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Using the Technology Acceptance Model to Analyze K–12 Students' Behavioral Intention to Use Augmented Reality in Learning

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Augmented Reality (AR) has gained popularity in K-12 education in the past decades (Bower et al., 2014; Dunleavy & Dede, 2014; Dunleavy et al., 2009; Leighton & Crompton, 2017). Researchers and educators agree that AR is a useful pedagogical tool in teaching because it is grounded on efficient teaching and learning models such as constructivist learning (Abdoli-Sejzi, 2015), situated learning (Liarokapis et al., 2004), and inquiry-based learning (Chiang et al., 2014). Research on AR in the K-12 context tends to focus on its impact on students' learning processes and learning outcomes (Calle-Bustos et al., 2017; Chang et al., 2016; Freitas & Campos, 2008; Wu et al., 2013). However, it is essential to understand K-12 students' behavioral intention to use AR—their perceptions of usefulness, ease of use, and enjoyment—so that teachers can better design and integrate AR-based learning into their courses. After defining AR in education, this literature-based research explores K-12 students' behavioral intention to use AR in learning guided by the Technology Acceptance Model. Specifically, we aim to answer this research question: What is K-12 students' behavioral intention to use AR-based learning in real classrooms?

(Re)defining Augmented Reality

AR has been defined differently from different perspectives. Our literature review demonstrates that there are at least three different approaches to defining AR. First, AR was defined in a very general and broad sense, focusing on the blending of the virtual and the real. Azuma (1997) conducted a survey of the applications of AR in a wide range of areas and industries including medical, manufacturing and repairing, annotation and visualization, robot path planning, entertainment, and military aircraft in order to describe AR's characteristics. Based on that survey, Azuma (1997) defined AR as systems that have three characteristics "1. Combines real and virtual; 2. Interactive in real time; 3. Registered in 3-D" (p. 356). He provided an example of such a combination of the real and the virtual by demonstrating a real desk with a 3-D virtual lamp on it and two virtual chairs around the desk in a real room. These three characteristics have become the foundation for later researchers to define AR. For example, Furht (2011) conceptualized AR as a technology that "augments the sense of reality by superimposing virtual objects and cues upon the real world in real-time" (p. 3). Similarly, Klopfer and Squire (2008) described AR as dynamically adding contextual virtual information into the physical world and enabling the virtual and the real to share the coherent location in real-time. In short, all these definitions have emphasized the interactive combination of the real and the virtual in a real-world context.

To what extent does AR represent the real world? Milgram et al. (1994) put forward their Reality-Virtuality continuum in which reality stands for the complete real-world and real experience while virtuality is the complete virtual world and virtual experience. Between reality and virtuality, there exists a mixed reality that combines both real and virtual elements, including augmented reality that is close to reality and augmented virtuality that is close to virtuality.

Second, AR has been defined primarily based on the communications technology used. For example, as the computer has developed into a vital tool for communication and collaboration (Billinghurst et al., 2001), many definitions of AR were based on the use of computers. Thus, Zhou et al. (2008) defined AR as a technology that enables physical items to be exactly overlaid by virtual imagery created by computers in real-time. Carmigniani and Furht (2011) also conceptualized AR as a tool that adds computer-generated virtual information to natural environment in real-time. However, they emphasized that AR users not only see the virtual items and clues superimposed on immediate surroundings directly, but also get an indirect view of the physical world, such as a live-video stream. As digital media became an essential technology for communication, the definition of AR evolved to be based on the use of digital media. For example, Ibáñez and Delgado-Kloos (2018) defined AR as "a 3D technology which merges the physical and digital worlds in real-time" (p. 110). Taskiran (2019) further clarified that the digital worlds include images, videos, and audio. Nowadays, as mobile devices have become the primary communication tool; users are able to see superimposed virtual objects displayed on a mobile device instead of a personal computer (Wong, 2013).

Finally, some researchers defined AR based on its function and purpose from the users' perspectives. The early face-to-face computer conferences were in an immersive virtual environment, and the separation of task space and communication space led to a lack of normal communication cues. However, AR enabled computer conference users to see each other's non-verbal cues in the real world. Based on this fact, Billinghurst et al. (2001) defined AR as a technology that provides rich and meaningful multimedia content that is contextually relevant and can be quickly and immediately acted upon. Similarly working from the perspective of learners, Rattanarungrot et al. (2014) defined AR as "a concept for displaying digital contents overlaid on top of real-world scenes that can enhance remarkably a user's learning experiences" (p. 327). Wu et al. (2013) also emphasized the learners' perspective, defining AR in terms of its ability to enable learners to visualize complex spatial relationships by placing virtual objects into the physical environment. It should be noted that the definitions of AR have changed with advances in the affordances of technologies used in AR (Wu et al., 2013). For instance, recent researchers have integrated more current technologies in AR definitions, such as 3D technologies (Ibáñez & Delgado-Kloos, 2018) and digital media (Taskiran, 2019). AR technologies have experienced several distinct developments: from handheld computing to mobile-AR, to the development of AR systems, to location-registered AR, and the development of AR in remote laboratories (Koutromanos et al., 2015; Wu et al., 2013). The usual hardware in AR includes computers, video cameras, storage space, 3D-simulated environment, an interface (e.g., Azuma,1997; Billinghurst et al., 2001; Bower et al., 2014; Zhou et al., 2008) and other technologies such as GPS, image recognition software, speakers and sound systems, internet access and intuitive interfaces (Johnson et al., 2011).

It is clear that none of the three approaches used to define AR can fully capture the essence of AR in education. For example, using certain types of technology to define AR can easily fall short because technologies used in AR are ever-changing. Educators should also keep in mind, as Azuma (1997) cautions, that AR should be considered supplementing rather than as replacing the real world. Finally, the implementation of AR in education should not be considered as an end in itself. Instead, the purpose of AR design and implementation should focus on student learning. Thus, by synthesizing the three aspects of AR that researchers have used in defining AR—the virtual and real interaction, the technologies used, and the purpose of AR in learning—we redefine AR in education as follows:

> AR is a pedagogical tool that blends physical and digital worlds in real-time through different technologies to enable learning of concepts that are hard to understand and to experience phenomena that are otherwise inaccessible or dangerous in real learning contexts.

Application of AR in Education

In K-12 education, AR has been applied to promote student-centered teaching and learning models such as inquiry-based learning (Chiang et al., 2014) and situated learning (Bower et al., 2014). AR has also been studied to increase students' motivation to learn (Chang et al., 2016; Freitas & Campos, 2008), bridge formal and informal education settings (Pérez-Sanagustín et al., & Blat, 2014) and create learning experiences that are not possible in the real world (Wu et al., 2013). Game-based learning has been frequently incorporated into AR's application. For example, Calle-Bustos and colleagues (2017) designed an AR game that placed virtual food on real dishes to create therapeutic education for patients with diabetes during childhood and adolescence in a way that would be user-centric, engaging, and interactive. Their results demonstrated that the children experienced a significant increase in knowledge about a healthy diet after playing the game. Similarly, in order to improve students' interests in learning about plants, Chang et al. (2016) designed an AR game system called *Flora* that included a webcam, a mechanical clock, and a microphone for students to act as gardeners seeding, watering, and caring for virtual plants. The results indicated that students not only acquired more understanding of the processes of plant growth but also were motivated to learn more about plants in the future.

The AR learning system designed by Chiang et al. (2014) for elementary students to learn natural science demonstrated how AR can enhance the learner's active role in the learning process. The system included five stages of activities, encouraging the students to ask, investigate, create, share, and reflect, enabling students to use the GPS to locate authentic learning environment, use iPads to capture images for investigation, search for information about the images in Wikipedia. More importantly, the AR system also facilitated students in sharing what they learned and reflect on their newly acquired knowledge on a deeper level. The whole process was a cycle of inquiry-based learning which allowed students to "develop the confidence to participate in activities, cultivate teamwork abilities, and feel greater responsibilities for controlling their learning process" (p. 353).

In addition to the positive learning outcomes described above, researchers have identified challenges in the process of AR-based learning that originate from three aspects: technological issues, activities and practices designed around the technologies, and student' responses (Radu, 2014; Wu et al., 2013). Technological issues included device failures (Wu et al., 2013) and usability difficulties (Akçayır, & Akçayır, 2017; Radu, 2014). Activities and practices issues ranged from "cumbersome and expensive design" to "inflexibility of the content in AR systems" (Wu et al., 2013, p. 46). Finally, challenges related to students' responses included "difficulties maintaining superimposed information" (Bacca et al., & Graf, 2014) and difficulties in the "interpretation of the clues" (Wu et al., 2013, p. 46), both of which increased students' cognitive load (Radu, 2014). Based on the analysis above, it can be concluded that current studies regarding AR's application in K-12 education have primarily focused on students' learning processes and learning outcomes. More studies of K-12 student experiences, especially regarding why they decide to use AR in their learning, are needed for researchers and teachers to better understand how learners respond to AR-based learning. To bridge this gap, we propose exploring student responses to AR through the lens of the Technology Acceptance Model that interprets users' behavioral intention to use a new technology.

Theoretical Framework

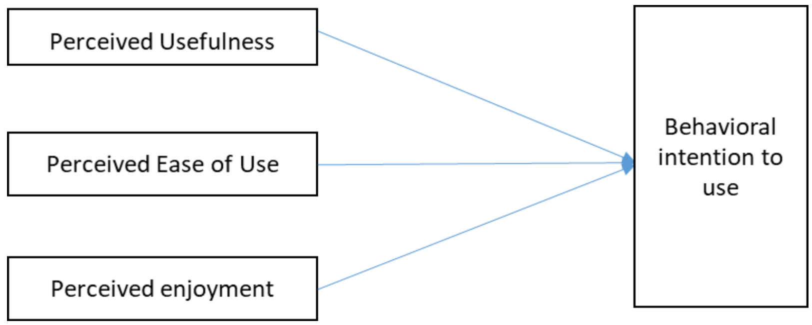
The Technology Acceptance Model (TAM), first proposed by Davis (1989), interprets potential users' behavioral intention to use a new technology (King & He, 2006; ŠUmak et al., 2011). Based on the theory of reasoned action proposed by Fishbein and Ajzen (1975), TAM seeks to explain and predict behaviors of people in a specific situation (Legris et al., 2003), and has been adopted by researchers to examine how and why individuals adopt new information technology. TAM includes two primary factors, the user's perception of usefulness and their perception of ease of use, both influencing the outcome of the user's behavioral intention to use the technology. According to Davis (1989), perceived usefulness is "the degree to which a person believes that using a particular system would enhance his or her performance" (p. 320). Perceived ease of use, on the other hand, meant "the degree to which a person believes that using a particular system would be free of effort" (p. 320). Intention of use is the prediction of a user's behaviors to use a technology (Sheppard et al., 1988). In his original model, Davis not only assumed that the two primary predictors—perceived ease of use and perceived usefulness—work together to determine behavioral intention, but also theorized that the perceived ease of use is a predictor of the perceived usefulness.

TAM has become one of the most widely used technology acceptance theories within information systems research (Chuttur, 2009; Holden, & Karsh, 2010; Lai, 2017). Many empirical studies have employed TAM with different technologies in different contexts (e.g., Venkatesh et al., 2003; Liaw et al. 2006), demonstrating that TAM can be a robust model to predict users' behavioral intention in employing a new technology. However, TAM research also generated inconsistent results and different effect sizes in different studies, which may be the result of different types of users, different types of task characteristics, and different types of technologies (Bourgonjon et al., 2010; Legris et al., 2003; ŠUmak et al., 2011; William & Jun, 2006). To address these limitations, many researchers have attempted to extend this model by including factors such as users' prior experience (Jackson et al., 1997; Oh et al., 2003), contextual factors such as cultural contexts (Huang et al., 2003; Straub et al., 1997), and other factors incorporated from other theories such as task requirements from the task-technology fit model (Dishaw, & Strong, 1999; Hardgrave et al., 2003). In addition to users' perceived ease of use and perceived usefulness as extrinsic motivation for them to use a technology, Davis et al. (1992) added perceived enjoyment as an intrinsic element that influences the user's behavioral intention to use the technology. According to the same authors, perceived enjoyment is "the extent to which the activity of using technology is perceived to be enjoyable in its own right, apart from any performance consequences that may be" (p. 1113).

Bearing in mind the strengths and limitations of earlier conceptions of TAM, we adopted the TAM modifications by Davis et al. (1992) for use as a theoretical framework, then conducted a literature analysis of research on AR in order to examine K-12 students' behavioral intention to use AR in learning from the perspectives of students. The TAM framework (see Figure 1) assumes the user's behavioral intention to use a specific technology is influenced by both an intrinsic factor (perceived enjoyment) and extrinsic factors (perceived usefulness and perceived ease of use).

Figure 1

A Framework for Students' Acceptance of AR



Methods

Our literature search included three phases. In the first phase, guided by the research question on students' acceptance of AR in the K-12 contexts, we used keyword searches using terms such as "acceptance," "student acceptance," "augmented reality," "K-12 education," and "technology acceptance model" in leading educational databases (ERIC, Education Full Text, and Education: A Sage Collection) as well as the much broader collections in JSTOR. We found a total of 25 empirical journal articles. In the second phase, we scanned through all the articles to narrow them down by selecting those that used the TAM framework to analyze K-12 students' acceptance of AR and excluded articles that fell into the following criteria:(1) participants are not K-12 students; (2) research did not use TAM as framework to guide their study. Eight empirical articles, six quantitative studies and two qualitative studies, were identified as meeting final inclusion criteria. Of the seven studies, one explored kindergarten children's acceptance of AR, and the other six articles explored students' acceptance of AR in middle and high schools. Table 1 provides an overview of the seven studies, including elements such as participants, sample sizes, activities, technologies used, research methodology, and results. Finally, we conducted a thematic analysis of the seven empirical journal articles (Clarke & Braun, 2013), guided by the framework of the TAM. We gave specific attention to the impact of the three elements from our theoretical framework, perceived usefulness, the perceived ease of use, and the perceived enjoyment on K-12 students' intention of using AR in their learning.

Table 1

Basic Information of the Analyzed Studies

Author/Year	Participants	Sample Size	Activity	Technology	Methodology	Results
Balog & Pribeanu (2010)	8th graders	139	AR-based learning scenarios	ICI's platform	Started with an exploratory study to develop the instrument followed by a confirmatory factor analysis to test the validity and reliability of the instrument. The established instrument was used to test the hypotheses.	➢ PE on BI (β=0.26, t =2.50, p<.05) ➢ PEOU on BI (t =0.42, p >.05) ➢ PE and PU (β=0.43, t =4.99, p<.05)

Author/Year	Participants	Sample Size	Activity	Technology	Methodology	Results
Gopalan, et al. (2016)	Secondary school students	70	Science learning	Enhanced science textbook using AR	Adopted previously validated instruments and the questionnaire was adapted mainly from the Instructional Material Motivational Questionnaire II(SMQII). Data were analyzed through Pearson Correlation and Regression Analysis.	➢ PEOU on BI (t =1.06, p >.05) ➢ PE on BI (β = 0.22, t = 2.05, p <0.04)
Arvanitis et al. (2011)	12-17 years old	170	Visiting museums	Head-Mounted Display	The constructs of the model as well as the hypotheses were tested by Common Factor Analysis, Structural Equation Modelling, and Harman Single Factor Test. Latent Mean Analysis was used to test the moderating factors	➢ PEOU and PU (R^2=0.546, p<.05) ➢ PEOU and BI (R^2=0.4., p<.05) ➢ PU and BI (R^2=0.743, p<.05)
Huang, et al. (2016)	A senior-level high school	30	Early art education	A mobile AR application	Qualitative data was analyzed by content analysis (QCA)..	90.9% of them wanted to use AR for class activities again.
Di Serio, et al. (2013)	13-16 years old	55	A visual art compulsory course	A markerless tool	Qualitative data was collected by observation of students interacting with the AR learning environment, and post-experience interviews.	Students have high behavior intention to study in AR-based environment.
Wojciechowski & Cellary (2013)	14-16 years old	42	Chemistry curriculum	AR environment	Eleven hypotheses were formulated based on literature review. Step Wise Multiple Regression Analysis was conducted to test all the hypotheses.	➢ PE on BI (R^2=0.737, p<.05) ➢ PU and PEOU (R^2 =0.346, p<0.05) ➢ interface style and PEU (R^2 =0.346, p<.05) ➢ interface style and PU (R^2 =0.478, p<.05) ➢ interface style and PE (R^2 =0.368, p<0.05).
Yuniarto et al. (2018)	Secondary	140	Game	AR-based card game	Discriminant Validity, and Path Coefficients PLS Algorithms Analysis were used to test the model from literature review. Hypotheses were tested by Path Coefficients from Bootstrapping Analysis.	➢ PEOU on BI (t=4.02, p<.05) ➢ PU on BI (t=3.88, p<.05) ➢ PEOU and PU (t=7.99, p<.05)

Author/Year	Partici-pants	Sample Size	Activity	Technol-ogy	Methodology	Results
Juniawan et al. (2020)	7-9 years old	19	AR appli-ca-tions/sys-tems	Intro-duction of tradi-tional music instru-ments	Pearson Correlation Coeffi-cient Analysis and Regres-sion Analysis	➢ PEOU and PU (*R*=0.117, p<.05) ➢ PE and PU (*R*=0.206, *p*<.05) ➢ PEOU and PE (*R*=0.254, *p*<.05)

Findings

Three primary findings emerged from the analysis. First, K-12 students' behavioral intention to use (BI) AR was positively influenced by their perceived usefulness (PU), perceived ease of use (PEOU) and perceived enjoyment (PE), though PEOU was not a stable factor to influence BI. Second, researchers demonstrated the relationships among perceived enjoyment (PE), perceived usefulness (PU), and perceived ease of use (PEOU). Third, a secondary finding merited attention: AR interface design did not significantly influence learners' behavioral intention to use AR in their learning.

PU, PEOU, and PE Influence on BI

Theoretically, the modified TAM model (Davis et al., 1992) assumes that a user's perceived ease of use, perceived usefulness, and perceived enjoyment work together to influence the user's behavioral intention to use a technology. Our analysis found evidence to support this assertion in K-12 students' acceptance of AR. For example, Yuniarto et al. (2018) designed a card game based on AR technology to evaluate the extent of secondary students' acceptance of AR technology. The results demonstrated that PEOU exerted a significant effect on their BI (t=4.02, p<.05). It also indicated that PU exerted a significant influence on BI as well (t=3.88, p<.05). In order to explore the relationships among the factors of TAM, Balog and Pribeanu (2010) performed an experiment in which 139 eighth grade students participated in two AR-based learning scenarios (a biology scenario and a chemistry scenario). The results indicated that PE exerts positive effects on BI (β=0.26, t =2.50, p<.05). In line with Balog and Pribeanu (2010), Wojciechowski and Cellary (2013) also proved that PE was a significant predictor for BI (R^2=0.737, p<.05) after evaluating 42 secondary students' attitudes towards AR-based classes.

However, some researchers also found that PEOU was not a stable predictor for BI. For example, Balog and Pribeanu's (2010) study demonstrated that there was no significant relationship between PEOU and BI (t =0.42, p >.05). Similarly, Gopalan et al. (2016) used an AR-based science textbook to examine whether AR was useful to promote secondary students' interests in learning science. Their results suggested that PEOU exerted an insignificant influence on BI (t =1.06, p >.05). Arvanitis et al., (2011) argue that PEOU was not a stable factor for measuring users' acceptance due to "different technologies, applications and level of experience" (p. 6), and they further suggested that PEOU did not matter for students' acceptance of AR unless they perceive AR's usefulness in their learning.

Relationships between PEOU, PU, and PE

In addition to the influences of PEOU, PU, and PE on BI, researchers also validated the relationships between PEOU, PU, and PE. First, research demonstrated that PEOU shaped PU significantly. In the study of Yuniarto et al. (2018), 140 secondary students' data were used for an independent sample *t*-test to ascertain the extent to which students accept AR technology. The results of the analysis indicated statistically significant differences between the PEOU and PU (t=7.99, p<.05), suggesting that PEOU exerted a significant effect on PU. Juniawan et al. (2020) conducted a study on nineteen students aging from seven to nine years old to learn traditional music instruments in an AR-based system built on Android. The result also validated that PEOU and PU were positively correlated (R=0.117, p<.05).

In addition, students' perceived enjoyment (PE) was strongly correlated to their perceived ease of use and perceived usefulness. According to Balog and Pribeanu (2010), students' perceived enjoyment (PE) for the AR-based learning scenarios had a positive relationship with their perceived usefulness (PU) of such learning (β=0.43, t =4.99, p<.05). Wojciechowski and Cellary (2013) found that students' perceived enjoyment (PE) was significantly correlated with their perceived ease of use (PEOU) of the AR-based class (R^2 =0.346, p<0.05). Juniawan et al. (2020) also found that elementary students' PE was positively related to PEOU (R=0.254, p<.05), with PU (R=0.206, p<.05) after they engaged with the AR-based traditional music instruments. In the case study of Huang, et al. (2016), a series of AR-based art education activities were carried out for 30 kindergarten students. The results indicated that all the participants felt it was enjoyable to play with AR, and 90.9% of them wanted to play AR activities again. The researchers discovered that "[the students'] reactions to the AR-based animation was very different from those to seeing a plane printed on a piece of paper" (p. 891).

Secondary Findings: AR Interface Design and Students' Acceptance of AR

Multiple studies demonstrated that the AR interface design had no significant influence on students' acceptance of AR. According to Wojciechowski and Cellary (2013), the correlation between interface style and students' acceptance of AR was small, with interface style and PEU (R^2 =0.346, p<.05), interface style and PU (R^2 =0.478, p<.05), interface style and PE (R^2 =0.368, p<0.05). Di Serio et al. (2013) established AR-based art classes for secondary students, finding that the technical problems related to the images used in their AR did not influence students' use of AR. For example, a student commented that "the image is shaking, this is a little bit annoying but…I can continue" (p. 7). Similar comments from students included, "I notice that I have to maintain the picture centered but…it is fine" (p. 7), and "sometimes I lose the image. Nevertheless, it is easy to recover it" (p. 7).

Discussion and Conclusion

Based on the findings above, it appears that, overall, K-12 students have high behavioral intention to use AR in learning. They tend to have high perceived usefulness, high perceived ease of use, and high perceived enjoyment in AR-based learning, thus demonstrating a relatively high behavioral intention to use AR. However, it is crucial to realize that although some research indicates PEOU's positive influence on BI, other research also suggests that students' PEOU is not a stable predictor of their BI because of different technologies and different purposes during AR implementation.

Regarding the interrelations among the PU, PEOU, and PE, research indicates that students' PEOU has a significant impact on their PU. In addition, students' PE has a strong correlation with PEOU and PU. Perceived enjoyment is a pleasant emotional state which is positively related to "learning-related motivation, regulatory efforts, activation of cognitive resources and performance" (Frenzel et al., 2009, p. 705) and arouses the learners' interest to reengage the learning activities over time (Hidi, & Renninger, 2006).

Research suggests that AR-based learning, as a new pedagogical tool applied in K-12 education, has a demonstrated effectiveness in enhancing student learning. For example, AR-based learning can enhance cognitive processes and thinking skills of K-12 students (Jee et al., 2014). Students' social processes of collective knowledge construction are also enhanced during AR-based learning (Kose et al., 2013). From the perspectives of schools, AR-based learning has the potential to improve effectiveness because new forms of digital technologies can be helpful to improve outcomes of schools such as increasing students' examination results and retention rates (Darling-Hamond, et al., 2014; Ilomäki & Lakkala, 2018; Selwyn, 2016; Wong & Li, 2011).

Though the educational benefits brought by AR-based learning are promising and this study has demonstrated that K-12 students have high acceptance of AR-based learning, K-12 educators and administrators have to bear in mind digital equity and recognize the potential pitfalls of AR becoming an institutional tool to exacerbate prevailing inequities in K-12 schools (Reich, 2019). Digital inequity can manifest as inequitable access to technological infrastructures and devices, uneven activities and practices designed around technology, and overall inequitable issues in the social context of K-12 schools (Liu et al., 2018; Liu & Ball, 2019; Selwyn, 2016). As with any technological innovation, AR must inevitably confront issues of digital inequity. For example, Rideout and Katz (2016) conducted a nationally representative telephone survey of 1191 lower-income parents with children from 6 to 13 years old to find out how school-aged children in disadvantaged families use technology at home. It showed that though 94% of the surveyed families had access to the Internet, the quality of their online experience was not satisfying. The lower income families were more likely to have "service cutoff, slow service, older technology or difficulty using equipment because too many people sharing devices" (p.10). Though schools have made improvements in providing all students equal access to technology at home, access to technology alone does not shrink opportunity gaps (Howard et al., 2018). Students from families with lower income tend to live in communities where schools have more challenges in hiring and retaining teachers who are able to design high-quality instructional practices using technology (Alliance for Excellence in Education, 2016). As such, school and district administrators need not only to provide equitable distribution of AR equipment and software among schools, and but also professional development opportunities for their teachers to learn how to design and implement AR-based learning in their classrooms.

The National Center for Education Statistics conducted a survey (U.S. Department of Education, 2016) about the percentage of K-12 children in households with a computer. When examined in terms of the participants' race, ethnicity, and linguistic diversity, the data indicated inequities in access to technological devices such as desktop, laptop, netbook, or notebook computer, handheld computer or smart mobile phone. As Howard et al (2018) observed, "access to computers in public schools over the years has mirrored the disparities [by race/ethnicity]" (p. 20). As a result, schools that have high percentage of students coming from racially, ethnically, and linguistically diverse communities need more infrastructure support to implement AR. Classroom teachers play an important role in addressing digital equity while implementing AR-based learning. On the one hand, they need to have high expectations of their students and design intellectually challenging activities based on

AR for students regardless of their racial, ethnic, or linguistic backgrounds, avoiding inequitable practices toward diverse students such as the technical drilling, disciplinary scare tactics and social isolation identified by Monahan (2004). On the other hand, when teachers design AR-based learning that requires home support and parent involvement, they need to have alternative projects for students who might not have access to the technology or adult supervision needed to complete the assignments. As discussed earlier, AR implementation in K-12 classrooms should not be considered as the end goal. The ultimate goal should be fostering learning for all students.

Limitations

There are a variety of limitations to this study, the most significant of which is the lack of information in the reviewed studies placing the sampled students in a fuller social-political context. As Selwyn (2016) observes, "Education change is not a straightforward process. Not everyone benefits from an educational innovation in the same way, and from a more practical perspective, the consequences of educational change are often difficult to assess" (p. 35). Yet without knowledge of the students' racial, class, and gender positionality it is a challenge to explain the high acceptance of AR-based learning. For example, the acceptance levels could be due to the school serving a relatively wealthy student population with high accessibility to educational technology in general as well as highly trained and well-prepared teachers; students in less well-funded schools might not have similar access to technology and teacher expertise, feel less comfort with the basic elements of educational technology, and thus accept AR-based learning at lower levels. Moreover, this limitation is generalizable to the TAM model adopted in this study, which does not take into consideration important contextual factors such as school culture and the socio-economic status of students.

Second, there is a relatively small number of empirical studies on K-12 students' acceptance of AR, and the available research primarily focuses on secondary school students. More studies on K-12 students, especially elementary students, would broaden the current understanding of students' acceptance of AR in their learning. Third, most studies analyzed in this paper are quantitative, demonstrating a lack of qualitative perspectives that explore students contextualized, real-life experiences in using AR. Finally, the activities and practices in AR applications studied in this paper are primarily designed for science, art, and chemistry learning, revealing little about students' acceptance of AR in other subject areas such as literacy and social studies. These limitations, however, provide opportunities for researchers to further study K-12 students' acceptance of AR in order to bridge these gaps.

Nevertheless, this study has both theoretical and practical implications. Theoretically, this study further supports that K-12 students' behavioral intentions to use AR is influenced by their perceived usefulness, perceived ease of use, and perceived enjoyment. From the practical point of view, understanding K-12 students' AR acceptance will inform the AR-based learning design and implementation with specific attention to the three aspects: making the AR-based learning useful for the students' real-life learning, designing AR-based activities that are easy for the students to navigate, and making the learning process fun and enjoyable. By doing this, teachers are more likely to improve the successful implementation of AR and avoid resistance from the students in the K-12 contexts.

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