Chapter 2
The State of Extended Reality Technologies in Language Education and Research

Alex Barrett
https://orcid.org/0000-0003-1229-9743
Florida State University, USA

Austin Pack
https://orcid.org/0000-0002-3861-5620
Brigham Young University, Laie, USA

ABSTRACT

Despite making headway in the entertainment sector, extended reality (XR) remains an experimental technology in many educational contexts. This chapter moves to enrich the understanding of XR for language researchers and educators with a review of the most current established theories, frameworks, and research. An exploration of recommended avenues for future research from recently published articles in VR for education will be discussed to provide readers with an outline of the current research conditions and suggested ways forward. The chapter concludes with an inspection of language learners' experiences using a high-immersion VR system for the purposes of learning paragraph structure. Trends in VR education and research point towards increasingly sustainable applications of the technology in the classroom with identified linguistic and affective benefits. As VR continues to evolve and its applications in language learning become more sophisticated, educators and researchers will need to stay acquainted with the prevailing usages. This chapter aims to assist in that endeavor.

INTRODUCTION

In his book *Crossing the Chasm*, Moore (2014) makes the case that technology undergoes an adoption life cycle wherein five psychographic groups accept or reject the adoption of a technology. These groups are labelled as innovators and early adopters at the forefront, followed by early and late majority, and

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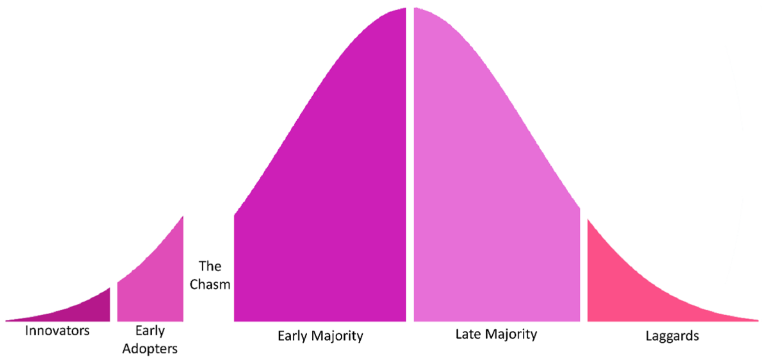
Figure 1. A depiction of the technology adoption bell curve described by Moore (2014).



finally laggards (Figure 1). Moore argues that there is a chasm between early adopters and the early majority where many innovative technologies succumb before they can be adopted by the early majority. In order for a technology to be embraced by society, the early adopters must narrow that gap between themselves and the early majority.

Extended reality (XR) technologies are arguably at different points within Moore's bell curve. Virtual reality (VR) technology, for example, now a major commercial industry, is predicted to add $1.5 trillion to the global economy by 2030 (PwC "Seeing is Believing" report, 2019). Commercially, VR technology can be understood as being in transition between the early adopters and the early majority portions of Moore's technology adoption life cycle. When it comes to the application of XR technology to language learning purposes, however, XR technologies, including VR, are still clearly in the innovator and early adoption stages; it remains to be seen if these technologies will survive the chasm. As Lan (2020a) notes, "there is a considerable amount of potential in VR language learning, but more empirical evidence (both positive and negative) is needed to guide its direction in order to fully realize the huge possibilities" (p. 10).

The goal of learning a new language is a lofty one. It requires no small amount of time and effort to become competent in communicating in a second language (L2). Educators and researchers have long attempted to identify the essential ingredients that facilitate successful language learning. Piaget's (1964) theory on cognitive development and Vygotsky's sociocultural theory (1978) are two educational theories that have strongly impacted language educators' and researchers' understanding of how a second language is optimally learned.

These theories have given rise to constructivism, which has been described as "an approach to learning that holds that people actively construct or make their own knowledge and that reality is determined by the experiences of the learner" (Elliott et al., 2000, p. 256). Central to constructivism are the ideas that: (1) knowledge is constructed (i.e. new knowledge is built on the foundation of previous knowledge); (2) learning is a process and the learner must be active for successful learning to occur; (3) knowledge is socially constructed and as such interaction with others is important; (4) learning occurs in the mind as learners internalize and process information from their environmental and social contexts; (5) because learning occurs in the mind and is built upon previous knowledge, learning is also personal (the same learning activity will not necessarily equate to all students constructing the same knowledge). These principles of constructivism can be seen as influencing common language teaching methodologies such as communicative language teaching, which places an emphasis on learner autonomy, the social nature of learning languages, the exploration of meaning, the development of creative and critical thinking skills, and the idea that students learn in different ways (Jacobs & Farrell, 2003; Richards, 2006).

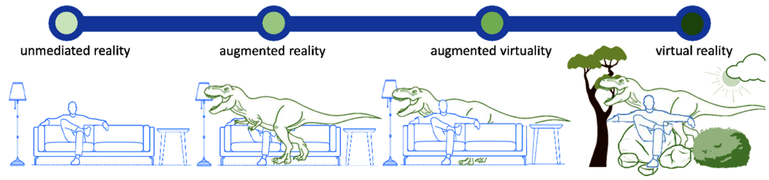
Researchers are increasingly taking advantage of the suitability of XR technologies to align with constructivism (Girvan & Savage, 2019; Huang et al., 2010; Radianti et al., 2020). A growing body of literature suggests that XR technologies may afford language learners with opportunities for both linguistic and affective gains. Lan (2020b) has argued that the unique qualities of VR, such as immersion, interaction, and imagination, can assist in facilitating language acquisition as virtual learning environments may provide realistic experiences in which learners actively participate in language tasks by means of social interaction. According to Lan's framework of language learning in VR, through innovative instructional design, learning tasks, and virtual immersion, language learners can experience a state of flow in which they have a sense of control of their environment and remain focused on language-specific goals.

A major appeal of VR in language learning is that the technology can afford users with opportunities for experiential learning, discovery, and knowledge construction, individually or with other language learners or native speakers, providing opportunities for interaction and communication that they may not have access to otherwise (Johnston et al., 2018). Equipped with the appropriate VR hardware and application, students can, for example, practice communicating in English in a virtual British pub or order in Chinese at a virtual dim sum restaurant with a teacher or other learners located anywhere in the world. Language learners can discuss what it is like living in a different country within a relevant virtual context with digital renditions of cultural objects they can interact with and talk about. In short, VR has the potential to offer language learners a high degree of autonomy in a social environment that would otherwise be beyond their reach.

Despite their potential, XR technologies have yet to be widely adapted by an early majority of language educators; it remains to be seen if XR technologies will manage the leap over Moore's metaphorical chasm. Yet, current trends in XR education and research appear to point towards increasingly sustainable applications of XR technology in the language classroom. As XR continues to evolve and its applications in language learning become more sophisticated, educators and researchers will need to stay acquainted with the prevailing uses, frameworks, and supporting theories.

The purpose of this chapter, then, is to provide readers with an update on the state of XR technologies in language education and research. The chapter is divided into three main parts. The first part provides an overview of XR technologies, including virtual reality and mixed reality (MR). Then, a detailed description of the unique qualities and affordances of VR will be given, including the constructs of immersion, interaction, and imagination. The second part highlights several models and frameworks proposed for utilizing XR technologies for language teaching and learning, and reviews recent literature on using VR and MR for language learning and teaching, including the challenges faced in implementing these technologies. The third and final part of the chapter looks closely at the possible avenues for moving forward in XR language education and research, and includes a representative sample of a research project, illustrating the key principles discussed throughout the chapter.

Figure 2. Reality-Virtuality Continuum.



PART 1

An Overview of Extended Reality Technologies

Extended reality, abbreviated as XR, is an inclusive term used to describe many different technologies which allow users to interact with computer-generated media in a manner that facilitates immersion, and in fact are often referred to as immersive technologies. Terms commonly included under the umbrella of XR are augmented reality, mixed reality, and virtual reality. Each XR technology has different immersive properties and can be vastly different in their application to language education.

Milgram and Kishino's (1994) reality-virtuality continuum is a convenient way to conceptualize the immersive properties of XR technologies. On one end of the continuum is unmediated reality as we normally experience it in our daily lives. Following this is augmented reality (AR), in which a digital element overlays reality. An example of this could be a time stamp in the viewfinder of a digital camera, or the popular smartphone game *Pokémon GO*, in which users find digital characters in their environment through their smartphone cameras. The third point on the continuum is augmented virtuality. This involves a deeper connection between the real world and the digital. In augmented virtualities, digital objects may appear to interact with the real world, such as a digital character hiding behind a piece of furniture. Wearable augmented reality technology, by developers such as *Nreal* and *Microsoft HoloLens*, provide augmented virtuality experiences in which users can perceive and interact with each other and with digital artifacts remotely, as they might if they were in the same room. Augmented reality and augmented virtuality are collectively called MR because they involve the combination of digital elements and the real world. On the opposite end of the spectrum from unmediated reality is fully-mediated reality, or VR. In VR, a user is totally immersed in a synthetic environment which they are able to interact with. In this chapter VR is used to describe a high-immersion completely synthetic environment and MR is used to describe both augmented reality and augmented virtuality. Figure 2 provides a basic depiction of Milgram and Kishino's (1994) reality-virtuality continuum.

A Closer Look at Immersive Technology

The unique qualities and affordances of immersive technology warrant special consideration. Immersive technologies afford a sense of inclusion with digital media. Frequently, the term immersive technology is used synonymously with VR, however, VR has been used to describe a wide range of systems since the first head mounted displays (HMDs) were invented in 1968 (Martirosov & Kopeček, 2017). Many studies researching VR have used varying XR systems on a cline of immersion from low to high. For example, Cave Automatic Virtual Environments (CAVEs), which are small rooms that users stand in wherein the virtual environment is projected on the walls and floor, and open social virtualities, which users often access and interact with on desktop computers or gaming consoles using a monitor, mouse, keyboard, or game controller, are known as low-immersion VR because users may still perceive the real world and are therefore not fully immersed (Kaplan-Rakowski & Gruber, 2019). AR is also considered low-immersion as it combines the digital with the real. VR systems, on the other hand, employ HMDs which monopolize the optical input of a user, and may also provide additional sensory stimulation through aural and haptic feedback. These systems, such as the *Oculus Rift* and *HTC Vive*, would be considered high-immersion (Kaplan-Rakowski & Gruber, 2019).

The virtual environments (VEs) that users can access with XR systems can also be categorized depending on their purpose. Broadly speaking, VEs include open social virtualities, massively multiplayer online games (MMOGs), and synthetic immersive environments (SIEs) (Sykes, 2008). Collectively known as 3D virtual worlds, open social virtualities and MMOGs have been heavily researched in language learning (Jabbari & Eslami, 2019; Wang et al., 2019). Open social virtualities are programs designed to create social communities online that are situated in 3D virtual environments. They are accessed through the internet and can support many users simultaneously. *Second Life* is one example of an open social virtuality, and has been used prominently in language education research. In *Second Life*, users control an avatar (a virtual representation of themselves) to explore and interact with the VE and with other users. MMOGs are similar to open social virtualities in that they are played online with multiple users simultaneously, however MMOGs are designed around a narrative and have a central goal which users can choose to accomplish through cooperation. *World of Warcraft* is an example of a popular MMOG which has been used in language education and research (Rama et al., 2012). 3D virtual worlds like *Second Life* and *World of Warcraft* are typically accessed through low-immersion systems such as personal computers. Conversely, SIEs are usually accessed through high-immersion systems which employ HMD hardware. SIEs comprise XR programs that function differently from open social virtualities and MMOGs in a few key ways. Firstly, SIEs can function offline; meaning an internet connection is not always necessary. This also results in the ability of users to engage with SIEs individually. A typical SIE will have a single-user mode, but may allow additional users to interact synchronously. SIEs are often commercial programs targeting consumers for specific purposes such as entertainment or creation. For example, the popular VR game *Half-Life: Alyx* is a single player SIE, while *Mozilla Hubs*, a browser-based SIE, allows up to 24 users to create, explore, and socialize.

SIEs are highly associated with the affordance of immersion, XR's most prominent attribute. Immersion, together with interaction and imagination are frequently cited as the three principal attributes of XR (Burdea & Coiffet, 2003; Huang et al., 2010; Lan, 2020b; Mulders et al., 2020).

The construct of immersion is often dichotomized into physical and psychological aspects. Physical immersion is the ability of XR to stimulate multiple senses, an objective technological property of the XR system (Slater & Sanches-Vives, 2016). Sensory stimulation traditionally associated with VR includes optical, aural, and haptic. Physical immersion causes a very rapid brain response which influences a user's behavior (Barret et al., 2021; Slater & Sanches-Vives, 2016). For example, when provided a wide stereoscopic field of view through an HMD, users will naturally interact with the virtual environment by turning their heads to look around and observe. This is akin to the parallel in reality of physical immersion in water, which causes a person to immediately hold their breath or to use their arms to swim. Psychological immersion, on the other hand, occurs in stages. According to Jennet et al. (2008), psychological immersion begins with engagement with the VE, leading to engrossment, and finally to a sense of presence in the VE. Presence is the subjective feeling of being in the VE and is correlated with the high states of psychological immersion associated with high-immersion VR use (Slater & Wilbur, 1997). Presence is a useful educational affordance of high-immersion VR because when users feel present in a VE they are more likely to behave as they would in real life (Slater & Wilbur, 1997), which can allow for situated learning and the transfer of skills and knowledge to the real world (Di Natale et al., 2020).

The construct of interaction can refer to human-computer interaction, as well as computer-mediated communication between users (Lan et al., 2013). VR systems and individual programs vary considerably in the type and level of interactivity they support. Low-immersion VR supports human-computer interaction through traditional PC hardware such as keyboards and mice. This allows for easier access to low-immersion VR for users who are already familiar with that hardware. Additionally, 3D virtual worlds are primarily accessed through low-immersion systems and are also prominent vehicles for computer-mediated communication, or interaction between users within the VE. The virtual world *Second Life* is frequently used by educators to engage users in synchronous communication, either verbally or textually (Lan et al., 2013). Higher-immersion systems may also support computer-mediated communication between users if multi-user SIEs are being implemented. However, high-immersion VR employs a unique human-computer interaction design known as a natural user interface (Johnson-Glenberg, 2018) which attempts to take advantage of user intuition to perform interactions within the VE such as gesture, bipedal movement, and head tracking. This type of natural user interface allows for a sense of embodiment from a first-person, or egocentric, point of view, increasing the sense of agency, immersion, and presence and the educational affordances they bring (Johnson-Glenberg, 2018).

The third principal quality of VR, imagination, has been described varyingly as a suspension of disbelief (Sheridan, 2000) aiding the sense of immersion and presence; as the users' ability to perceive non-existent things (Burdea & Coiffet, 2003); and as users' visions generated in their minds that stem from the combination of pre-existing information and novel sensory information provided by the virtual environment (Cowan & Dai, 2014). It is thought that imagination may lead to higher levels of involvement and that imagination is an important factor in the creation of user agency (Sherman & Craig, 2019). From an educational standpoint, imagination is a key element to the pedagogical use of VR. VR has been used in a variety of ways beyond entertainment, such as in therapy, training, socializing, work, and education, but VR programs for entertainment still dominate the market, and programs for other purposes are typically adapted from these or are created ad-hoc in laboratory settings. It is no different for language education; programs that are designed for language education may still involve an amount of freedom which allows for user imagination but it is invariably so with programs that were designed for other purposes and have been adapted to language education. In either instance, imagination manifests when users make connections between program content and their existing mental schemata, to reinforce learned material or render entirely new knowledge, especially when this knowledge was not explicitly programmed into the VE. For example, a learner using *Google Expeditions* for linguistic purposes may acquire new vocabulary items because they read or heard them even though vocabulary acquisition was not the purpose of the program.

PART 2

Models and Frameworks for Using XR for Language Learning

Immersion, interaction and imagination, along with other frameworks such as Whitelock et al.'s (1996) representational fidelity, immediacy of control, and presence, are useful for conceptualizing XR technology itself and how it may impact user experience. However, in recent years a number of frameworks for applying XR technology to education and/or language learning and research have been proposed. These models and frameworks provide a foundation from which researchers and educators can approach the application of XR technology to language learning. In the following review of models and frameworks for using XR for language learning, the primary focus will be on VR, as researchers who have developed these models and frameworks have done so for VR, however, they can be applicable to other immersive technologies as well.

In researching user interactions in 3D virtual worlds, Wang, et al. (2019) proposed a schema of language learning which describes three kinds of interaction. These include the interaction between avatars, between avatars and contexts, and the intra-relation between avatars and a context. These authors argue that sociocultural theory, situated learning, and immersion are essential to these three types of interaction, advising that learning in the 3D virtual world should include mediation and scaffolding, provide opportunities for collaboration and authenticity, and afford physical and mental immersion.

Mulders et al. (2020) proposed the Meaningful iVR Learning Framework to assist developers and educators in designing and implementing immersive VR (iVR, or high-immersion VR, in the language of this chapter) learning experiences. Grounding their framework in Cognitive Theory of Multimedia Learning (e.g. cognitive load, dual coding, and generative learning theories) and instructional design goals (e.g. reducing extraneous processing, managing essential processing, and fostering generative processing), these authors suggest the key features of immersive VR (immersion, interaction, and imagination) can be leveraged to generate meaningful learning experiences with high-immersion VR technology. They offer six recommendations for implementing their framework, based on empirical evidence in the extant literature. The final two can occur inside or outside of the high-immersion VR learning environment.

1. Learning first, immersion second - Developers and educators should carefully consider how much immersion is necessary; less immersion is better if a high degree of immersion is not essential to the learning objectives.
2. Provide learning relevant interactions - The high degree of interaction afforded by high-immersion VR (e.g. object manipulation via motion tracking) facilitates learning. Yet, unnecessary interaction should be avoided. Learners benefit from undergoing a pre-training, where they learn basic concepts and how to use the high-immersion VR equipment.
3. Segment complex tasks into smaller units - Given high-immersion VR can increase the cognitive load of learning (because the student must focus on the learning task and become familiar with the high-immersion VR equipment and VE), researchers and educators should segment complex tasks into smaller units, thereby reducing the cognitive load of the learners.
4. Guide immersive learning - With the goal of reducing cognitive load, developers and educators should program hints or guidance into the learning environment; doing so will enable users to more easily understand how to navigate the program and to focus on the learning task.

5. Build on existing knowledge - To prevent under, or overstimulation, learners ought to be prepared inside and outside of the high-immersion VR environment, thereby allowing them to balance new information with prior knowledge.
6. Provide constructive learning activities - Learning activities should be carefully considered to ensure that learners can construct new knowledge and then apply it to problem-based tasks inside or outside of the high-immersion VR learning environment.

Lege, et al. (2020) noting the complexity of VR applications, recommend educators carefully analyze the suitability of VR applications for specific instructional purposes. Their VR Application Analysis Framework takes into consideration language learners' experiences both inside and outside of VR and is comprised of four components: immersive capacity, cognitive load, purpose, and communicative capability. Immersive capacity is broken into high and low, with the former being commonly indicated by 6 degrees of freedom in motion tracking, high visual fidelity, visual consistency of 3D assets, and higher interactivity with the environment. Common indicators of low immersive capacity VR include 3 degrees of freedom in motion tracking, low resolution, and low interactivity with the environment. As for cognitive load, those VR applications that produce lower cognitive loads are frequently scaffolded with participants often acting as spectators with low levels of interaction with others. Medium levels of cognitive load allow for participants to pause and plan while completing tasks and may involve simultaneous interactions with others in the virtual or real world. High levels of cognitive load require all mental faculties and may prevent users from communicating in an L2 as their working memory, focus, and other mental faculties are consumed by the VR experience. Lege, et al. propose that VR applications fall into four categories of purpose: to entertain, to inform, to provide opportunities for communication, and to facilitate design and creativity. VR applications have a range of communicative capabilities, or features that enable users to communicate with each other either within the VR learning environment or in the real world. On the low end of the spectrum are solo or offline virtual experiences. Towards the middle are applications that allow for asynchronous voice and/or text chat, as well as filtered interactions. Applications that allow for synchronous voice and/or text chat with no content filtration are considered as having high communicative capabilities.

Similar to Lege et al.'s (2020) proposed categorization, Lan's (2020a) rough classification of VR language learning and teaching VR programs, comprising the following five categories, makes for a useful framework: visual experiences, entertainment, social networking, operation, and creation. Many VR applications provide simple visual experiences such as 360° videos or pictures. *YouTube VR* and *Google expeditions* are examples of VR for visual experiences. They can be accessed immersively through low-cost smartphone-based HMDs but do not offer the level of interaction of more sophisticated platforms. VR for entertainment includes the bulk of commercial products available for VR such as MMOGs and other games, which may be adapted to language learning contexts. VR for social networking includes open social virtualities such as *Second Life* and *VRChat*. These have been used widely in language education because they afford synchronous communication and can both culturally and linguistically immerse learners. VR for operation emphasizes the interactive affordances of VR through manipulation and simulation. For example, a VE that allows users to touch or click virtual objects to hear their names in a target language, or taking part in a simulated experience such as a speech or flying a plane are examples of VR for operation. Lastly, VR for creation includes programs that allow users the freedom to create their own virtual objects or environments. *Tiltbrush*, for example, is a VR painting program that allows users to paint in three dimensions, creating objects and environments. *Mozilla Hubs,* also, allows users to upload 3D artifacts or use and combine those that others have uploaded to a database to create unique multi-user environments.

In terms of researching VR, Suh and Prophet (2018) adopt a stimulus-organism-response (S-O-R) framework. This framework is particularly suitable for research in VR and education. Stimulus can be achieved either technologically through sensory stimuli, such as the VR visual display, perceptual stimuli, such as the interactivity of the VE, and through content stimuli, such as gaming or a training simulations. Organism reactions can be cognitive or affective, including the sense of immersion or enjoyment. And the response includes positive outcomes such as learning effectiveness, or negative outcomes such as cognitive overload. This framework asserts that VR system features stimulate users cognitively and affectively, resulting in positive and negative responses. Based on previous research, Suh and Prophet (2018) pose that individual user differences, such as age and gender, will have moderating effects between stimuli and organism, and between organism and response.

Review of VR for Language Education Studies

Despite the technical and financial hurdles that researchers and educators face when engaging in research focused on VR and language education, there has been a growing interest in exploring VR as a pedagogical tool in second language acquisition (SLA) (Lin & Lan, 2015). Given that VR technology and its application to learning change quickly, this section will focus on the most recent literature that focuses on applications of VR technologies in language learning and discuss their linguistic and affective affordances.

Li and Wong (2021), in their review of AR, VR, and MR in language learning, provide a general view of how these technologies have been used for research within the educational context. They note that these technologies have been primarily used in the context of higher education, that English is the most prominent target language examined, and that speaking is the most frequent language skill investigated. They highlight better linguistic performance as a linguistic affordance, and higher levels of motivation and engagement as affective ones. Adding to this list, Bonner and Lege (2020), in their review of the state of VR in education argue that immersive VR learning environments “offer a window to another place and time, and can put students into places that were not accessible” (p. 88). Such learning opportunities may enhance participants’ ability to recall and recognize objects, supply learners with opportunities for empathy training, and provide avenues for distance learning.

In regards to speaking, Gruber and Kaplan-Rakowski (2020) investigated how the sense of presence and plausibility afforded by high-immersion VR influenced learners’ anxiety while using a foreign language to address a virtual audience. The authors suggest that using VR as a tool to present to virtual audiences can help language learners manage public speaking anxiety while using a second language and that learners can develop presentation skills, such as maintaining eye contact with audience members. Niebuhr and Michalsky (2018) compared prosodic measures of speaking styles between a control group and VR test group of 12 speakers each. Participants in both groups were asked to prepare an elevator pitch, or a short two-to-three-minute presentation on a business idea. Prosodic features were analyzed from recordings of the participants as they rehearsed four times. While the control group practiced without an audience present, the test group wore an HMD and presented to a virtual audience by means of a VR learning environment called *Presentation Simulator*, similar to the many commercial programs which simulate various speech, presentation, or interview scenarios such as *Ovation* or *Virtual Speech*. The authors found that the test-group speakers demonstrated an audience-oriented and charismatic speaking style, unlike the control group. Additionally, the test group had reduced signs of prosodic erosion due to repeated rehearsal. The authors conclude that presenting to VR audiences can serve as a useful tool in a variety of digital-humanities applications, including but not limited to public speaking.

VR experiences have also been demonstrated to assist in writing (Lan et al., 2019), listening (Lan & Liao, 2018), and autonomy (Yeh & Lan, 2018). Lan et al.'s (2019) study explored the usage of *Second Life* for improving Chinese as a second language learners' ability to write essays in Mandarin. Analysis of control and experimental group's writing plans, compositions, coupled with in-class observations suggested that the experimental group that explored authentic contexts in *Second Life* as a pre-writing activity demonstrated higher motivation and performed significantly better in the planning of their writing as well as higher overall writing quality, when compared to the control group students that had no immersive VR experience. Lan and Liao (2018) explored how authentic contexts in *Second Life* might be used to improve the listening comprehension of Chinese as a second language learners. These learners expressed positive attitudes towards having listening lessons in 3D immersion. Furthermore, performance tests, questionnaires, and interview data suggested that the students benefited from the 3D immersion in regards to their listening comprehension. Yeh and Lan (2018) investigated how a 3D virtual learning platform called *Build & Show* might influence learner autonomy. They argue that the process by which students created in the VE, and the uses of the program in English classes afforded students with higher levels of autonomy.

In addition to improving language competencies, VR learning environments have been used to improve intercultural communication and understanding. Berti, Maranzana, and Monzingo (2020) explored language learners' stereotypes and generalizations of a foreign culture by means of high-immersion VR, as well as their beliefs on using VR for this purpose. University Italian language learners used smartphones, headphones, and a cardboard VR viewer to explore a variety of environments in Italy. Results suggest that the users maintained positive perceptions towards their VR learning experience and that such an experience afforded students with a more in-depth cultural understanding than traditional pedagogical materials. Yeh, Tseng, and Heng's (2020) study stands out as it explored the intercultural awareness of 60 advanced English foreign language learners as they created VR content. They found that the features of VR technology, including panoramic environments with audio, interaction, and structuring, enhanced student's intercultural awareness. Shih (2015) investigated how *Google Street View* as a 3D virtual environment could be used to provide learners with a virtual tour of London, with the guidance of a native English-speaking instructor. Shih argues that the learners benefited from their cultural immersion, with linguistic proficiency, motivation, character traits, and attitudes, influencing the learners' understanding of the target culture.

As to specific programs that may be suitable for language teaching purposes, several authors have compiled and reviewed lists of commercially available VR programs. Berns and Reyes-Sánchez (2021), for example, reviewed 17 VR-based language learning apps based on their languages and supporting operating systems, monetization, target students and levels, language content and modes of instruction (vocabulary, grammar, pronunciation), language competences (listening, reading, speaking), topics and learning scenarios, types of immersion, learning approaches, and interaction, and, lastly, feedback. Bonner and Reinders (2018) offer 10 practical ideas for using AR and VR in the language classroom. These include creating a campus tour, giving and following directions, location-based puzzle treasure hunts, providing instant-access supplementary materials for readings, virtual reality video creation, backchanneling with the teacher during classwork or homework, and orienting students to a reading topic through 360-degree videos. For each of these activities the authors provide a mini lesson plan that can be adapted to the needs of students. Lastly, Johnston et al. (2018) compiled a list of 35 popular VR-based applications and evaluated them for their pedagogical merit, focusing on descriptions of direct instruction, experiential learning, discovery learning, situated cognition, constructivism, and unclassified approaches. They concluded that among the 35 selected applications, experiential learning, discovery learning, and constructivism were the most common pedagogical foundations that emerged from their analysis.

Lastly, outside of the laboratory, several startup companies have begun creating VR hardware, such as untethered HMDs or smartphone-based HMDs along with VR programs which target language learning. *Veative*, *Mondley*, and *Redbox VR* are just a few of the businesses working to capitalize on the emerging market for VR language learning. They have marketed class sets of VR equipment with mobile storage and charging stations and typically offer subscription services to customers to access an array of language learning and educational applications. These applications offer conversation simulations and vocabulary building activities in a variety of languages, and provide other educational programs in STEM subjects. These companies are just beginning to attract attention from researchers. Nicolaidou et al. (2021), for example, recently compared Mondly's HMD-based conversation simulator to a mobile version from the same company. They found that although both versions aided comparatively in vocabulary acquisition, learners were much more engaged by the immersive version. However, much more research is needed to understand the efficacy of these programs and platforms.

Review of MR for Language Education Studies

Within studies on MR, augmented reality (AR) has garnered more attention than augmented virtuality; likely a result of AR being readily available with smart devices that students already own (Avila-Garzon et al., 2021). Fewer studies have been done on augmented virtualities (Avila-Garzon et al., 2021), as they require the use of wearable devices such as the *Microsoft HoloLens* or *Magicleap*, which can be cost prohibitive to scale their use to the classroom level. Therefore, much of this section will focus on AR as accessed through smartphones or tablets.

An AR experience is often activated either by a user being in a certain location, triggered by the device's camera or GPS, or through the recognition of a target or marker, such as a QR code, picture, or real-life object (Godwin-Jones, 2016; Khoshnevisan & Le, 2018; Ponners & Piller, 2020). This can make educational experiences that are typically less interactive, such as reading a textbook, more engaging by including animated media and digital annotations. AR is also a method for providing information at locations where it may be needed, such as having relevant vocabulary words pop up on the screen to facilitate interactions when learners are at a certain place or engaging in a certain activity.

According to Dunleavy (2014), AR is facilitative of situated and constructivist learning, as AR has been found to enrich the learning affordances of interactive learning environments wherein "learners can both make sense of the real world and apply what they have gained to the augmented learning environment with the presence of the multimedia aiding as scaffolding, background knowledge activator, motivator, and facilitator" (Khoshnevisan & Le, 2018, p. 61). Meta-analyses of AR in education have found a medium to high effect on learning outcomes (Avila-Garzon et al., 2021). There have also been numerous frameworks and methodologies proposed by researchers for the successful adoption and application of AR technology in educational contexts (Fernandez, 2017; Zhang et al., 2020).

Current trends in educational AR include the use of AR by students with special needs, AR that provides for educational activities that involve storytelling, the use of mobile devices for deploying AR learning experiences, and game-based learning with AR (Avila-Garzon et al., 2021). Select recent studies in AR in language education will be discussed in more detail below.

The most common use of AR in language learning is using AR for vocabulary acquisition (Parmaxi & Demetriou, 2020). A recent study by Uiphanit et al. (2020) reported on the use of an AR application which was activated when presented with a vocabulary flash card, and depicted 3D digital objects representing the vocabulary item accompanied by audio of the vocabulary item being pronounced. A post-participation questionnaire showed that students felt the AR helped them to study better and was easy to use. In a different approach to vocabulary learning, Fan and Antle (2020) used AR PhonoBlocks, a set of physical letters, which, when arranged to form different words, colorize and create animations when viewed through a tablet screen to help young learners with word meaning, spelling, and phonation. Although needed improvements to the design of the AR app were noted by the researchers, and flexible scaffolding was suggested to help young learners navigate the technology, they found that the learners had an overall favorable impression of the AR technology and saw that the color cues appeared to draw learners' attention to alphabetical rules. What's notable about both of these studies is that the experiments were carried out in rural villages, in Thailand and China, respectively, demonstrating the accessibility of AR technology to those already possessing mobile technology.

The development of AR applications by individuals to meet specific language learning needs is becoming more common. For example, to teach the endangered Quechua language of Peru to preschool aged learners, Zapata-Paulini et al. (2019) used an AR application they created themselves. Similarly, Che Dalim et al. (2020) created an AR application which used speech recognition to teach young learners English prepositions, color words, and shape words. Learners' used voice commands to position digital, colored shapes in different locations. Although the technical knowledge necessary to create a prototype AR application is likely beyond most language teachers, these studies do show the versatility of AR and how it is evolving.

Challenges in XR for Language Education

Despite the affordances of XR technology for language learning highlighted above, researchers have encountered and reported on various obstacles when employing XR for educational or language learning purposes. There are pragmatic challenges such as competency, limited available instructional design, insufficient time, and limited environmental resources (Alalwan et al., 2020), but also difficulties stemming from the technology itself. Cognitive load is often cited as a debilitating factor of immersive VR use, which can occur if users struggle with the VR system controls while performing tasks in the VE, by being presented with multiple virtual objects in the VE, through constraints on presented information due to limited field of view, and by hyper-fidelity of system graphics, to name a few causes (Makransky et al. 2019). Another barrier to XR use in language education is accessibility (Scavarelli et al. 2020). Learners with physical or cognitive disabilities, and economically disadvantaged learners, may not be able to access XR for learning purposes, or may only have limited access to it. Motion sickness and fatigue are also common problems associated with HMD use (Lege et al. 2020). Another important struggle in adopting XR to learning contexts is the digital and virtuality literacies of learners (Barret et al., 2020; Dengel, 2018; Eisenlauer, 2020), which involves users' adaptation to interacting in an immersive environment or engaging with virtual media. These obstacles, and others, represent a large field in educational XR research wherein discoveries are being made in mitigating and addressing them (see, for example, Moon et al., 2020; Shi et al. 2021).

Firsthand accounts of teachers who have adopted the use of VR for language education and other subjects have revealed additional challenges (Patterson & Han, 2019; Stranger-Johannessen & Olsen Fjørtoft, 2021). Interviews with nine K-12 teachers who have used VR in the classroom between one to five years revealed that teachers felt VR technology was complex and took time to learn how to use for both themselves and their students; they voiced concerns over privacy, as many devices required students to create login accounts or required data tracking; and younger children appeared to be uniquely vulnerable, as their psychology reacts differently to immersive media (Stranger-Johannessen & Olsen Fjørtoft, 2021). Another early adopter of VR in the K-12 classroom commented that some problems persisted even with simpler devices, such as HMDs that function with users' smartphones, as Wi-Fi connection interruptions and students who experienced motion sickness disrupted some lessons (Patterson & Han, 2019). Although these challenges are currently being addressed, final solutions would help XR be accepted by a majority of teachers.

PART 3

Researching XR: Ways Forward

With the rapid evolution of XR technology there is an ever-emerging system feature, educational niche, or program that provides an opportunity to conduct research. This has resulted in a rather enthusiastic research climate. Research in XR technology typically follows two avenues; measuring the effects of XR system features on user experience, and examining how XR affects user performance or behavior (Suh & Prophet, 2018).

According to Suh and Prophet (2018) there are also several pitfalls common to XR research which should be avoided if possible. For instance, the features of XR technology are usually defined differently in different studies and are often context-specific, making it impossible to compare measurements between studies. Included in this is a frequent lack of description of the XR technology being used. Additionally, experimental and survey designs dominate the literature in XR, which limits the insight available to how and why the technology influences users; triangulation with more qualitative or neurophysiological measures could help remedy this. Furthermore, XR research suffers from relatively small samples due to the expense of the technology and challenge of scaling use beyond the classroom level. It is important to be aware of, and plan to avoid, pitfalls like these in order to enhance the quality of the literature in XR research.

Looking forward, there are multiple research recommendations which have been identified across several recent reviews of XR research (Table 1). It is gratifying to see that many of these suggestions are aimed at overcoming the pitfalls identified by Suh and Prophet (2018). Moreover, there appears to be a new trend in XR research to incorporate the technology into instructional systems by, for example, developing activities and materials which take advantage of XR's unique affordances. This could be an indication that XR is moving beyond Moore's (2014) chasm into the realm of early-majority users of technology.

Table 1. Current research recommendations.

Article	Research Recommendations
Di Natale et al. (2020)	● Proposing instructional activities and materials design in VR that minimize cognitive load. ● Investigating the causal link between high-immersion VR and better learning with consideration to sound methodology, such as randomized trials, large sample sizes, balanced samples, and validated measures.
Hamilton et al. (2020)	● Understanding how the novelty effect of new technology use influences learning outcomes and how that can be mitigated through extended familiarization. ● Following-up classroom VR use with qualitative analysis such as interviews, focus groups, or reflective writing. ● Capitalizing on the known empathy elicitation and perspective taking experiences that VR affords; for example, by putting the language learner in the shoes of a native speaker during interlanguage interactions.
Huang et al. (2021)	● Creating relevant teaching materials that can be incorporated with XR tools. ● Applying XR technology to infrequently studied language skills such as grammar and listening. ● Applying quantitative methods to gauge abstract user perceptions such as enjoyment, satisfaction, and learning engagement.
Li & Wong (2021)	● Examining the role and involvement of teachers. ● Discerning how XR can address language learning needs at various levels of education.
Parmaxi (2020)	● Developing real-life tasks in VR that are aligned with theory and pedagogy for authentic language production. ● Aligning VR features with learning strategies, styles, and practices. ● Conducting larger scale, cross-disciplinary, and experimental studies.
Parmaxi & Demetriou (2020)	● Establishing a structural model of AR experience and a standardized methodology of assessing the impact of AR. ● Considering instructional design with AR
Radianti et al. (2020)	● Homogenizing of terms defined disparately in the literature, such as immersion and realism. ● Identifying a taxonomy of learning theories and other framing factors for educational VR applications. ● Establishing a comprehensive overview of existing VR applications and best practices in their utilization. ● Starting a framework for describing VR application use that includes quantitative and qualitative data, technical feasibility, learning outcomes, and evaluation perspectives from both teachers and students.
Scavarelli et al. (2020)	● Addressing issues of accessibility with XR technologies and learners with cognitive, physical, or economic disadvantages. ● Furthering XR research in authentic educational contexts.

A Framework for Conducting Research

Pack and Barrett's (2021) common-sense framework for utilizing VR in English for Academic Purposes (EAP) pedagogy and research can be applied to any kind of practical application of XR technology for language learning and teaching. This framework consists of 7 basic steps, as shown in Figure 3. These steps will be described in more detail below.

The first two steps are foundational as they highlight the importance of having a clear purpose in using XR technology for language learning; the technology should be used as a tool to improve the language learning experience either through linguistic or affective (e.g., motivation) gains. Two guiding questions researchers and educators can ask themselves are "what do students need to be able to do?" and "how can VR enhance the learning experience?" The answers to these two foundational questions will inform important decisions later. Additionally, it's imperative to establish a theoretical foundation from existing research. As Radianti et al. (2020) point out, current XR research suffers from being overly exploratory and not generalizable.

Figure 3. Framework for conducting research on XR and language education.

The third and fourth steps are concerned with selecting appropriate software. Options fall into two categories: using and/or adapting existing programs, and creating a new VR learning environment or AR tool. Individuals looking to collect data from many users, or impact learners at the classroom level or beyond, may want to consider programs which can accommodate multiple users at once, such as open social virtualities, MMOGs. VR and AR which function on personal mobile devices may also be useful for this. SIEs tend to be limited in how many users can interact in them at once, which may also constrain the educational impact and quantity of data. There are both free and purchasable programs for XR platforms that may fit the objectives of educators and researchers. While free programs require no expenditure, they tend to be less developed, contain more glitches, be less visually appealing, and offer less support than their purchasable counterparts, which can impact user experience. Commercial programs may require a one-time purchase or a monthly subscription fee, but have the benefit of being a polished product. Lastly, creating a new XR environment is not unheard of (see Barrett et al., 2020; Zapata-Paulini et al., 2019) but can require the resources of money, time, and expertise. However, the advantage of individuals creating their own programs is that they can be designed from the ground up with the specific research or pedagogical concept in mind. Cheaper and easier self-made immersive VR experiences can also be done with a 360° camera. These can be limited by the interactions they do not afford, but can, nevertheless, prove to be highly motivating experiences for learners (Eisenlauer, 2020; Hamilton et al, 2020).

The fifth step involves the selection of suitable XR hardware. It cannot be overemphasized that when making this decision researchers and educators should be well aware of the limitations and affordances of the hardware they are contemplating purchasing. They should ask themselves “does the hardware support the chosen software?” and “what kind of experience (in terms of immersion, interaction, and imagination) do we want learners to have?”. XR technology and platforms are evolving rapidly and different hardware offer a range of features such as varying degrees of freedom in motion (3 degrees versus 6 degrees), eye tracking, body, head, or hand tracking, and varying sensory stimulation systems. It is also advised to ensure the device can run programs with minimal latency, as this is a primary cause of motion sickness in VEs (Shaw et al., 2015). Researchers and educators ought to familiarize themselves with XR terminology and features supported by hardware before significant expenditures are made. In Figure 3 the third, fourth, and fifth steps are placed on the same horizontal level of the pyramid, denoting that decisions regarding software ought to be considered in combination with decisions related to hardware, and vice versa.

Once suitable software and hardware are selected, research and practice can commence. We encourage researchers and practitioners to be actively engaged in disseminating best practices and research findings within the larger academic community as XR technologies in language education will never make the leap from early adopters to early majority unless communities of research and practice are established.

Representative Research in VR and Language Learning

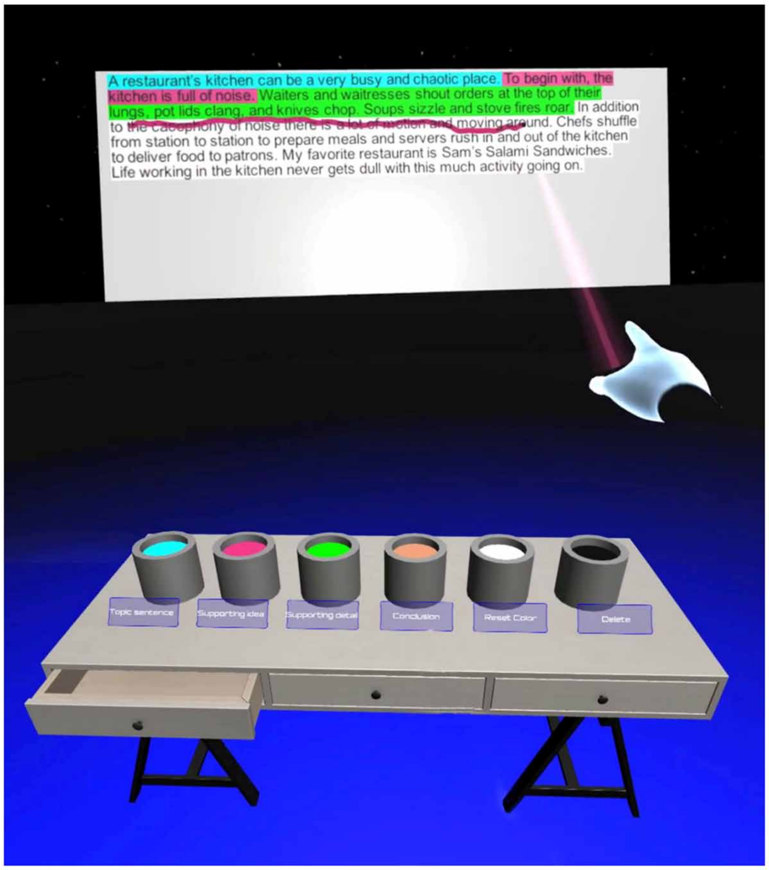
Many language educators unfamiliar with XR technologies may, naturally, be hesitant to engage in using them for pedagogical or research purposes. This section will analyze a recent research article (Pack et al., 2020) in order to illustrate, with practical examples, many of the various applicable terms, theories, and frameworks mentioned in this chapter thus far.

China represents one of the largest markets in English language learning (Nunan et al., 2018). Recently, many universities are emerging in China that use English as the medium of instruction (EMI), of which, increasingly more are jointly operated by universities in English speaking countries, such as the University of Nottingham Ningbo, Duke Kunshan University, and NYU Shanghai. English for academic purposes (EAP) is a mandatory program of study at these universities as students need these skills to operate completely in English in an academic setting. In this context, Pack et al. (2020) noticed a general lack of motivation and engagement among students during EAP lessons. This came as a surprise, because as an EMI university, policies, lectures, textbooks, assignments, and assessments are all in English, establishing a clear need for EAP skills. Without a solid foundation of EAP, students would be unlikely to understand lectures, assignments, assessments, and therefore perform poorly in their studies (Pack, 2021). A particular pedagogical need presented itself: students were not motivated to learn the conventions of academic writing in English (e.g., Hyland, 2009), conventions critical to their success in higher education.

Having identified a specific pedagogical need, a review of VR learning environments and their potential as a tool to provide motivating and engaging supplemental learning experiences outside the EAP classroom was conducted. From the survey, it was evident that a program did not exist which addressed elements of academic writing (e.g., cohesion and cohesiveness). Programs that had been used in writing instruction were typically adapted to the task, and often used as inspiration during pre-writing stages. Adapting an existing program did not seem feasible, so the development of a novel SIE was considered. Inter-departmental collaboration was established with computer science faculty members for the possibility of designing, programming, implementing, and researching a novel SIE.

Researchers worked closely with a small team of undergraduate computer science students to develop the program. After a functional program was created, an exploratory research design was implemented with 10 EAP student volunteers. Exploratory research was chosen due to the prototype nature of the SIE and the limitation of only having one VR system on which to use the program, making a larger sample improbable. The end product offered a high-immersion VR experience wherein students could practice a writing activity (Pack, 2019) that involved demonstrating knowledge of paragraph and essay structure through coloring sentences in a paragraph according to their function (Figure 4). As learners were intended to manipulate objects in the VE with the purposes of constructing knowledge on the relationships between sentences in a paragraph, the program was classified as VR for operation (Lan, 2020a) and conducted under the theoretical framework of constructivism (Elliot et al., 2000). Decisions

Figure 4. The Virtual reality environment designed for learning paragraph structure.



related to the development of software and the procurement of hardware were intertwined and centered around three needs: (1), hardware that would provide high-immersion experiences with motion tracking and six degrees of freedom; (2), budgetary constraints; and (3), the level of knowledge and skill of the undergraduate computer science students who would be developing the program.

Effects of cognitive load as a result of program use were speculative, as measurements were not included in the study. However, the program was low-stakes and allowed for users to pause and plan, thereby possibly minimizing the cognitive load of the users (Lege et al., 2020). However, the communicative capability of the program was problematic. There was no opportunity to communicate designed into the SIE and instead users spoke with researchers who watched user interactions in the SIE projected on a monitor. This communication style was ad-hoc for purposes of guiding users through the task, and its impact on user-experience was not measured in the study. It is probable that this increased cognitive load, as users operated inside the SIE while communicating with someone outside of it (Makransky et al., 2019).

The program task was supplemental to learning in the classroom, and thus placed learning in the classroom first and immersion second (Mulders et al., 2020). Some students, however, expressed a preference for non-VR instruction in post-experience interviews.

I personally prefer to learn in the classroom. Well cause like some people are not used to have like this kind of stuff, maybe have negative feelings about it. I don't know, because I haven't used VR for a long time and I think if I use VR for a long time then my eyes will be hurt. (P1)

The negative things I think… such as if there is a word I don't know, I want to learn it and write it in my notebook, but in VR I couldn't do that. Paper pen, I get used to it. (P10)

Whereas other students described the experience as interesting, and aiding in focus.

I think that was interesting. It could let students who don't really like study to study hard... I think it could be used to let some students who don't really want to learn this subject to translate into wanting to learn this subject. (P3)

I think it will help because VR is a new way to help us to learn about it so maybe we will get interested in that. Yes, raise interest. I think it's more interesting. I just use pens for too many years I want to try something new. (P6)

Maybe with using pen and paper I cannot focus on what I'm reading. But use VR, because the whole world is changed and there is nothing but the paragraph, so I can focus on what I'm reading and maybe it makes it more efficient. I will read it faster. (P8)

Overall, results from the study seemed to indicate that students were very interested in the immersive experience and saw educational value in it but also encountered difficulties with using the VR hardware and expressed mixed feelings about whether the university should adopt such programs for wider use. Based on the results of this exploratory study, a second larger study was conducted to better understand how learner attitudes and opinions towards VR for learning writing structure impacted their intention to adopt the technology. This study resulted in two articles, one which examined how learners' attitudes toward the subject content (e.g., EAP) and their self-efficacy in using the VR system affected their intention to adopt the technology (Pack et al., 2020), and another which focused on how the unique qualities of VR affected their intention to adopt the technology (Barrett et al., 2021).

Dissemination of research findings in this project occurred on three levels. Firstly, results were shared with colleagues at in-house professional development symposiums. This provided immediate access to the result for those who were directly associated with the population sample studied. The second level of dissemination was at international conferences and workshops. This garnered the advantage of meeting and networking with interested parties in person. And thirdly, research was published in international journals in order to reach as wide an audience as possible.

CONCLUSION

It is easy to be enchanted by the hyperbolic descriptions of new educational technology, but history has taught us to be pragmatic. In 1987, Spitzer sought to answer the question of why educational technology had failed. Over two decades later and more failures in educational technology have been documented than successes. From the one laptop per child debacle (Cristia et al., 2012) to the failed promise of the iPad (Geist, 2011), educational technologies appear to have a habit of dying in Moore's (2014) chasm between early adopters and the early majority. It is odd that both laptops and iPads are ubiquitous outside of the classroom but have not manifested a major transformation in the classroom. Perhaps the chasm is especially large from the perspective of educators. XR technologies should likewise be considered with caution, and researchers and educators should be careful in the claims or predictions they make with this, and other, educational technologies (Mertala, 2021).

XR has not been adopted by the majority, and may never be, but there is reason to think it could play an important role in education. Studies on immersive technologies have been growing quickly (Suh & Prophet, 2018). Each year sees more publications on XR in education than the previous year. This shows that teachers and researchers continue to see value in applying and studying XR. Also, if you compared iPads from 2011 to those of 2021, you would not find them very dissimilar, however, XR technology today is markedly different from systems that were introduced just five years ago. HMDs have become untethered from supporting computers, stand-alone motion sensors have been built into HMDs, and the headsets have become lighter and more comfortable. If, as predicted by market research, XR continues to garner more investment, then the technology may be unrecognizable a decade from now (Business Wire, 2021). Lastly, XR is frequently identified as having incredible potential in education by leading experts (Bechtel et al., 2021). This last claim, however, deserves some scrutiny.

Claims about the incredible potential of an educational technology are not hard to find, so why would anyone think XR is somehow different or special? In partial answer to that, educators have grown more savvy in their relationship with educational technology. Educators are critical of the myths such as students as digital natives, or technology that can replace a teacher (Kirschner & van Merriënboer, 2013). It is more commonly understood that technology plays a supporting role in the classroom, not a central role, and that support should be provided for both students and teachers. But also, XR technology provides immersion. Immersion appears to be a valuable tool that has not yet been fully harnessed in educational settings. XR technology may fade from the spotlight, but immersive experiences will likely endure.

Although it is easy to fall victim to the enthusiasm surrounding a novel technology, it is just as easy to fall victim to reluctance in adopting a little understood, possibly unwieldy, technology that burdens educators with a new layer of responsibility. A middle ground needs to be traveled. The goal of this chapter was to outline the current state of XR technology in education and research, using prevalent examples of practice, theory, and frameworks. With this outline it is hoped that educators and researchers who are unfamiliar with XR technology now have enough of a foundation to imagine using it for their own purposes. It is also hoped that the information provided here helps experienced XR educators and researchers find a coherent foundation from which to continue building on our understanding of XR.

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KEY TERMS AND DEFINITIONS

Augmented Reality (AR): Technology that provides an overlay of digital elements on the real world, often viewed through smartphones and tablets but also wearable see-through visors.

Chasm: A perceived gap between people who adopt a new technology early and the majority of people who may or may not choose to adopt it.

Extended Reality (XR): Any digitally immersive addition to or replacement of reality; usually provided by technology through the addition of digital elements or a completely synthetic environment.

Immersion: The quality of feeling surrounded and included in something, such as a story, a virtual environment, or a physical medium like water.

Immersive Technology: Any technology that affords an immersive experience; typically associated with AR and VR.

Mixed Reality (MR): Any state in between reality and a completely virtual environment, exclusive.

Virtual Reality (VR): A technology that provides a synthetic environment that is immersive, interactive, and stimulates imagination, often associated with head-mounted display goggles that completely block out the real world.

Virtual Worlds: Large 3D digital environments that can accommodate multiple users simultaneously, typically accessed through PCs or gaming platforms.