

Students' Experiences in Higher Education With Virtual and Augmented Reality: A Qualitative Systematic Review

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Abstract

Virtual reality involves 3-D computer graphics that are experienced using a desktop computer or advanced tools including head-mounted displays. Augmented reality is usually experienced on a mobile phone and involves combining real and computer-generated digital information. These platforms have been introduced into higher education settings, however, little is known about their impact on student learning. This meta-synthesis examines the experiences of higher education students with virtual and augmented reality. A thematic synthesis integrating qualitative evidence was undertaken where eight electronic databases were searched. Twenty-three articles met the inclusion criteria ($n = 1,334$ students) and were examined by two reviewers using a constant comparative approach. Four themes emerged: technological factors,

student characteristics, learning outcomes and recommendations. Our findings indicate there are factors to consider with these platforms as well as with the learners themselves when incorporating this technology in higher education.

Keywords: Higher Education; Virtual Reality; Augmented Reality; Systematic Review; Qualitative Research

Introduction

By 2020, there will be over 1 billion people accessing virtual reality (VR) and augmented reality (AR) (Davidge, 2017). This projection will lead to a production value between €15 billion and €34 billion in Europe and create up to 480,000 jobs (ECORYS, 2017). Similar trends are expected in Canada and United States, which are estimated to hold over \$6 billion (Statista, 2018c) and \$7.5 billion (Statista, 2018a) respectively of a worldwide market revenue worth \$209 billion by 2022 (Statista, 2018b). These statistics show how VR and AR have attracted a worldwide audience and have the potential to impact various sectors including education.

VR involves 3-D computer graphics used in conjunction with interface devices to create an interactive experience (Madathil, 2017). This experience with VR can take two forms: desktop which exposes users to 3-D multimedia simulations using a personal computer and immersive which provides a portable environment through head-mounted displays (Madathil, 2017). In contrast, augmented reality involves combining "real and computer-generated digital information into the user's view of the physical world in such a way they appear as one environment" (Olsson, Lagerstam, Karkkainen & Vaananen, 2013, p. 288). One example is PokémonGo where a mobile phone is used to catch Pokémon in real-world locations, such as parks and shopping centres (Niantic Incorporated, 2016).

VR headsets are accessible to the consumer market (Hollander, 2018), ranging from high-end (e.g., HTC Vive and Oculus Rift) to more affordable options like Google Cardboard. AR related sales are also expected to increase in the future (Statista, n.d.) and as such, it is important to understand the impact on higher education. After all, approximately 46 percent of higher education institutions in the United States are using these platforms (Hills-Duty, 2018), making it important to identify best practices.

Research has revealed that the learning curve associated with VR and AR has created an obstacle for educators (Castaneda & Pacampara, 2016). Students were also left to find their own solutions with these platforms, which led to "student in-class experts" (Castaneda & Pacampara, 2016, p. 532). This role reversal is not surprising given that video games represent the largest industry involved in VR and AR (Statista, 2018d) and therefore provide an opportunity for practice outside of school.

In this article, we synthesize and critically interrogate the qualitative research on higher education students' experiences with VR and AR. The use of qualitative research methods is suggested when little is known about a phenomenon (McLeod, 2001). Given the recent emergence of VR and AR in education, a focus on qualitative findings is a logical first step. Qualitative strategies allow investigators to develop an understanding of social phenomena (Tong, Morton, Howard, & Craig, 2009). Metasyntheses of research findings also allow investigators to develop a deeper appreciation of a topic than can be obtained from a single study (Erwin, Brotherson, & Summers, 2011). To our knowledge, no previous authors have published a metasynthesis on this topic.

Qualitative research findings can inform evidence-based practice (Grypdonck, 2006), which is important in order to provide student-centered teaching and learning. Evidence-based practice is not always evident in the classroom. Consider learning styles, which suggest individuals have a preference in terms of how they learn and teaching students according to this learning style will lead to better performance (Newton, 2015). This matching between teaching and learning style has been labelled a "neuromyth" (Dekker, Lee, Howard-Jones & Jolles, 2012), although, this thinking is still prevalent among educators (Newton & Miah, 2017). This thinking might pigeonhole learners while reinforcing inaccurate beliefs about how the brain processes information.

Theoretical Perspective

We examine VR and AR in terms of the implications for higher education learning. We examine these platforms in the context of learning preferences rather than learning styles as part of a larger framework consistent with Universal Design for Learning (UDL; see Meyer, Rose, & Gordon, 2014). There is a need to incorporate UDL principles, which make learning accessible through the activation of three brain networks: affective, recognition and strategic (National Center on Universal Design for Learning, 2015). The affective network provides multiple ways of engaging students, such as by setting clear learning outcomes. The recognition network provides multiple representations for students, such as auditory and visual. Finally, the strategic network provides multiple ways of expression, such as written or verbal (National Center on Universal Design for Learning, 2015). Together, these networks address different aspects of learning: why (affective), what (recognition) and how (strategic) (British Columbia Ministry of Education, 2017).

Methods

Search Strategy

The first author developed a search strategy in consultation with a college librarian. The following databases were searched: ERIC, Academic Search Premier, PubMed, ProQuest, MEDLINE (OVID), Healthstar, Web of Science and Google Scholar. The search strategy involved the following terms with the use of modifiers: virtual reality OR desktop reality OR immersive reality AND augmented reality AND qualitative research OR focus group OR interview OR ethnography OR phenomenology OR grounded theory OR hermeneutics AND college OR university OR higher education. This search strategy was completed as part of an advanced search where these terms had to be located in the abstract of an article. Reference lists of included articles were also searched.

The inclusion criteria involved: peer-reviewed published research between 1990 and 2018 focusing on the experiences of higher education students; article focused on students' experiences with VR or AR; article focused on implications for education including benefits and challenges of these platforms or learning contributions; and qualitative design was used for data collection and analysis. Articles containing only quantitative data, opinions, editorials, content analysis, teachers' perspectives, discussions about virtual (online) environments, case studies or unpublished work were excluded.

The first author and the librarian conducted the literature search where 3,787 articles were identified. Next, the first and second authors reviewed the titles and abstracts of these articles. After removing the duplicates and applying the inclusion criteria, 88 articles were read in full by the first and third authors in

discussion with the second author. All authors agreed 23 articles met the inclusion criteria.

Analytical Approach for Review and Synthesis

The analytic approach adopted included structured abstraction (Tong et al., 2009) and narrative synthesis (Petticrew & Roberts., 2005). The third author read each article and summarized the key characteristics of each study in tabular format. Data were abstracted and compiled by the third author and independently verified by the first author (Tong et al., 2009). The findings were then synthesized in three stages using narrative synthesis guidelines (Petticrew & Roberts, 2005; Saini & Shlonsky, 2012). In the first stage, studies were organized into categories, which represented the reason for incorporating VR and AR including teaching students new skills or exploring these platforms.

In the second stage, findings were analyzed within sub-categories including pros and cons of using VR and AR as well as the type of learners to benefit from these platforms. This second stage allowed a profile to be created about the platform or students themselves, with remarkable similarities across articles. These similarities are attributed to the "newness" of these platforms within education and as such, authors are interested in similar questions, such as how the technology works and what students liked or disliked.

The last stage involved synthesizing findings across all studies with a focus placed on how the profile of the platform or students was consistent with UDL principles. Specifically, we mapped our findings to the affective, recognition, and strategic networks to determine how VR and AR is consistent with UDL principles.

Four primary themes emerged from the narrative synthesis process. The themes include technological factors, student characteristics, learning outcomes, and

recommendations. All studies included in this review contributed to the development of these themes and exemplars (representative quotations) were recorded.

Analytic Reliability and Source Appraisal

During the analytic process, we adopted two aspects integral to the use of consensual qualitative research methods (Hill, Thompson, & Williams, 1997). These aspects included resolving discrepancies by discussion and consensus and establishing reliability via the use of "investigator triangulation" (Carter, Bryant-Lukosius, DiCenso, Blythe, & Neville, 2015). The first and third authors independently coded the data with discrepancies resolved through discussion. The second author audited the review and synthesis process, and served as final check on the abstraction, categorization and thematization of data.

The quality of included studies was appraised using the Critical Appraisal Skills Programme (Critical Appraisal Skills Programme International, 2010). The first and third authors made notes about each item, which were verified by the second author. Discrepancies were resolved by discussion. Research quality was generally good with no article excluded from our analysis.

Results

Characteristics of Included Studies

Twenty-three articles were identified in our search (see Appendix for an overview of the characteristics of each study). The included studies involved 1,334 students (30% males and 70% females). Most studies focused on students at the undergraduate level ($n = 13$), followed by graduate level including pre-service teacher training and Master's degree or higher ($n = 10$). Students

represented a range of academic areas including education, engineering, nursing, computer science and social work. The majority of the studies ($n = 11$) involved samples from the United States, followed by Turkey ($n = 4$), United Kingdom ($n = 2$) and one in each of the following: Australia, Columbia, Finland, Israel, Japan and Taiwan. The majority of the studies ($n = 17$) involved VR, followed by AR ($n = 4$) and "mixed reality" where VR and AR were blended together ($n = 2$).

Four themes emerged: technological factors (usability and functionality), student characteristics (demographics and academic background), learning outcomes (hard skills, soft skills and essential skills) and recommendations (theoretical framework and applications). Representative quotations from each theme are provided in Table 1.

Table 1. Representative Quotations from Themes

Theme	Quotation
Technological Factors	<p>"I am able to operate this system at home or at school. Even on the way to school in traffic, I can do it, too. This is very convenient" (Chao et al., 2016, p. 248).</p> <p>"I really was amazed at how much I had learned about navigating in Second Life through my several attempts earlier in the month...I can see how I am progressing from novice to advanced beginner!" (Benham-Hutchins & Lall, 2015, p. 407).</p> <p>"The virtual participants were able to talk to us, jump, wave, type information. Giving the avatars these human qualities...made me feel like I was communicating with my classmates face-to-face" (Bower et al., 2017, p. 420).</p>

<p>Student Characteristics</p>	<p>"It was, indeed, good. But generally this kind of technologies do not draw my interest" (Yildirim et al., 2018, p. 65).</p> <p>"Because of my inarticulateness, I cannot explain my works well. Now by using this system, I could prepare my illustration information and combine it with my works in advance. This is great to me" (Chao et al., 2016, p. 248).</p> <p>"I would learn a whole lot more if I was actually physically in the room" (Ausburn et al., 2009, p. 72).</p>
<p>Learning Outcomes</p>	<p>"It will be easier and more convenient for students to think in 3D. The geometry lesson will no longer be a nightmare" (Onal et al., 2017, p. 159).</p> <p>"It was perfect...I don't know where to start really. First of all it was good to meet others. Often you learn alone, usually at home, reading the text and thinking about things, on your own" (Edirisingha et al., 2009, p. 466).</p> <p>"...it allows students to use multiple senses, diverse materials, and to be active and autonomous in the classroom" (Can & Simsek, 2015, p. 121).</p>
<p>Recommendations</p>	<p>"There are pros and cons. It's always good to experience new concepts/technology to expand one's knowledge base. I see how it would/could be interesting to implement in the classroom" (Gregory & Masters, 2012, p. 433).</p> <p>"...summing up my remarks and rationale, I want to convey through the VR creation that 'knowledge is power' and therefore we need to explore, to discover, and experiment with everything that goes on around us" (Nissim & Weissblueth, 2017, p. 57).</p> <p>"...I learned how to control and navigate my avatar...There are videos and simulations that you can show your class. If used effectively it could be beneficial to help teach students a topic" (Bahng & Lee, 2017, p. 233).</p>

Theme 1: Technological Factors

Seventeen studies involved themes related to the platforms themselves where students discussed issues related to usability and functionality (see studies 1-10, 13-14, 16-17, 20, 21, 23 in Appendix). This theme relates to UDL principles, specifically, the affective network where these platforms create highly engaged learners. Through the use of 3-D graphics, interactive design and clear instructions, these platforms can enhance higher education learning.

Usability. Students described a range of experiences related to the usability of VR and AR. Some experiences were negative, particularly when students first learned how to use these platforms (Alizadeh, Mehran, Koguchi, & Takemura, 2017; Ausburn, Martens, Washington, Steele, & Washburn, 2009; Bahng & Lee, 2017; Benham-Hutchins & Lall, 2015; Bower, Mark, Lee, & Dalgarno, 2017; Chien, Davis, Slattery, Keeney-Kennicutt, & Hammer, 2013; Edirisingha, Nie, Pluciennik, & Young, 2009; Maher, Schrader, Ormond, & Kerr, 2015). One student explained: "At first, it was very difficult to find my way around and maneuver my robot [avatar]. As I continued exploring Second Life, I was able to find very interesting icons that allowed me to get around a lot easier" (Bahng & Lee, 2017, p. 231). Some struggled with the fast-paced, interactive elements: "...when you want to say something, and by the time you typed it out, they [other participants] have changed the subject...It takes time to get used to it" (Edirisingha et al., 2009, p. 472). Others complained about the quality of the audio, especially when live streaming into a virtual world (Bower et al., 2017) while others had hardware issues: "As I didn't have my own PC and I couldn't follow the lessons regularly" (Can & Simsek, 2015, p. 121). Despite the challenges, some students persevered and appreciated the value-added of these platforms (Chen, 2014; Chao, Chang, Lan, Kinshuk, & Sung, 2016; Onal, Ibili, & Caliskan, 2017). Other students got frustrated and wanted to return to familiar practices (Alizadeh et al., 2017; Nadolny, Woolfrey, Pierlott, Kahn, 2013; Ochoa-

Alpala & Ortiz-Garcia 2018). One student explained: "I would have much preferred doing a report" (Nadolny et al., 2013, p. 991).

Functionality. Students described the functional elements of VR and AR critical to learning. Some students focused on engagement: "Our attention can be lost quickly but here, there is not such possibility because you are in it, you totally live" (Yildirim, Mehmet, & Yildirim, 2018, p. 66). Other students enjoyed the 3-D representation allowing them to learn about subjects, such as geometry and engineering in new ways (Onal et al., 2017; Toh, Miller, & Simpson, 2015). As an example: "[virtual dissection] takes it apart faster and you don't have the parts flying off" (Toh et al., 2015, p. 64). Interestingly, these platforms were not only used to improve teaching and learning, but also the evaluation of work. One student described using augmented reality for this purpose: "There were no classmates beside when I assessed works by using this system...blind assessment could make me tell the truth" (Chao et al., 2016, p. 248). Students also appreciated the ability to role play and engage in simulation exercises (Bahng & Lee, 2017; Benham-Hutchins & Lall, 2015; Can & Simsek, 2015; Chao et al., 2016; Speed, Bradley, & Garland, 2015). For all the elements students liked, there were elements they did not enjoy including the graphics and artificial nature of virtual worlds (Yildirim et al., 2018). One student explained: "you don't see the real face. It is the avatar. You don't hear the voice...These are missing so it is a very neutral environment" (Edirisingha et al., 2009, p. 475).

Theme 2: Student Characteristics

Fifteen studies involved themes related to the characteristics of the learners including demographic information and academic background (see studies 2-4, 6-7, 11-12, 14-17, 19, 21-23 in Appendix). This theme relates to UDL principles, specifically, the recognition network where these platforms create knowledgeable

learners. Through the use of visual, auditory and kinesthetic cues, VR and AR make learning accessible and thus, inclusive to learners.

Demographic information. Some students reported having no previous experience using VR and AR, which affected their attitudes (Onal et al., 2017; Yildirim et al., 2018). One participant described: "I do not know, maybe, it is because I used it the first time but I found it scary" (Yildirim et al., 2018, p. 65). Gender differences were also reported with women being less receptive to these platforms and more likely to downplay previous gaming experience (Ausburn et al., 2009). Some students emphasized the need to be open-minded with these platforms as well as with the overall learning (Nissim & Weissblueth, 2017; Reinsmith-Jones, Kibbe, Crayton, & Campbell, 2015). One student shared her reaction after walking through the Holocaust museum in Second Life: "I do not think that I would be able to be as strong as the people nor be able to live each day of my life in fear while worrying about my family and friends" (Reinsmith-Jones et al., 2015, p. 103). Given the self-paced nature of virtual worlds, some students benefitted most from this learning: "Because you can reach that environment anytime and from anywhere it is definitely positive, especially in individualized learning..." (Can & Simsek, 2015, p. 121). These platforms also encouraged self-reflection as described by a student using augmented reality: "I am not good at memory, and I forgot things quickly. The information showed on the works can be read repeatedly by me" (Chao et al., 2016, p. 248). Perhaps because of differences in background, students could not agree even when trained on the same platform: "The training process was not easy for me because I did not know the software" (Onal et al., 2017, p. 157) versus "The training provided was very efficient...It's easy to use once one listens carefully to what is explained" (Onal et al., 2017, p. 157).

Academic background. Students represented a range of academic

backgrounds, which impacted their receptiveness to these platforms. Those in the health sciences seemed most familiar with VR and AR based on their exposure to virtual worlds and patient simulations (Ausburn et al., 2009; Benham-Hutchins & Lall, 2015; Keskitalo, 2012). Pre-service teachers were also exposed to these platforms frequently (Can & Simsek, 2015; Gregory & Masters, 2012; Nissim & Weissblueth, 2017; Onal et al., 2017; Turk, Kalkan, & Yildirim, 2017), however, this training was inadequate at times. One pre-service teacher explained: "This made me realize that in my three hours of investigating this virtual world, I had only experienced a glimpse..." (Bahng & Lee, 2017, p. 231). Some students were receptive to these platforms because they were in technology friendly fields, such as engineering and computer science whereas other students struggled with the relevance of these platforms (Nadolny et al., 2013; Ochoa-Alpala & Ortiz-Garcia2018; Toh et al., 2015).

Theme 3: Learning Outcomes

Thirteen studies involved themes related to learning outcomes where students discussed the skills they developed while using VR and AR (see studies 1, 3, 5-6, 10, 12, 14-19, 23 in Table 1). Hard skills involve technical know-how, such as how to use a mobile app while soft skills relate to people, such as being a good communicator (ACCES Employment, 2018). Together, these skills create essential skills, which allow individuals to maintain employment (ACCES Employment, 2018). This theme relates to UDL principles, specifically, the recognition network where these platforms create resourceful learners. That is, VR and AR provide students with the opportunity to practice their skills, which in turn, increase their job readiness.

Hard skills. VR and AR were used to develop a variety of hard skills. As an example, students who were learning English used the augmented reality app, BlippAR to make their poster presentation interactive (Alizadeh et al., 2017).

Another study with English learners involved a virtual world, Machinima, which was used to practice their language skills: "When we record ourselves and listen there is a chance to delete, be aware when the words are mispronounced and if necessary to record it again" (Ochoa-Alpala & Ortiz-Garcia, 2018, p. 50). Other students used VR to learn about history: "...Egyptian Pyramids are in one of the Seven Wonders of the World but how much opportunity do we have to go and see those...if Ancient Pyramids are shown with VR technologies, I can visit those places...I can learn information" (Yildirim et al., 2018, p. 67). Even challenging academic subjects benefitted from the use of these platforms: "Students can see the objects more easily by seeing them in 3D. It can make the lessons more fun and make the students more active" (Onal et al., 2017, p. 159). Overall, these experiences helped students to practice their technical skills while building self-efficacy: "My confidence at first was shattered...really I didn't understand anything...after I practiced and gained a little patience then it didn't seem so bad" (Bahng & Lee, 2017, p. 231).

Soft skills. Students reported improvements in soft skills as a result of interacting with other users. In the virtual world, Second Life, a pre-service teacher reported: "A friend of mine who has never spoken to me in the class face to face asked me a question in SL for help, this was very interesting to me" (Can & Simsek, 2015, p. 121). Another study using the virtual world, TransGen Island taught students about ethical issues while encouraging them to think critically: "I believe the SciEthics definitely pushed me outside of my comfort zone, which is something that I should expect when I am involved in higher education" (Nadolny et al., 2013, p. 991). Other students described the independence afforded by these platforms as well as the need to work through challenging situations (Can & Simsek, 2015; Nissim & Weissblueth, 2017). One student described: "I think VR can help students think positively and not give up" (Nissim & Weissblueth, 2017, p. 56). Ultimately, students described improved

perspective-taking (Reinsmith-Jones et al., 2015) while feeling part of a learning community (Bower et al., 2017; Edirisingha et al., 2009; Pan & Steed, 2017). One student explained: "I felt like part of the group more than when I was studying from home" (Edirisingha et al., 2009, p. 466).

Essential skills. Through the development of hard and soft skills, students reported VR and AR prepared them for their careers. One example was reported in healthcare with ENVI, which is a mixed reality environment where students practice their clinical skills (Keskitalo, 2012). One student explained: "It is nice that we can practise in a simulated situation before being with real patients" (Keskitalo, 2012, p. 848). Other students discussed the importance of these platforms in terms of keeping knowledge relevant: "I think it develops different ways of thinking, and it also allows self-study...the use of technology prepares us for the future" (Nissim & Weissblueth, 2017, p. 57). Finally, these platforms encouraged students to reflect on challenging social circumstances: "The video about racial discrimination at [that company] was eye opening. It shows that racism is still prevalent, even in the job force..." (Reinsmith-Jones et al., 2015, p. 102).

Theme 4: Recommendations

Five studies involved themes related to recommendations where students described the impact of theoretical frameworks and applications of these platforms (see studies 3, 9-11, 15 in Table 1). This theme relates to UDL principles, specifically, the strategic network where these platforms create goal-directed learners. By providing guidelines about how VR and AR will enhance learning, students make connections with the material while using different means of expression.

Theoretical frameworks. Some studies used a theoretical framework in which to understand the learning with VR and AR. These frameworks involved communities of practice (Wenger, 1998), dialogic inquiry (Wells, 2000), cognitive interactionist theory (Long, 1981, 1983), Currere approach (Pinar, 2004), five-stage model (Salmon, 2004), six thinking hats framework (de Bono, 1985) and self-efficacy theory (Gist & Mitchell, 1992). Studies using a theoretical framework included learning objectives for these platforms, which produced rich learning experiences: "We got space suits and saw the moon. This was the first place we landed...we're learning how to communicate with each other and explore...We fell from the cloud... and walked on the sea floor. We learned about using angles" (Bahng & Lee, 2017, p. 231). The learning from virtual worlds also transcended the classroom: "...I will spend most of my time educating the public on what has been accomplished and formulating awareness tactics that will allow the public to understand how to continue to prevent these devastating situations from reoccurring" (Chien et al., 2013, p. 213). The studies using a theoretical framework also used multiple data collection techniques including journaling, peer teaching, surveys, interviews and observations (Bahng & Lee, 2017; Chien et al., 2013; Edirisingha et al., 2009; Gregory & Masters, 2012; Nissim & Weissblueth, 2017). One student described the self-reflection afforded by journaling: "The biggest changes will be as I plan for my future. I feel a sense of duty and urgency to talk about issues with my students" (Chien et al., 2013, p. 213).

Applications. Despite the enthusiasm, students described that these platforms did not apply to all learning scenarios. Students involved in virtual dissection stated: "On the computer, everything happens quickly, but going step-by-step and physically moving the parts and feeling them, how rigid they are and how things snap or fit together I think is very valuable" (Toh et al., 2015, p. 64). Another example where students appreciated real-world learning is described by

pre-service teachers: "I don't see myself using this [Second Life] in the future. I just don't like the fact a computer is teaching children rather than face-to-face" (Gregory & Masters, 2012, p. 432). Furthermore, pre-service teachers were also concerned about a saturation effect: "I don't think that it will work...they will also get bored if they use it all the time" (Gregory & Masters, 2012, p. 432). Still yet, students believed VR and AR have their purpose by making learning meaningful (Nissim & Weissblueth, 2017; Onal et al., 2017; Yildirim et al., 2018). One student explained: "People can forget what they write, can also forget what they listen to, but do not easily forget what they live. This is indeed a kind of living" (Yildirim et al., 2018, p. 66).

Discussion

The purpose of this article was to synthesize and critically interrogate the qualitative research about higher education students' experiences with VR and AR. Using UDL principles as our theoretical framework, we examined how students' experiences mapped onto the affective, recognition and strategic networks. We identified four themes: technological factors, student characteristics, learning outcomes and recommendations.

The first theme involved technological factors, which corresponded to the affective network or "why" of learning. This theme had two sub-themes involving usability and functionality. Our synthesis showed students struggled at first to use VR and AR. However, with practice, students were able to use these platforms as evidenced by their navigation of avatars and ease with which they used mobile apps for AR. Interestingly, our results confirm the pattern reported for further and compulsory education, such that desktop VR is more common than immersive (Madathil, 2017). This popularity can be explained by costs, but with VR headsets accessible to the consumer market, immersive VR is expected

to increase in popularity. As an example, *Second Life*, which was the most prominent virtual world featured in our review was introduced to personal computers in 2003, but now offers an immersive option (Metz, 2017). Another reason for the popularity of desktop VR could be gaming experience, which may reduce the learning curve associated with these platforms. This aspect about desktop VR is attractive because higher education faculty may not receive training with these platforms as we reported among pre-service teachers. Thus, it is incumbent on faculty to create a community of practice and thereby, make these platforms accessible, particularly to areas like social sciences that were lacking representation in our paper.

The second theme involved student characteristics, which corresponded to the recognition network or "what" of learning. This theme had two sub-themes involving demographic information and academic background. Our synthesis showed students represented a range of backgrounds from no experience to extensive practice with video games and mobile apps. Some studies did not examine this prior experience, which may have impacted on some students' willingness to engage with these platforms. For teaching purposes, we recommend instructors do a learning check, which is similar to the "pre-assessment" in the BOPPPS Model where the lesson starts by understanding what students already know about the topic (University of British Columbia, 2017). In this pre-assessment, it is also important for instructors to address misconceptions related to these platforms. These misconceptions were found in the study by Ausburn et al. (2009), which reported evidence of technophobia among female undergraduates. Technophobia involves a "fear or dislike of advanced technology or complex devices and especially computers" (Merriam-Webster, n.d.) and has been reported in older adults (Hogan, 2008). These group stereotypes need to be addressed in a classroom setting as they can potentially lead to a stereotype threat where targeted groups will underperform

on tasks (American Psychological Association, 2018). By understanding the profile of learners, educators can determine the amount of scaffolding needed and potentially reduce the number of issues reported with the platforms themselves.

The third theme involved learning outcomes, which corresponded to the recognition network or "what" of learning. This theme had three sub-themes involving hard skills, soft skills and essential skills. Our synthesis showed these platforms could enhance a range of skills including English fluency, 3-D manipulation and historical knowledge while developing social-communication and computer literacy. Research examining the top employability skills revealed soft skills, such as communication and teamwork are ranked highest in the workplace (University of Kent Careers and Employability Service, 2017). Interestingly, VR and AR have the ability to develop skills through near and far transfer. Near transfer involves learning in situations similar to the original learning context while far transfer involves situations where the original learning and the transfer event are different (Laker, 1990). After practicing with these platforms, students are able to use VR and AR applications more easily (near transfer) while showing improved verbal communication skills (far transfer). Interestingly, when the transfer appeared to be far from the task, such as improving English skills (e.g., Alizadeh et al., 2017; Ochoa-Alpala & Ortiz-Garcia, 2018), students struggled to appreciate the relevance of these platforms. It is therefore suggested educators be explicit with the instruction provided to students including the learning outcomes associated with these platforms.

Finally, the last theme involved recommendations, which corresponded to the strategic network or "how" of learning. This theme had two sub-themes involving theoretical framework and application. Our synthesis showed articles using a theoretical framework provided more structured learning and varied ways for

students to express themselves. This learning also appeared to be qualitatively different than studies not using a theoretical framework, such that students were encouraged to take action. This learning resonates with Maslow's Hierarchy of Needs where at the highest level is self-actualization where individuals are encouraged to think beyond themselves (Maslow, 1943). Interestingly, VR is increasingly being used to foster empathy about the plight of others including *Clouds Over Sidra*, which was developed by the United Nations to educate decision-makers about the Syrian refugee crisis (United Nations, 2015). Despite the usefulness of these platforms, there is still a lack of selectivity plaguing the use of VR and AR. That is, there is a sense the technology is available and therefore, should be used indiscriminately. This was shown in the fact that very few studies we reviewed made reference to a theoretical framework (Bahng & Lee, 2017; Chien et al., 2013; Edirisingha et al., 2009; Gregory & Masters, 2012; Nissim & Weissblueth, 2017), which served to guide teaching and learning. The consequence of not having a theoretical framework was that some students were more likely to extract the "edutainment" quality of these platforms (e.g., Alizadeh et al. 2017) rather than see them as a legitimate learning opportunity. This lack of selectivity can also lead to a saturation effect (Gregory & Masters, 2012), such that too much exposure to VR or AR can lead to boredom and even a lack of buy-in on the part of learners.

Our review has several limitations to address in future research. First, the studies examined more applications of VR than AR. More research is needed to understand the challenges and benefits of AR and the learners most likely to benefit from this platform. This is particularly important given research showing 86 percent of higher education students own a smart phone (Chen, Seilhamer, Bennett, & Bauer, 2015). Our review also examined the experiences of students. More research should be done to examine teachers' experiences with these platforms and whether their experiences corroborate with those of students.

Our review revealed VR and AR have the ability to engage higher education learners. However, these platforms cannot be used as a one size fits all model. That is, educators have to have a clear sense of how these platforms add but critically, do not replace traditional teaching and learning practices. Thus, there are factors to consider with these platforms as well as with the learners themselves when incorporating this technology at the higher education level.

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Appendix. Summary of Qualitative Studies

Author, Year (Country)	Sample Characteristics	Objective	Method	Analysis	Main Findings	Themes
(1) Alizadeh et al. 2017 (Japan)	71 humanities students at the undergraduate level; 35 males and 36 females; age ranged from 18 to 22 years	Evaluate the effectiveness of an augmented reality app, BlippAR to improve English language skills	Data collected through user experience questionnaire, open-ended feedback form, and observation of respondents' attitudes	Content Analysis	Responses covered topics related to user experiences with this app and improvement to language skills	Technological factors; learning outcomes
(2) Ausburn et al. 2009 (USA)	42 surgical technology students; 6 males and 36 females; age ranged from 18 to 26 years	Evaluate the effectiveness of using desktop virtual reality to practice surgical skills	Data collected using interviews	Content Analysis	Responses covered topics related to user experience and gender differences in surgical navigation	Technological factors; student characteristics
(3) Bahng & Lee, 2017 (South Korea)	229 elementary teacher candidates; 24 males and 205 females	Examine the experiences of students using the virtual reality platform, Second Life	Data collected through semi-open-ended questionnaire, science journal notebooks, science lesson plans, peer teaching classroom observations, and instructor semester notes	Thematic Analysis	Themes identified: (1) playing around as avatars, (2) learning by discovery, (3) learning by social interaction, (4) skeptical integrators, (5) observant integrators, and (6) innovative integrators	Technological factors; student characteristics; learning outcomes; recommendations
(4) Benham-Hutchins et al. 2015 (USA)	20 nursing students at the graduate level; 2 males and 18 females; age ranged from 21 to 59 years	Describe the experiences of students using the virtual reality platform, Second Life	Data collected using journal entries and user experience questionnaire	Thematic Analysis	Themes identified: (1) mastering Second Life, (2) technological challenges, (3) social interaction, and (4) knowledge dissemination	Technological factors; student characteristics
(5) Bower et al. 2017 (Britain)	45 pre-service teacher candidates	Describe the experiences of students using a blended (mixed) reality environment	Data collected using open-ended survey and focus group	Content Analysis	Responses covered topics related to pedagogical, technological and logistical factors	Technological factors; learning outcomes

		where audio and visual are lived streamed into a virtual world				
(6) Can & Simsek, 2015 (Turkey)	26 undergraduate foreign language pre-service teacher candidates; 10 males and 16 females	Describe the experiences of students using the virtual reality platform, Second Life	Data collected using survey and semi-structured interview	Content Analysis	Responses covered topics related to likes and dislikes, effect of learning, and learning applications	Technological factors; student characteristics; learning outcomes
(7) Chao et al. 2016 (Taiwan)	50 sophomore students in the culinary department of a technical institute	Examine how augmented reality can be used in a student performance assessment	Data collected using survey and interview	Content Analysis	Responses covered topics related to the attitudes about peer assessments and helpfulness of mobile performance assessments	Technological factors; student characteristics
(8) Chen, 2014 (Ireland)	9 undergraduate students studying English as a foreign language	Examine language strategies and experiences using the virtual reality platform, Second Life	Data collected using journal entries and survey	Thematic Analysis	Themes identified: (1) factors affecting virtual learning, (2) attitudes toward learning English via avatars, and (3) beliefs about the effects of task-based instruction	Technological factors
(9) Chien et al. 2013 (USA)	31 education students at the graduate level	Explore how the virtual reality platform (Second Life) curriculum reflects the participants' perceptions and practices on teaching	Data collected using virtual observations; virtual reflective writings; individual Currere writings; interview	Content Analysis	Responses covered topics related to four stages: (1) regressive, (2) progression, (3) analysis, and (4) synthesis	Technological factors; recommendations
(10) Edirisingha et al. 2009 (Britain)	4 undergraduate students in archeology	Examine how the virtual reality platform, Second Life can facilitate social presence and foster	Data collected using interview, in-world observations of learning, and analysis of chat logs	Thematic Analysis	Themes identified: (1) nature of in-world socialization, (2) 'meeting' others, (3) perception of 'exploratory' learning, and (4)	Technological factors; learning outcomes; recommendations

		socialization among distance learners			process of socialization	
(11) Gregory & Masters, 2012 (USA)	96 pre-service teachers; 22 males and 74 females	Examine whether the virtual world, Second Life is a feasible educational tool to be incorporated into a repertoire of resources	Data collected using observation, survey, and online dialogue	Content Analysis	Responses covered topics related to the advantages and disadvantages of using a virtual world for learning	Student characteristics; recommendations
(12) Keskitalo, 2012 (Finland)	97 undergraduate healthcare students	Examine expectations regarding the use of mixed reality where the physical environment and simulation manikins are combined	Data collected using questionnaire	Content Analysis	Responses covered topics related to the age of students and their expectations for learning	Student characteristics; learning outcomes
(13) Maher et al. 2015 (USA)	graduate students from a Multimedia Learning Studio; age ranged from 36 to 55 years	Examine the effectiveness of full dome planetarium software and VR headsets	Data collected using questionnaire	Content Analysis	Responses covered topics related to utility and functionality	Technological factors
(14) Nadolny et al. 2013 (USA)	53 undergraduate students from various academic backgrounds including science, engineering and computer science	Examine the application of virtual reality in ethics education	Data collected using survey and interview	Content Analysis	Responses covered topics related to student experiences with the platform and learning outcomes	Technological factors; student characteristics; learning outcomes
(15) Nissim & Weissblueth, 2017 (Israel)	176 students training to become elementary or secondary school teachers	Explore the experiences of pre-service student teachers in a teaching unit involving virtual reality	Data collected using free reflections written by students	Thematic Analysis	Themes identified: (1) learning processes become entertaining, (2) better understanding of technology, (3) creative learning, (4) interest in technology, (5)	Student characteristics; learning outcomes; recommendations

					problem solving, (6) stamina, and (7) learning in real life	
(16)Ochoa-Alpala & Ortíz-García, 2018 (Columbia)	60 undergraduate students from various academic backgrounds; age ranged from 19 to 24 years old; 23 females and 37 males	Examine the relationship between the creation of real life and virtual videos, and the development of oral presentation skills	Data collected using survey, interview and student work	Content Analysis	Responses covered topics related to student experiences with the technology and learning outcomes	Technological factors; student characteristics; learning outcomes
(17) Onal et al. 2017 (Turkey)	40 elementary mathematics teacher candidates; 29 females and 11 males	Examine the effect of augmented reality technology on geometry teaching	Data collected using semi-structured interview forms	Thematic Analysis	Themes included: (1) attitudes towards usage, (2) learning and (3) implementation	Technological factors; student characteristics; learning outcomes
(18) Pan & Steed, 2017 (United Kingdom)	48 undergraduate students; age ranged from 18 to 42 years; 24 females and 24 males	Examine the effect of a self-avatar on collaborative outcomes in a shared virtual environment	Data collected using questionnaire	Content Analysis	Responses covered topics related to student experiences with technology and learning outcomes	Learning outcomes
(19) Reinsmith-Jones et al. 2015 (USA)	70 undergraduate students in social work	Examine the educational value of virtual reality platform, Second Life in an Introduction to Social Welfare and Social Work class	Data collected using survey and reflective journaling	Thematic Analysis	Themes identified: (1) emotion, (2) empathetic understanding, (3) critical thinking, and (4) effects on personal behavior	Student characteristics; learning outcomes
(20) Speed et al. 2015 (USA)	9 graduate students in creative studies	Examine the impact of TeachLivE simulation on ability to effectively manage behaviors in facilitation sessions	Data collected through a feedback form, survey and observation	Thematic Analysis	Themes identified: (1) confusion and concern over TeachLivE, (2) pedagogical response to learning, and (3) perception of the "resource group" as an entity	Technological factors

(21) Toh et al. 2015 (USA)	33 undergraduate students in engineering; 23 males and 10 females	Examine the effect of a virtual product dissection on learning	Data collected using survey, focus group and interview	Content Analysis	Responses covered topics related to the advantages and disadvantages of virtual dissection	Technological factors; student characteristics
(22) Turk et al. 2017 (Turkey)	100 pre-service science teachers	Examine the effects of teaching about the seasons using virtual reality or physical models	Data collected using an open-ended question form	Content Analysis	Responses covered topics related to the pros and cons of using virtual reality over physical models	Student characteristics
(23) Yildirim et al. 2018 (Turkey)	25 undergraduate students in history; 12 males and 13 females	Examine the use of virtual reality in teaching about history of civilizations	Data collected using a semi-structured interview	Content Analysis	Responses covered topics related to the advantages and disadvantages of using virtual reality	Technological factors; student characteristics