed the concept of providing experiences for deeper learning and transfer of that learning in his 1938 book, *Experience and Education*. The concepts that Dewey uses to describe the approach to constructing learning experiences can be applied to the development of virtual learning experiences (Aiello et al. 2012). Educators can simulate experiential learning opportunities for students in VR, without leaving the classroom (Herrera et al. 2018). Because consumer level VR is a newer development, a great deal of the existing research in virtual learning is actually based in what Milgram

Fig. 1 Note: This data is mandatory. Please provide.

would call Mixed Reality, as it exists in primarily flat screen displays (Dede et al. 1996; Hayes et al. 2013). However, early studies are beginning to emerge around head-mounted displays and their impact on immersion and information recall (Krokos et al. 2019). The technology used to deliver these experiences exists along a spectrum as well. The hardware ranges in costs from $10 US to $500 in addition to a powerful computer. The levels of immersion afforded by more immersive experiences are known to contribute to varied outcomes. This discourse will review available hardware in terms of costs, affordances, and access to content.

Challenges to Implementation, Strategies, and Tradeoffs

While there are many established and projected benefits to student learning and engagement afforded by VR, there are limitations to implementation. From cost and available infrastructure (internet access, power, number of devices) to classroom management and finding appropriate experiences, educators have new considerations when integrating VR in lessons. Whereas practitioners should not arbitrarily integrate VR into their coursework, instead they can systematically consider how VR applications can enhance their curriculum and lessons, then follow with an evaluation of success in consideration of further use. Various frameworks exist and can be utilized for instructional design when integrating VR resources, including the TPACK model and the ASSURE model.

Based on research, Pantelidis (2010) designed a 10-step model to help educators determine when to implement VR into learning. The TPACK model, as shown in the following section, can be applied effectively to guide implementation of VR tools within a district, school, or classroom. Using a modified version of Pantelidis's model with TPACK to guide how implementation should look can help educators begin to develop impactful learning experiences with available technology.

TPACK (Technological Pedagogical Content Knowledge)

The Technological Pedagogical Content Knowledge (TPACK) framework recommends that technological implementation in the classroom include the technological knowledge (TK) being considered, the pedagogical knowledge (PK) the teacher implements, and the content knowledge (CK) of the material being delivered (Koehler and Mishra 2009). While the teacher may have a great deal of Pedagogical Content Knowledge (PCK) the integration of VR will require new considerations around the Technological Content Knowledge (TCK), that is, what content will the teacher use? Where will they find the content? Further, the implementation of VR may challenge the teachers Technological Pedagogical Knowledge (TPK). The teacher will need to decide what areas of the course objectives implementing immersive technology will serve most effectively.

In terms of the TPK, there are hundreds of new immersive VR experiences available on every platform discussed in this paper. Some heuristics (rules of thumb) for deciding whether VR will enhance K12 lessons:

1. VR is useful to provide experiences that could not be done easily, safely, or inexpensively with other tools;

- E.g. exploring human anatomy (Jang et al. 2017).

2. VR is useful to experiences enhanced by three dimensionalities;

- E.g. physics lessons or geometry (Lindgren and Moshell 2011).

3. VR is useful in transporting students to new places;

- E.g. Virtual Field Trips to space, another city, a historical landmark (Spicer and Stratford 2001; Tuthill and Klemm 2002).

4. VR is useful in allowing users to experience the world through another's perspective or to let a student walk in someone else's shoes (Maister et al. 2015);

- E.g. learning what it is like to be homeless or a refuge (Herrera et al. 2018).

5. VR is effective in allowing learners to practice physical tasks in a simulated environment;

- E.g. performing surgery (i.e. Ahlberg et al. 2002), learning plays in football (i.e. Huang et al. 2015).

6. VR is useful if a goal is to increase motivation, interest, and engagement.

- E.g. Learning Science principles (Parong and Mayer 2018; Hayes et al. 2013).

Figure 2 frames the heuristics above as questions one should ask as they make choices about the tradeoffs faced when integrating VR into the classroom.

Classroom Management

Adding VR to a classroom has many potential benefits, when done with purpose, but adding VR to a classroom also adds new classroom flow and classroom management considerations. Because many virtual experiences are directed simulations of real-world phenomena, students can have memorable experience that they can apply to course content in very short periods. Many individual experiences in virtual reality can be completed between 3 and 5 min. One best practice for integrating VR in a classroom is the use of learning stations or centers. This implementation would have students in a 50-min class rotate between 4 and 5 stations, in which only one station has VR equipment (Kassner 2000). Because the teacher may not want to or be able to keep the students engaged with the technology for an entire lesson period, the alternate learning stations can keep students engaged with the content in multiple ways.

Some effective learning stations may include writing about the experience, drawing the experience, reading similar content, researching the content, or even designing test questions for peers around the content. The use of learning stations can reduce the number of distractions created in the classroom and address limitations due to access of the technology. Other teachers have found it effective to use the immersive media experience as a reward for students when they complete their work (Davies 2020). It is generally effective to have a timer to limit the amount of time students spend in an experience, as some students may not leave the immersive environment freely in a time-frame that provides needed experience and allows other's similar experiences.

TPACK and ASSURE both suggest an integration strategy for the VR in the classroom of tying course learning outcomes with the integrated VR experiences. One example of this strategy is to determine the course learning outcomes and integrate them into the design of the virtual experience. An example of tying learning outcomes to the technology applied would be in a class intending to learn the planets in the solar system, as there are several virtual solar system experiences across platforms. The teacher will have to decide what the goal is for the student's experience. Teachers should keep the heuristics for integrating VR in mind and be sure that the implementation is meeting the expectation.

A teacher trying to teach the relationship between planets in the solar system can exemplify this integration using TPACK. The teacher would consider their content knowledge and pedagogy and then work to discover technology related to the lesson objective. The theoretical teacher identifies engagement and experience of the natural phenomena of the planets in space in three dimensions. The Merge VR, Samsung Gear, Oculus, and Vive all provide a solar system virtual experience. The example teacher must decide which device is most effective for engagement. After reading reviews of the different experiences, the teacher chooses the Oculus Go Experience, because it is the lowest cost with high ratings that refer to the quality of interaction with the planets. This meets the example teacher's goals. Ideally, this sample teacher, and all teachers who endeavor this kind of integration, will then reflect on the

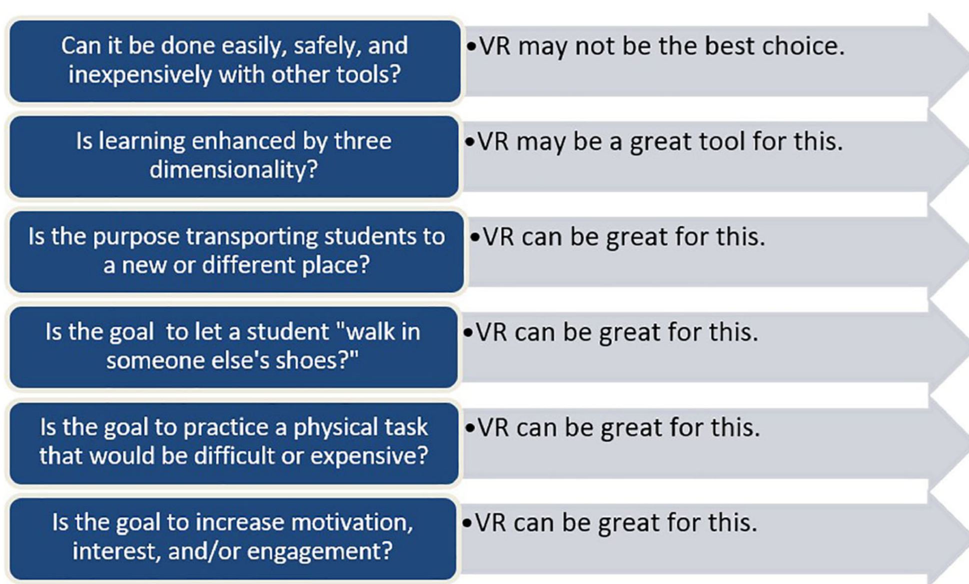

Fig. 2 Note: This data is mandatory. Please provide

session to determine if the interaction provided the students the intended experience. If the process does not yield the intended outcome, the teacher may change the delivery of the content, the classroom management, or even the technology.

Immersive Technology Hardware

There is a great deal of consumer VR hardware on the market. This section provides insight into the cost and benefit of each of the leading VR devices available in 2019. This analysis will help teachers determine what would be appropriate and affordable for their class and learning goals. Further, educators and stakeholders can use this information to justify grant funding for procurement of additional technology. While the Oculus Rift and the HTC Vive are considered the most immersive consumer VR (Te 2015), they are financially prohibitive for most school districts. This section reviews a range of options to empower educators to make decisions about the tradeoffs, this is not an exhaustive list, but clarifies the differences between many of the market leaders.

Google Products

Ranging from Google Cardboard to Google Expeditions and Google Daydream, Google has a variety of VR tools available to educators. Google cardboard is a simple cardboard headset that affords experiences through 360-degree videos displayed by a smart phone. Google Expeditions allows a teacher to guide student "explorers" through 360-degree videos and 3D images. Google Expeditions also addresses safety by allowing teachers to limit student access to the internet through connection with a centralized router. 360-degree videos are displayed in VR headsets that, purchased in classroom sets or Google Expeditions' videos, can be viewed in the less immersive format of desktop computer, laptop, or tablet, as resources demand. The cost of these Google products ranges from $10 US for Google Cardboard in addition to the cost of the smartphone used to $100 US for the Google Daydream, in addition to the cost of the phone. While the Google Expeditions experiences can be free, if the teacher uses existing tablets or computers in their classroom and does not engage with the VR aspects, The Expeditions classroom kits ranges from $1500 US.

Merge VR/AR

MERGE is a VR viewer system that adds to the aesthetic and the affordances of the Google Cardboard VR viewer. This product is marketed to users 10+, referencing its' colorful, drop-resistant characteristics. The most noteworthy quality of the Merge is the mixed reality nature of the experiences. MERGE experiences integrate an interactive holographic cube (the Holo-cube) that users can see in the Augmented Reality mode. While users can use the MERGE headset to interact with any Google Cardboard experience, they can also use the integrated Holo-cube to experience low-cost mixed reality. Existing at multiple points in the virtuality continuum, the Merge affords 360 experiences and more immersive interactive experiences. The cost of the Merge VR headset is $30 US in addition to the cost of the smartphone used ($200 US+).

Samsung Gear

Samsung Gear uses a Samsung smart phone to power VR experiences from 360-degree videos to slightly interactive experiences in which users can use a controller on the side of the headset to interact with the environment. The price range for this headset is $150 US in addition to the cost of the Samsung Galaxy S6, S7, or S8 (generally available for about $200 US).

Oculus Products (Rift, Go, Quest)

Oculus was the first company to demonstrate that VR was ready for the consumer market. The Oculus Rift allows users to experience high-definition virtual spaces, autonomously control movement, and interact with objects and other people in virtual space. Because the Oculus tracks the position of a user's hands and head, a user can also see himself/herself as an avatar or as a set of hands that show their movement within the context of some experiences. Users can also experience 360-degree videos. While the Oculus affords high quality, highly immersive interactive experiences, the cost is prohibitive. The Oculus Rift headset cost is $399 US in addition to a high-end computer costing upwards of $1000 US. Aside from cost, another restriction that accompanies the Oculus is that the headset must be connected to the computer by wires, which can be a tripping hazard in a classroom.

The Oculus Go is a standalone wireless VR headset that requires no other hardware and provides 360-degree video experiences like those in the Samsung Gear. These are modestly immersive experiences available for this headset, but none are interactive to the level of the Oculus Rift experiences. However, this headset is $199 US, and it does not require a computer or cellular phone.

The Oculus Quest is the newest prototyped Rift product that researcher's laud as a "game-changer" as it is immersive standalone and wireless VR with controllers that allow the user to interact with virtual space and virtual objects, but without requiring a computer. The cost of this Oculus Quest is $399 US, and it does not require a computer. The Oculus Quest also does not require any wires during use, which means no tripping hazards.

HTC Vive Products (HTC Vive, HTC Vive pro)

HTC Vive allows users to experience high-definition virtual spaces, autonomously control movement, and interact with objects and other people in virtual space. The Vive also affords users to move in an environment by tracking their physical movement and translating that to movement in the virtual space. Because the Vive uses room scale tracking, a user can also see himself/herself as an avatar or as a set of hands that show their movement in some experiences. The Vive connects to a computer by wires, which can be a tripping hazard, but there are wireless adapters available at an additional fee. Users can also experience 360-degree videos in the space. The cost of the Vive headset is $499 US in addition to a high-end computer costing upwards of $1000 US.

HTV Vive Pro provides all the features of the Vive, increased resolution, improved audio, improved comfort, and is a wireless headset, which solves some of the safety and comfort limitations that exist. The Vive Pro also connects to a computer by wires, which can be a tripping hazard, but there are wireless adapters available at an additional fee. The other features increase the potential to connect users in virtual spaces and increase immersion. The cost of the Vive Pro HMD system is $1098 US in addition to a high-end computer costing upwards of $1000 US.

Finding Educational VR Content

There are platforms through which teachers can download and install the virtual experiences. Each of the platforms, described below, have a search function. Users can search for content specific to the course objectives. For instance, there are experiences that come up for free when the search term is "solar system." The platforms also allow user reviews, so before teachers download or install any new experience, they can look over the reviews and star rating of the average user to get an idea of what to expect.

Content for Google Products

Finding educational content for Google VR products starts with the Google Play Store. While one may choose to use an Apple phone in Google Cardboard, the Google Cardboard is designed for Android devices. Likewise, there are more VR experiences available through the Google Play store on Android devices than there are on the Apple App Store. Of course, as Google created the Android Operating system, it would be most prudent to use Android (Google) devices with the Google VR products. Like Cardboard, Expeditions by Google provides experiences for both devices but is packaged as kits specifically for K12 education. The entire resource list for Google Expeditions is available on their website and packaged in a spreadsheet providing further information about each experience. As with all products, developers are regularly designing new experiences for Google's platform.

Content for Merge VR/AR

Searching for content for MERGE VR is as simple as searching the app store on the cellular device that will be used in the headset. Merge VR also provides an educator's portal app through which educators can search for apps. Some of the applications are free, while others range from $.99 to $9.99. While Merge VR supports both Apple and Android devices, there are more virtual experiences for Merge VR for Android devices. As with all these platforms, developers are regularly developing new experiences for this platform. MERGE VR has experiences that range from STEM and the humanities, including Space Systems, Underwater, National Parks, and proctored 360 degree Youtube videos.

Content for Samsung Gear and Oculus Products

Samsung Gear and other Oculus products use the Oculus store. The Oculus store has many free experiences. There are also hundreds of educational experiences, including Google Earth and NASA's Explorations to Anne Frank House VR and The Body VR. Users download experiences directly to the Oculus Quest and Oculus Go. Samsung Gear users download through the Oculus app on the Galaxy device. Moreover, Oculus rift users download to the high-end computer to which they connect their device. As with all these platforms, developers are regularly developing new experiences for this platform.

Content for HTC VIVE Products (HTC VIVE, HTC VIVE PRO)

HTC Vive users find content on the Steam Store, an app that must be installed on the computer to which the device is connected. As of a search on April 27, 2020, there were 5776 VR titles available on Steam. While the majority of immersive content available to consumers is recreational, many titles are geared toward education across disciplines from STEM to the humanities. A number of these titles are also free of charge (e.g. In Cell VR, Google Earth, the Anne Frank House, and Becoming Homeless).

Physical Distancing, Access, and Sharing Devices

Regarding cost, some less immersive, but still engaging Virtual and Mixed Reality experiences can be a good way to experiment with the medium in the classroom. Similarly, once the teacher has the VR equipment, they can download many experiences free of charge. Internet connectivity is another consideration for implementing VR solutions. Depending on connectivity and policies at the school or at student's homes, practitioners may need to verify that implemented VR applications are useable without internet access.

The face of education has been ever-changed by the COVID19 global pandemic. Educators, administrators, and parents all have new considerations regarding sharing equipment, sanitation of shared devices, and social distancing. Museums and other field trip experiences are closed and remain cautious about when or if people will be able to interact in the ways they have in the past. In one sense, VR provides perfect opportunities for shared experiences without sharing space, which could replace some cancelled or cost prohibitive real-world field trips. Ideally, students can enter virtual spaces and interact with one another from home or from a classroom. Of course, the cost of most VR equipment is still prohibitively expensive for many individuals and classrooms.

This barrier to access could be addressed by students sharing equipment. Likewise, students could engage through the lower fidelity, but less expensive Google cardboard. If students share equipment, the equipment will have to be sanitized between users.

Implications for Future Research and Practice

While there are many implementations of virtual, mixed and augmented realities in classrooms and around the world (Won et al. 2020; Fauville et al. 2020; Liou and Chang 2018), there is a lack of consistency in the administration and integration of immersive media. Some approaches formally integrate immersive media into the curriculum (Sissons and Cochrane 2019), while others use it as a supplemental tool (Hayes et al. 2013). Similarly, there are inconsistent approaches to evaluating the technology tools available, as well as to evaluating their integration into learning (da Silva et al. 2019). While many studies focus on knowledge retention, the usability of the experiences, and behavior or motivation, they differ in contexts (Southgate et al. 2019). These inconsistencies warrant evaluation since implementations and efficacy of immersive tools are difficult to generalize. Additionally, application of the TPACK framework with considerations of the instructor's technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) of the material being delivered, can create common ground for evaluating and planning the implementations of immersive technologies. These considerations can mitigate for contextual differences when planning implementation and evaluation of immersive tools into K-16 lessons. Additionally, as COVID19 and its educational impact continue to play a role in the transformation of learning environments, the significance of VR and its ability to yield shared experiences in a virtual world should be considered. As VR advances and costs for implementation lessen, the implications and resources for classroom learning will continue to expand as new opportunities for research emerge.

Conclusion

The process of integrating VR into the classroom seems to be more an art than a science, but the conceptual framework presented here provides clarity to the process. While this discourse identifies key considerations to the process, each classroom, teacher, set of objectives is unique. The key to success in this area is being consistently aware of learning objectives, student needs, and resources as they emerge. Growth of this young industry will make it easier for K16 teachers to find significant resources, address challenges, and apply strategies to optimize any investment of time or money into integrating VR in the classroom.

Experts have done a great deal of research that demonstrates the efficacy of VR in the classroom, but the generalizability of these positive outcomes can only be shown through the integrations done by K16 educators. It is critical that the teachers begin with the end in mind when planning to integrate virtual reality experiences to their classes. Not only should they be intentional with the choices of whether they are Substituting, Augmenting, Modifying, or Redefining content, they should also keep in mind their own Pedagogical, Technological, and Content Knowledge as they iterate on curriculum. If practitioners and researchers are not mindful in planning, the technology integration may not meet the intended outcomes. Practitioners must be willing to revise or even abandon a tool that is not working. It is important to remember the goal of integrating VR into the classroom should be to engage students and improve learning outcomes; the technology is a tool, not a panacea.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethics Approval No study was conducted, and no ethics approval was needed for this review of literature.

Informed Consent No participants were used in this study so no informed consent has been provided.

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