Augmented Reality Applications in Education

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ABSTRACT

Technology is ever changing and ever growing. One of the newest developing technologies is augmented reality (AR), which can be applied to many different existing technologies, such as: computers, tablets, and smartphones. AR technology can also be utilized through wearable components, for example, glasses. Throughout this literature review on AR the following aspects are discussed at length: research explored, theoretical foundations, applications in education, challenges, reactions, and implications. Several different types of AR devices and applications are discussed at length, and an in-depth analysis is done on several studies that have implemented AR technology in an educational setting. This review focuses on how AR technology can be applied, the issues surrounding the use of this technology, viewpoints of those who have worked with AR applications; it also identifies multiple areas to be explored in future research.

Keywords: augmented reality, science education, self-determination theory, flow theory, situated learning theory, just-in-time learning, constructivism

INTRODUCTION

In today's society, technology has become a crucial part of our lives. It has changed how people think and apply knowledge. One of the newest developing technologies is augmented reality (AR), which can be applied to computers, tablets, and smartphones. AR affords the ability to overlay images, text, video, and audio components onto existing images or space. AR technology has gained a following in the educational market for its ability to bridge gaps and bring a more tangible approach to learning. Student-centered activities are enhanced by the incorporation of virtual and real-world experience. Throughout this literature review on AR the following aspects will be discussed at length: research explored, theoretical foundations, applications in education, challenges, reactions, and implications. AR has the potential to change education to become more efficient in the same way that computers and Internet have.

RESEARCH

Research conducted for this literature review focused on educational applications of AR. The initial search of K-12 applications was far too broad to provide a valuable synthesis. The keywords included educational applications, science or STEM focus, and augmented reality. Journals with a concentration in technology and education that held significance to AR within the classroom setting were sought. References were included that explained the concept of AR as well as studies that implemented AR. Most of the references for this analysis were published within the past five years; however, a few articles included were published as early as 2001. The majority of the research found focused on applications in a middle or secondary level. AR appears to have potential extending into lower elementary grades. Additionally, research at the college level provides insight into windows of opportunity that may extend into the K-12 sector. Researchers often choose students at a middle school level because of the critical time period it is for increase in science interest and building self-confidence (Bressler & Bodzin, 2013).

Several studies seemed to take a mixed methods approach combining both quantitative and qualitative analysis. Researchers noted that providing case studies and opportunities for participant feedback extended the wealth of knowledge available and provided key insights to the quantitative data (Bressler & Bodzin, 2013; Enyedy, Danish, Delacruz, & Kumar, 2012; Iordache & Pribenu, 2009; Morrison et al., 2011; Serio, Ibanez, & Carlos, 2013). Qualitative data was also thoroughly inspected, specifically acknowledging the positive and negative components of AR that both students and teachers experienced (Arvanitis et al., 2009; Billinghurst & Dunser, 2012; Bressler, & Bodzin, 2013; DeLucia, Francese, Passero, & Tortoza, 2012; Iordache & Pribeanu, 2009; Morrison et al., 2011; Serio, Ibanez, & Carlos, 2013).

One of the quantitative research studies completed by Dunleavy, Dede, and Mitchell (2009), used a design-based approach with interviews to put the engagement of high school students under the microscope. The authors use the AR situation *Alien Contact!* with role- playing scenarios. The study was conducted over the 2006-2007 school year and used data from three schools in order to determine if AR technologies aid in the learning process. Jefferson High School, Wesley Middle School, and Einstein Middle School are all located in the northeastern United States. Through the collaboration of MIT and the University of Wisconsin at Madison, a hand-held AR program known as *Alien Contact!* was created. This game was designed to focus on several educational aspects such as math, language arts, and scientific literacy (Dunleavy et al., 2009). Students used this device throughout the study to participate in roles and collaborate as a team. The authors found that there was a high level of engagement.

Engagement was also found while using augmented books through a qualitative research study. Billinghurst and Dunser (2012) surveyed user studies concerning elementary and high school students to determine if AR enhances the learning experience. The authors found that, "AR educational media could be a valuable and engaging addition to classroom education and overcome some of the limitations of text-based methods, allowing students to absorb the material according to their preferred learning style" (Billinghurst & Dunser, 2012, p. 60).

THEORETICAL FOUNDATIONS

AR educational programs are student-centered and related to student interests. It allows students to explore the world in an interactive way. Constructivism also encourages students to work collaboratively, and AR provides students the opportunity to do this in a traditional school setting as well as in distance education. Dunleavy et al. (2009) believe that the engagement of the student as well as their identity as a learner is formed by participating in collaborative groups and communities. Constructivism has also changed the role of the teacher to become a facilitator, where the responsibility to organize, synthesize, and analyze content information is in the hands of the learner (DeLucia et al., 2012). Wang (2012) warns that because AR follows a constructive learning theory it does not generate consequences for students' actions as needed, compared to a behavioral learning environment; however, AR can be used to bridge the gap between practical and theoretical learning practices along with real and virtual components being blended together to create a unique learning experience.

AR also relates to the just-in-time learning theory. This theory suggests that students learn information that they need to know now. Collins and Halverston (2009) stressed that teachers should "reconceptualize" how they view learning and "rethink" what they should teach. AR allows them to do both of these things by letting educators use a new and engaging technology to view aspects of the real world in a different way.

Dunleavy et al. (2009) discussed the possible connection between the situated learning theory and AR. According to situated learning theory, learning occurs naturally during activities. Some AR situations, like *Alien Contact!*, allow students to use real-life experiences to facilitate learning. Some learning will occur naturally, as they go through their problem-solving environment. Students will use social interaction and collaboration to learn from one another.

Rigby and Przybylski (2009) identified that AR can be linked to the self-determination theory (SDT). SDT defines learning that occurs through motivation. People have the natural tendency to do what is healthy, interesting, important, and effective. The virtual learner hero situation created in the virtual worlds focused on in this study determined that students are engaged because they are in charge of their own learning. The same concepts can be applied to an educational setting.

Flow theory describes how people who are engaged in meaningful activities are more likely to stay focused. Bressler and Bodzin (2013) investigated a science gaming experience in relation to flow experience. Their study had a mean flow experience score of 82.4%, which indicates that the average student experienced flow throughout the science mystery game that they played on an iPhone. This particular type of AR, as well as various others, connects their real-world surroundings to learning in a new and engaging way.

APPLYING AR IN EDUCATION

AR allows flexibility in use that is attractive to education. AR technology can be utilized through a variety of mediums including desktops, mobile devices, and smartphones. The technology is portable and adaptable to a variety of scenarios. AR can be used to enhance content and instruction within the traditional classroom, supplement instruction in the special education classroom, extend content into the world outside the classroom, and be combined with other technologies to enrich their individual applications.

Traditional classroom uses

In any educational setting, there are often limitations in the various resources available. This is often seen foremost in the traditional classroom. Due to budget restraints or constraints on time, the means to teach students in scenarios that allow them to learn by doing can be a challenge. Desktop AR allows students to combine both real and computer-generated images. Iordache and Pribeanu (2009) used desktop AR that combined a screen, glasses, headphones, and a pointing device that allowed students to conduct a hands-on exploration of a real object, in this case a flat torso, with superimposed virtual images. It would not be feasible to explore the digestive process interactively as these students were able to do along with visualizing the nutrient breakdown and absorption in a classroom setting without the AR technology. Computer images could show the process, but the pointing device allowed students to guide their learning.

Classrooms can shift from the traditional lecture style setting to one that is more lab and student-oriented. A case study conducted with a visual arts class noted that allowing students to freely explore a room that was set up with webcams and desktops encouraged more activity while the students perceived that they were more motivated to learn (Serio et al., 2013). Instead of receiving information via images and lecture, students had access to multimodal representations including text, audio, video, and 3D models.

Quick response (QR) codes can also open up opportunities to have a mixed reality setting within the actual classroom. DeLucia, Francese, Passero, & Tortoza (2012) conducted an evaluation study on collaborative classroom environments in a university setting. Students had access via their mobile devices to information provided directly from the instructor and other students. The QR codes within the classroom allowed for location determination, which was necessary because the information was not available online. Having the virtual environment accessible in a single location encourages consistent and active participation in person instead of just the virtual environment. The learning experience of the traditional classroom was enhanced by the content sharing of both instructor and peers.

Special Education Uses

With the ability to bridge learning and physical barriers, AR has the potential to bring value and high quality educational experiences to students with learning and physical disabilities as well as the special education classroom. Billinghurst and Dunser (2012) found that using augmented storybooks have led to more positive results as students were able to recall stories and have better reading comprehension. Augmented storybooks could especially help students who were less able to comprehend only text-based materials. Physical movement is often a component and consideration for AR tasks. A student who may struggle to engage under normal circumstances can become more actively involved in the kinesthetic nature employed by augmented tasks. Dunleavy et al. (2009) found in their interviews that teachers felt that students who were identified as ADD as well as unmotivated students were 100% engaged in the learning process during an AR simulation.

Because of the variety of tools that can be overlaid in an augmented environment, students with physical disabilities can benefit from the potential learning aides that could be incorporated. Something as simple as overlaying audio for those with visual impairments or text for those with hearing disabilities can be effective tools when considering disability access (Forsyth, 2011). Physical limitations can make handheld AR devices more difficult to work with. Head-mounted displays (HMD) can provide a hands-free device to project the overlay visuals to a student and adjust the images based on the orientation of the student while other devices enable students to interact with the environment via voice recognition, gesture recognition, gaze tracking, and speech recognition (Van Krevelen

& Poelman, 2010). Bringing this technology to the classroom has the potential to allow for differentiated instruction and enrichment of the learning experience of students with special needs. Evaluation trials conducted by Arvantis et al. (2009) showed that using wearable AR technology with students who had physical disabilities produced, "interestingly comparable results with able-bodied users," (p. 250) in terms of "wearability" and pedagogy.

Outside the Classroom

Mobile applications can extend the traditional classroom beyond the physical walls. Annetta, Burton, Frazier, Cheng, and Chmiel (2012) reported that the percentage of 12 to 17 year olds who have their own mobile device is 75%, compared to 45% in 2004, and regardless of a student's socioeconomic status, the number of students carrying their own mobile devices is growing exponentially every year. Camera phones and smartphones allow users to gather information in a variety of locations. QR codes and GPS coordinates can be used to track and guide movement of the students. Although several researchers chose to take students off campus and conduct investigations in a field trip setting, others chose to remain within the grounds of the school.

In an off campus setting, the AR technology needs to be portable and relatively easy to use. Students traveling to a local pond have the ability to study water quality at specific locations while having access to overlaid media about the pond from the AR device (Kamarainen et al., 2013). This type of experience opens up a world of opportunities to mesh classroom information into the real-world environment. Morrison et al. (2011) used real paper maps and GPS coordinates in a treasure-hunt-style game that allowed for group collaboration. Participants in the game were aware of their surroundings and chose to work together on a task that fostered small group collaboration. An important point to note from this research is that GPS will not work inside of buildings. Therefore, any indoor activity would need to be conducted without a location-based AR technology.

Using QR codes allows individuals a means to avoid relying on location-based technology and focus on the augmented experience. Bressler and Bodzin (2013) chose to use vision-based mobile AR within the confines of the school campus. Students used iPhones that were Wi-Fi enabled to collaborate in small groups to complete a science inquiry game. Not only did the technology enable the students to move freely about the campus, but also the design of the game fostered a social constructivist approach by using a jigsaw method in which students had independent roles that relied upon one another to complete the task. Dunleavy et al. (2009) employed a similar approach to jigsaw collaborative methods for successful completion of an AR simulation.

Combined Learning

The technology employed with AR does not need to be exclusive to the AR experience. Motion sensors that modeled force and motion during Learning Physics through Play (LPP) activities and AR in the form of QR codes enabled students to use, visualize ideas and share them with others for discussion (Enyedy et al., 2012). Combining the technologies helped to enhance the learning experience, which is similar to research done by Kamarinen et al. (2013) who pointed out that the combination can help to enhance the learning experience in a way that neither could do alone.

If an educator is looking to model scientific practice, AR provides the opportunity to support the multifaceted world of science exploration. As a general rule, scientific researchers typically do not use a single tool for evidence to come to a conclusion. Likewise, a literature review that embodies just research from one scientific journal does not begin to tap the wealth of knowledge widely available. Using probeware and sensors to collect data and AR technology to guide and visualize helps to bring a more student-centered dynamic to a learning experience, resulting in gains in student engagement and content understanding (Enyedy et al., 2012; Kamarinen et al., 2013).

Applications Beyond Science

Research shows that the use of AR, regardless of grade level or subject area, allows students to be actively engaged in the learning process. "Building and using AR scenes combines active complex problem solving and teamwork to create engaging educational experiences to teach science, math, or language skills, and studies have found that this activity enhances student motivation, involvement, and engagement" (Billinghurst & Dunser, 2012, p. 60). Though most research shows the use of AR in education through middle school science, there are some implementations in other subject areas and age groups. For example, AR was utilized in a visual arts class as researched by Serio et al. (2013) and during the MapLens research by Morrison et al. (2011) when participants ranging in age from 7 to 50 were observed.

Outside of a traditional school setting, AR has many uses and can be applied to other areas of interest as well. The medical field can utilize this technology to see information about the body systems without having to leave the sight of the patient. In addition, families can see what furniture will look like in their house before purchasing, contractors are able to design different components and see how they will fit together before construction, and tourists can find information out about the area without an in-person tour guide. Van Krevelen and Poelman (2010), determined that AR can be particularly helpful in industrial situations in designing and assembling vehicles as well as military applications for combat training. Companies such as Volkswagen and BMW have already started to use AR technologies in their assembly lines (Van Krevelen & Poelman, 2010). Therefore, AR has many benefits outside of the educational field.

CHALLENGES

Training

Training is an important aspect of AR. "Most educational AR systems are single-use prototypes for specific projects, so it is difficult to generalize evaluation results" (Billinghurst & Dunser, 2012, p. 61). Each AR situation researched was unique and required a different program and requirements of the educator. Due to this uniqueness, training is needed for both educators and students to understand how to utilize each AR program to its fullest potential. During the Dunleavy et al. (2009) *Alien Contact!* AR lesson, teachers expressed a concern for more support. Teachers did not feel confident when setting up or implementing the program. In addition, teachers who are normally lecture focused had a hard time letting go and allowing students to explore the learning environment on their own. A training should be provided for teachers to learn a hands-off approach with their students and show them how this way of teaching will foster an effective learning environment. The fear of not knowing what is on each student's device can be elevated according to the authors through the process of allowing the students more control over their learning. In addition, Kamarainen et al. (2013) also found that teachers felt they would be unprepared to manage the same experience over again if they were by themselves without the researchers present. Training should be provided to the educators from the researchers if continued use of the AR technology is expected to be implemented.

Many AR applications require the use of the environment to set up areas for study. Students walk around and use their AR technology devices in order to receive information. The information must be triggered by either GPS coordinates or other methods when students get near the correct locations. The developer, as well as the educator, must be aware of the environment in order for this to work effectively (Van Krevelen & Poelman, 2010). Therefore, teachers need to either train themselves or attend training sessions on the environment that they can use. For example, if an AR application is specifically designed to be completed in a school where students get close to fire alarms, information appears on their device about fire safety, and the educator or developer must be aware of where all the fire alarms are located.

Resources

Billinghurst and Dunser (2012) understood that there are many aspects of AR that are considered to be obstacles when trying to implement this type of technology in the classroom. Many teachers do not have the skills to program their own AR learning experience and therefore must rely on the ability to create this AR environment through pre-made creation tools, which are rare. This was slightly contradicting to the Annetta et al. (2012) statement that there are many free resources available for teacher use but stress that because teachers are not properly trained they are unable to use these available resources.

AR tools are becoming more user-friendly and require less programming skills making them more attractive to the common educator. Mullen (2011) focused his work around providing individuals with a resource for basic skills that would enable them to not only understand how AR applications run but also to get started with creating AR content. Kamarainen et al. (2013) pointed out that AR platforms could be employed that allow "an author to create augmented reality games and experiences with no programming experience required" (p. 547). In addition, Billinghurst and Dunser (2012) predicted that by the year 2030, students will be building AR educational content on a regular basis to connect collaboratively with the outside world from within their classroom.

Technical Problems

Dunleavy et al. (2009) showed that the GPS failed 15-30% during the study. A GPS error refers to either the software of the GPS itself or incorrect setup. This was considered the "most significant" malfunction. Other malfunctions identified in this study were the ability for the devices to be effectively used outdoors. The glare from the sun as well as the noisy environment could impair the learning of the students.

Morrison et al. (2011) identified that students who collaborate in teams score higher than students who worked on their own. These multi-user teams need to share information with each other. Therefore, one of the challenges identified in this study is the need for developers to create places for collaboration among team members. Without this additional platform, the successfulness of the AR environment can be compromised.

There are several different kinds of devices that can be used when implementing AR in the classroom. Glasses, hand-held devices, and headwear are ways for the user to see computer-generated images imprinted on their reality. Iordache and Pribeanu (2009) determined that the cameras the students were using should be hands free and that they should be set at table level for the maximum results. Carrying around large devices can make AR inconvenient and frustrating. Arvanitis et al. (2009) had students wear a backpack as part of their AR technology device. The study showed that students felt that it was hard to wear and made them feel embarrassed. If AR technologies hinder the self-esteem of the students, this can also affect how much information the student can retain within each lesson. Van Krevelen and Poelman (2010) also identify that certain AR technologies can be uncomfortable and embarrassing to wear. Gloves, backpacks, and headgear can all cause a student to become uncomfortable and distract them from the purpose of the assignment. In addition, such items could potentially discourage students from trying AR in the first place.

Van Krevelen and Poelman (2010) identified the need for the AR technologies to be designed effectively and with high usability. For instance, the video display must make sure that the images shown do not appear closer or farther away than they really are. This problem can lead to misconceptions if dealing with location-specific tasks. Some devices may require calibration, and this can potentially be very difficult to do. Acquiring devices that are calibration free or auto-calibrated can be beneficial to the user as to avoid malfunction and user frustration.

Bressler and Bodzin (2013) found that players involved in gameplay within the building did not fully utilize the GPS on their mobile device, since the students were familiar with their surroundings. This seemed to reduce the overall cognitive load; however, location-based AR can add a new level of frustration when students are placed in an unfamiliar place, where they must rely on GPS navigation to complete gameplay. Using AR technologies that include both audio and visual components can allow students to use their cognitive abilities to retain information more efficiently based on cognitive load theory.

Student Issues

One issue identified in Dunleavy et al. (2009) determined that some AR situations can be dangerous. In this particular *Alien Contact!* scenario, students must look at their handheld devices to participate. When engaging in activities outdoors the students are unable to work on their devices and watch where they are going simultaneously. Therefore, students were found to be wandering into roadways and needed to be redirected to safety by teachers.

Some of the AR learning experiences require the student to be mobile. Exploring the world is not an uncommon task; however, Annetta et al. (2012) were concerned with gaining approval from school administration for students to travel outside of the classroom. Without this component the teachers and students would be very limited in their use of the AR technologies. The authors found that classroom management is an important part of using AR technologies with students.

Certain health problems can arise from using AR devices if they are not properly designed. Tunnel vision can be a side effect of using poorly designed AR devices, and this should be avoided (Van Krevelen & Poelman, 2010). Developers and educators should be aware of the method and the amount of information being presented. This could prevent the brain from being overloaded. In addition, when the user feels overwhelmed, stress and other frustration can arise, which will distract the student from the objective of learning.

AR learning environments are often designed to have many roles in order for students to work in teams and collaborate with each other. Dunleavy et al. (2009) stated, "As is, if one of the roles is absent, it severely restricts if not disables the game" (p. 19). Student absences are a natural occurrence but affect the learning environment drastically. In addition, students who are working without constraints can rush through or skip information depending on the AR program, teacher assertiveness, and intrinsic motivation. Kamaraien et al. (2013) also found that students might rush through the activity without fully comprehending the information presented in that part. Therefore, though AR leads to a high engagement level students should be monitored to stay on task and on pace as well.

As AR scenarios are developed for the classroom the developers must be aware of their target audience. For example, Enyedy et al. (2012) made a point that the AR technology used in their experiment was made for students to be able to make right and wrong decisions in order to foster play; however, this would not be the ideal situation for older students learning physics. Therefore, the cognitive development of the students should be taken into consideration when developing programs as well as utilizing already existing AR applications.

REACTIONS

Students

Overall, students reacted positively to using AR technology both in and outside of the classroom. AR is a fairly new development within the field of education, and there are areas that students reported that need improvement. Annetta et al. (2012; as cited in Benford and colleagues, 2003) listed four educational uses to AR mobile technology, which are in no particular order: field science, field visits, games, information services, and guides. AR games can be played independently or dependently. Researchers, teachers, and students alike were very pleased to find more collaboration while using the AR technology (Annetta et al., 2012; Billinghurst & Dunser, 2012; Bressler & Bodzin, 2013; DeLucia et al., 2012; Dunleavy et al., 2009; Kamarainen et al., 2013; Morrison et al., 2011). Students reported after completing an AR game called *School Scene Investigators: The Case of the Stolen Score Sheets (SSI)* they had a desire to perform at a higher level, felt a sense of exploration, and 93% of students were more curious to learn about forensics (Bressler & Bodzin, 2013).

Students also reported that learning in an AR environment is more stimulating and appealing than viewing a traditional slide presentation (i.e., Microsoft PowerPoint, SmartNotebook) because they preferred the audio, video, and feeling as if they were part of the 3D model that was transposed into a real physical space (Serio et al., 2013). Finding "hotspots" also known as "triggers," and using the smartphone were both reported as what the students really enjoyed while using AR technology (Kamarainen et al., 2013). Utilizing handheld devices was considered the most motivating and engaging factor when students played the AR simulation game *Alien Contact!* (Dunleavy et al., 2009).

AR is continuously growing and improving every day, and using students' feedback allows AR technology developers to incorporate these helpful tips to improve user experience. Students had issues keeping the AR superimposed images in the right position; they could not select an image as well as they would have liked, and sometimes the image was shaky, which could ultimately lead the program to lose the image altogether (Iordache & Pribeanu, 2009; Serio et al. 2013). DeLucia et al. (2012) noticed that when using AR technology the students had to hold the mobile device in order to complete the activity, which limited the users' maneuverability. To work around these situations, Morrison et al. (2011) found that users would sit down to stabilize their device. Other researchers used head-mounted displays (HMD) for students with muscular dystrophy, cerebral palsy, and arthogerposis to experience

AR simulations (Arvanitis et al., 2009). These students used the HMD because they depended on a wheelchair for their mobility. Students felt embarrassed and self-conscious wearing the HMD, and they also found the device uncomfortable. Both Arvanitis et al. (2009) and Iordache and Pribeanu (2009) reported stress on student vision after completing the AR simulation. However, Goodrich (2013) noted that technology developers are already working on a more user-friendly AR technology called Google Glass. This device is set up like a pair of glasses the student could wear with ease and confidence. The superimposed images are displayed to the glasses through a small projector that is viewed only by the individual student. Researchers are working on expanding this technology to include bionic eyes that function without the glasses and would have far reaching potential for students with visual impairments (DNews, 2013).

GPS is a major factor in completing AR simulations. GPS signals are not normally obtained in a building and to adapt, in order for AR simulations to function properly inside a classroom, QR codes have been developed. The mobile device using AR technology can scan a QR code and retrieve the information, where it is then loaded on the device (Bressler & Bodzin, 2013; DeLucia et al., 2012). Dunleavy et al. (2009) found that the biggest limitation for students and teachers while completing a simulation was GPS error.

Educators

Educators may feel alarmed as if AR will "overtake" their classrooms; it seems that once students experience this type of learning, they will not go back to their previous ways of learning. However, Annetta et al. (2012) expresseed that AR can be an activity to engage students in future units and discussions. Billinghurst and Dunser (2012) believe that AR is a new form of face-to-face instruction, as students share the learning experience. Teachers have reported students taking responsibility and ownership of their learning (Kamarainen et al., 2013). Therefore, educators using AR technology are becoming facilitators to their students. Even within the elementary grade levels, teachers plays a very important role in engaging the students, especially when introducing complex technical equipment to their students so they can take part in AR activities (Enyedy et al., 2012).

Teachers are concerned with the programming and coding that is required to integrate AR activities into their classrooms. Software is being developed (i.e., The Art of Illusion) in order for teachers to focus on building educational content and not having to worry about programming skills (Billinghurst & Dunser, 2012). Another concern is how quickly some students are completing the AR activity in comparison to other students. Going through the activity too quickly, as the student cannot wait to see what will come up next on the screen, can hinder their comprehension (Kamarainen et al., 2013; Dunleavy et al., 2009). In contrast, Serio et al. (2013) mentioned that students who finished early or could fix technical problems were willing to help other students. When using AR on a field trip, teachers expressed concern with how they would manage all of the technology, along with technical difficulties that arise throughout the trip—on their own.

Some AR simulation games require a significant amount of complex material the student must process. For example, running the mobile device, using the AR software, following the navigation, completing all the required tasks for the activity, and collaborating with peers about the information, can be quite daunting tasks, even for a student who is advanced at multitasking. Teachers are always looking out for the best interest of their students resulting in worry that AR simulations may cause students to have cognitive overload. Students reported cognitive overload when participating in an outside AR game, and teachers could expect this to be more likely to happen when students are in an unfamiliar area (Dunleavy et al., 2009).

Administration

One of the advantages of AR simulations is it allows students to participate in multiple field trip-like experiences from the comfort of their own building, which can be a huge incentive for districts that are affected by budget constraints (Dunleavy et al., 2009). AR simulations can take place in or outside of the traditional classroom, and administrative support is needed in all cases. For example, administrative approval is needed anytime traveling outside of the school's premises. Innovative teachers can capture administrative support for their students using AR technologies by maintaining strong classroom management skills and, equally important, facilitating good instruction (Annetta et al., 2012).

IMPLICATIONS FOR RESEARCH

The importance of this literature review is that it not only showcases the current trends in AR technology but also its focus on the increased research and potential further application in the educational setting. Several components remain to be explored. When using AR outside of the classroom, teachers and students are able to use this as a tool for physical activity (Dunleavy et al., 2009). Linking learning with exercise and activity in an educational way can improve the perception that technology creates a non-interactive environment (NAEYC & Fred Rogers Center, 2012). Since AR varies in the amount of room required, there is a concern for how much space is needed in order to make implementation successful (Dunleavy et al., 2009; Morrison et al., 2011; Wither, Tsai, & Azuma, 2011). Particular interest within AR is that it has not expanded to fully utilize other learning styles, such as audio and kinesthetic (Billinghurst & Dunser, 2012). Another is that the amount of visual information that can be displayed on the screen can be overwhelming to students. Studies should further explore the effects AR has on cognitive load in the brain and how much information should be displayed before it turns from a beneficial device into a distracting device (Bressler & Bodzin, 2013; Van Krevelen & Poelman, 2010). Many educators are already concerned with how to hold students' attention to keep them engaged throughout the lesson and maintain focus beyond the novelty of the technology (Kamarainen et al., 2013). In one study, Serio et al. (2013) discussed how AR could potentially increase memorization and concentration skills and suggested that further research should be conducted to validate these claims.

Educators must be digitally literate with an understanding of child development theory to select digital tools that are age specific and avoid the potential negative impact on learning (NAEYC & Fred Rogers Center, 2012). Dunleavy et al. (2009) pointed out the challenges of using AR before students have collaborative problem solving skill sets and behaviors that are necessary for learning, the tendency for student competitiveness, and the infancy of effective instructional design. How these challenges factor into placement of AR materials in a single classroom or broad age level warrants extensive focus by future researchers. Although much of the research focuses on student or teacher reactions to AR in the classroom and how it can be used, the technology itself has not allowed for long-term studies on the appropriate guidelines to implementation that will assure student growth and achievement of learning goals. The long-term effect of AR past a single classroom or group of students needs to be evaluated and compared. DeLucia et al. (2012) suggested that the effects of their AR system be evaluated over a longer period of time. Supplementary research could explore what is the most appropriate range of members utilizing AR in groups and when is the best time for AR to be introduced (Dunleavy et al., 2009). To further expand upon possible future research, additional studies would need to seek out if students using AR communicate more effectively and frequently compared to students who are not exposed to AR platforms (Arvanitis et al., 2009; Rigby & Przybylski, 2009). Throughout the multiple studies that were examined, many of them suggested further analysis in what types of AR platforms would be the best fit for educational purposes (Azuma, Baillot, Behringer, Feiner, Julier, & MacIntyre, 2001; Dunleavy et al., 2009; Forsyth, 2011; Iordache & Pribeanu, 2009).

CONCLUSION

AR has already begun to help students learn more efficiently as well as increase their knowledge retention (Billinghurst & Dunser, 2012). However, before AR becomes mainstream in education, like desktops, laptops, tablets, and even cell phones have become, special consideration must be taken into account on the usability, cost, power usage, visual appearance and the like, in order for content AR simulations activities to become part of the regular academic curriculum (Van Krevelen & Poelman, 2010). AR has proved to be an engaging way for students to participate in their learning. This new technology allows the learning to be student-centered and create opportunities for collaboration that fosters a deeper understanding of the content. AR is on the way to becoming an important part of education, and its use will continue to grow.

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