The Implementation of Augmented Reality for Language Teaching and Learning: A Research Synthesis[1]

Dodi Zain[2], Universitas Muhammadiyah Purwokerto, Purwokerto, Indonesia

Abstract

As technology dynamically progresses with new inventions, Augmented Reality (AR) technology emerges as one of the prominent inventions of the current technology development. This technology works by producing additional data including texts, animations, images, audio, and even haptic feedback embedded in the real world without manipulating the existing real environment. This study attempts to highlight the potential of AR technology as an educational tool, specifically for language teaching and learning. Using particular criteria of inclusion and exclusion, this study collected and reviewed a total of 22 articles from 21 journals and one proceeding. The findings revealed the research purposes, methods and instruments, language focus, participants, and the types of AR Applications. Subsequently, regarding the affordances of this technology, this study revealed that AR technology could contribute to the development of language performance and learning achievement, increase learning satisfaction, and reduce learning anxiety. This technology facilitated situated, personalized, and collaborative learning settings. Barriers to the application of this technology were identified including technical limitations, inequal technological competence, and health and social issues. Based on these findings, several implications were formulated.

Resumen

A medida que la tecnología avanza dinámicamente con nuevos inventos, la tecnología de Realidad Aumentada (AR) surge como uno de los inventos destacados del desarrollo tecnológico actual. Esta tecnología funciona mediante la producción de datos adicionales, incluidos textos, animaciones, imágenes, audio e incluso comentarios hápticos integrados en el mundo real sin manipular el entorno real existente. Este estudio intenta resaltar el potencial de la tecnología AR como herramienta educativa, específicamente para la enseñanza y el aprendizaje de idiomas. Utilizando criterios particulares de inclusión y exclusión, este estudio recopiló y revisó un total de 22 artículos de 21 revistas y un procedimiento. Los hallazgos revelaron los propósitos, métodos e instrumentos de la investigación, el enfoque lingüístico, los participantes y los tipos de aplicaciones AR. Posteriormente, con respecto a las posibilidades de esta tecnología, este estudio reveló que la tecnología AR podría contribuir al desarrollo del desempeño del lenguaje y el logro del aprendizaje, aumentar la satisfacción del aprendizaje y reducir la ansiedad del aprendizaje. Esta tecnología facilitó un entorno de aprendizaje situado, personalizado y colaborativo. Se identificaron barreras para la aplicación de esta tecnología, incluidas limitaciones técnicas, competencia tecnológica desigual y problemas sociales y de salud. Con base en estos hallazgos, se formularon varias implicaciones.

Introduction

Augmented Reality (AR) technology possesses the ability to connect the real and digital world providing an opportunity to change the way people interact with their environment. The system employing this technology can bridge a gap between the digital and the real world by gathering information through digital devices and combining it with that from the real world (Blevins, 2018; Bronack, 2011; Dunleavy et al., 2009). This technology works by producing additional data including texts, animations, images, audio, and even haptic feedback embedded in the real world without manipulating the existing real environment (Blevins, 2018; Li et al., 2016). It makes an impression that the images exist in the environment (Azuma, 1997) and can interact with users which affects the perceptions of reality. Azuma et al. (2001) explained that this system possesses three main characteristics which serve its values for various aspects of life: (1) supplementing the real world with virtual images; (2) bridging a connection between the real world and digital objects; (3) operating on a real-time setting and in an interactive way. In the last decade, the accessibility of this technology has improved through its integration in mobile technologies such as mobile phones, tablets, or even smart glasses.

AR technology has drawn the attention of teaching practitioners as a way to elevate the quality of learning (Diegmann et al., 2015; Dunleavy et al., 2009; Tomi & Rambli, 2013). As of now, this technology has been embedded into teaching aids and materials including flashcards and textbooks allowing students and teachers to interact with them through mobile devices (Wu et al., 2013). One of the earliest applications of AR for language learning was initiated by Wagner and Barakonyi (2003). In their study, a device utilizing this technology for learning Japanese Kanji, logographic characters for Japanese written scripts, was created equipped with certain flashcards. Through the device, the learners were able to see projected images forming the name of the item on the card. However, this device was only aimed at adult learners. In a more

[1] This is a refereed article. Received: 21 March, 2022, Accepted: 22 September, 2022. Published: 17 July, 2023.
[2] dodizain@uark.edu, 0000-0002-0755-5098

recent study, Yilmaz and Goktas (2017) pointed out that AR technology has its unique value in developing students' creativity while presenting entertaining elements. This study presented how the mobile game Pokemon Go can be implemented enjoyably and intuitively. This game creates a space for interaction between users and digital images which are produced and overlaid in the real-world setting. The number of this kind of game is expected to increase giving teaching practitioners the opportunities to be creative and innovative to develop the existing model of teaching. The possibility of new models of teaching is also high with the potential of AR technology that enables teachers to develop their own teaching media (Kesim & Ozarslan, 2012; Sorrentino et al., 2015; Sykes, 2018).

Studies about the AR implementation are necessary to provide the required updates of information about the implementation of AR. With the emergence of various AR-based applications, the practicality of AR should be further examined to provide evidence of how this technology can be effectively utilized for language teaching and learning. Therefore, this study is conducted to describe how AR technology has been adopted in various studies focusing on language teaching and learning. Subsequently, this study reveals the impacts and the barriers for the integration of this technology. The following questions serve as the guideline of the study.

1. How has AR technology been implemented for language teaching and learning in previous studies?
2. What are the impacts of AR technology on language teaching and learning?
3. What are the barriers to the integration of AR technology?

Methodology

Data collection

This study adopted a design of a systematic review to describe how AR technology has been adopted in various studies focusing on language teaching and learning. To achieve this goal, it collected articles from several databases including ProQuest, ERIC, EBSCO, and Google Scholar, and several recognized journals which specifically focus on the use of technology for language instruction. Specific keywords including "augmented reality", "language learning", and "language teaching" were used to select and collect the articles for the review process.

Data Analysis

Subsequently, a set of criteria were formulated to include and exclude the reviewed articles. For instance, this study only included empirical research to describe the current application of AR and formulate the implications for future research regarding the topic. The research had to be published in peer-reviewed journals and presented in the English language. To address the novelty of the studies, this review study only collected articles published from 2016 to the late 2021. Table 1 displays the inclusion and exclusion criteria in this study.

Inclusion	Exclusion
Empirical studies	Non-empirical studies
Published in the English language	Published in a non-English language
Published between 2016 and 2021	Published before 2016
Peer-reviewed articles	Non-peer-reviewed articles

Table 1: Inclusion and exclusion criteria on the reviewed articles

Findings and Discussion

Search results of data collection

The process of gathering the articles was conducted subsequently based on the inclusion and exclusion criteria. Initially, the keywords were used to gather articles from the databases and journals published between 2016 and 2021 which resulted in a total of 256 articles. The number was reduced to 78 by scanning the titles and excluding the duplicates. The abstracts for each article were collected and screening was done to check the content of the study. The content was checked to ensure that it was aligned with the topic of AR and the contexts of language learning. This process led to 21 research-based articles from reputable journals which met the inclusion criteria in this systematic review. An additional article published in a proceeding by Chen and Wang (2016) was included in the study considering its valuable findings for this study. Table 2 presents the distribution of reviewed studies based on the journal references

Journal Reference	Number of studies	Study
Computers and Education	3	Hsu (2017); Wang (2017); Wu (2019)
British Journal of Educational Technology	2	Chen (2020); Yilmaz et al. (2017);
Educational Technology and Society	1	Ho et al. (2017)
TESOL Quarterly	1	Sydorenko et al. (2019)
Educational Technology Research and Development	1	Wen (2021)
Virtual Reality	1	Yilmaz & Goktas (2017)
Computers in Human Behavior	1	Bursali & Yilmaz (2019)
Journal of Education for Teaching	1	Yang & Mei (2018)
Mobile Information Systems	1	Miranda Bojórquez et al. (2016)
International Journal of Human-Computer Studies	1	Dalim et al. (2020)
IEEE Transactions on Visualization and Computer Graphics	1	Ibrahim et al. (2018)
Early Childhood Education Journal	1	Redondo et al. (2020)
SAGE Open	1	Lai & Chang (2021)
Universal Journal of Educational Research	1	Li et al. (2016)
Education and Information Technologies	1	Koç et al. (2021)
Research and Practice in Technology Enhanced Learning	1	Santos et al. (2016)
Computer Assisted Language Learning	1	Lee & Park (2020)
International Journal of Information and Education Technology	1	Jalaluddin et al. (2020)
2015 IEEE 2nd International Conference on Information Science and Security	1	Chen and Wang (2016)

Table 2: Distribution of reviewed studies based on journal references

The Application of AR technology for language teaching and learning

The findings showed the diversity of methodologies and multiple AR applications in each reviewed article. Table 3 presents the matrix of the studies that provides information regarding the research purposes, methods and instruments, language focus, participants, and AR applications.

Study	Purpose	Methods and instruments	Language focus	Participants	AR application
Bursali and Yilmaz (2019)	Adopting AR technology to teach reading skills and examining students' attitudes towards this technology	Mixed method approach, a quasi-experimental study using reading comprehension tests, and a survey questionnaire	Turkish	89 fifth graders consisting of 43 female and 46 male students in Turkey	Augmented reality-supported reading and listening content taken from course books
Chen (2020)	Investigating the effects of AR technology in EFL instruction	Mixed-method, quasi-experimental design using tests, questionnaires, a one-on-one interview	English as a foreign language	97 sixth graders aged 11-12 years old in northern Taiwan	An AR video-enhanced learning (ARVEL)
Chen and Wang (2016)	Examining the impacts of a mobile augmented reality (AR) assisted learning for multiple learners' learning styles and language competence level	Mixed-methods approach, quasi-experimental design using the group embedded figures test, and a semi-structured student interviews	English as a second language	52 third graders ranging from 9-10 years old at an elementary school in New Taipei City, Taiwan	Mobile AR Instructional Tool
Dalim et al. (2020)	Investigating a combination of AR and speech recognition technologies for language learning among young learners	Quantitative, experimental design employing a pretest and a posttest, task completion time, and a questionnaire of Intrinsic Motivation Inventory (IMI)	English as a foreign language	120 Malaysian preschool students (62 females, 58 males) ages 4 to 6 years old (M=5.36 years old, SD=0.658)	TeachAR (an integration of AR and speech recognition technologies installed in a workspace setup

Ho et al. (2017)	Adopting a Ubiquitous Learning Instruction System with Augment Reality features (UL-IAR) in EFL instruction	Quantitative, experimental design using Embedded Figures Test (EFT)	English as a foreign language	90 participants including college students, medical care workers, service industry employees, social workers, and kindergarten teachers aged 18 to 30 years old	A Ubiquitous Learning Instruction System with Augment Reality features (UL-IAR)
Hsu (2017)	Investigating the effects of two types of AR-based game systems for teaching vocabulary based on students' learning styles	Quantitative, quasi-experimental design using a pre-test, a post-test, and a questionnaire	English as a Foreign Language	38 third graders from an elementary school in northern Taiwan. (Age mean = 9)	Two Augmented Reality (AR) educational game systems
Ibrahim et al. (2018)	Investigating the effects of AR technology for teaching vocabulary	Mixed method approach, experimental design employing vocabulary tests, a questionnaire, and a short interview	The Basque language	52 participants (33 females, 19 males, mean age of 21, SD of 3.8) in a university in the United States	AR-based flashcard application used through a Microsoft HoloLens
Jalaluddin et al. (2020)	Examining the impacts of using a Mobile Augmented Reality (MAR) application to teach vocabulary to low-achiever students	Quantitative, pre-experimental method with a one group pre-test and post-test	English as a second language	45 second-graders aged 8 years old from two primary schools in Selangor rural areas, Malaysia	Vocabulary materials and two augmented reality-based applications
Koç et al. (2021)	Investigating the impacts of AR-based materials on students' writing performance and students' perceptions of this technology	Quantitative, quasi-experimental design employing compositions two written questionnaires	English as a foreign language	48 high school students aged 15 to 16 years old in Turkey	The AR-based experience included a total of forty-seven scenes created in line with five instructional stages
Lai and Chang (2021)	Implementing Augmented Reality apps to improve learning motivation and enrich students' vocabulary	Quantitative, quasi-experimental design employing a questionnaire and a vocabulary test	English as a foreign language	47 first graders from a public primary school in northern Taiwan	Vocabulary cards and Aurasma AR application installed on tablets
Lee and Park (2020)	Investigating how the students used the physical context and properties in their scenes and how AR technology facilitates language learning	Mixed-method approach, case study examining student learning outcomes, post-surveys, and reflection papers	English as a foreign language	40 college students, majoring in English (24 Korean and 16 international), in Korea	An interactive a location-based AR (LBA) mobile app
Li et al. (2016)	Examining the use of AR technology for language learning	Qualitative, phenomenological study Employing semi-structured in-depth interviews	English as a foreign language	Six experts (university professors) of technology in language learning in Taiwan	A model of the English AR classroom which includes five teaching elements (agents, themes, media, operational area, and tutor)
Miranda Bojórquez et al. (2016)	Investigating students' perceptions and acceptance of the adoption of AR technology under a scheme of student-centered learning	Quantitative, case study design using a survey questionnaire	Mayo language (language spoken in Northwestern Mexico)	85 undergraduate students from the Autonomous Indigenous University of Mexico (UAIM)	Mobile Augmented Reality (MAR) application
Redondo et al. (2020)	Implementing AR-supported activities to develop young learners' performance in EFL learning	Quantitative, quasi-experimental design Using a pretest, posttest, and questionnaire	English as a foreign language	102 preschool students (ages 3 to 5) from a rural, state school in Spain	AR-supported flashcards developed through Aurasma and Quiver application

Santos et al. (2016)	Designing a handheld device for an AR system to facilitate situated vocabulary learning	Quantitative, quasi-experimental design using vocabulary tests	Filipino and German	31 information science graduate students ages 23 to 42 to learn Filipino and 14 Filipino undergraduate students ages 17 to 20 to learn German	A particular handheld device to operate AR system
Sydorenko et al. (2019)	Integrating an AR-based game in language learning	Qualitative, descriptive case study using the analysis of video-recorded interactions	English as a second language	4 mixed-proficiency groups, each of which had 2 students and 1 expert speaker of English in the United States	ChronoOps, a quest-type mobile AR game
Wang (2017)	Exploring the effectiveness of integrating augmented reality-based materials to support writing activities	Mixed method approach, quasi-experimental design using a comparative test, questionnaires, and interviews	Chinese	30 twelfth-grade students (ages 16 to 17) from a girls' senior high school in Taiwan	AR-supported materials to support writing activities
Wen (2021)	Adopting an AR-supported Chinese character learning game for young learners	Mixed method, experimental design utilizing video-recorded target groups' learning processes, focus group discussion, and teacher interview data	Chinese	53-second graders and two teachers from a Singapore government primary school	An AR-supported Chinese character learning game
Wu (2019)	Examining the effectiveness of AR-based mobile games to teach English prefix, root, and suffix	Quantitative, experimental design using tests and questionnaires	English as a foreign language	61 students, 28 males and 33 females ages 20 to 26 in Taiwan	Pokemon Go mobile game
Yang and Mei (2018)	Delving into students' perceptions of the adoption of AR technology in language instruction	Qualitative, case study design employing semi-structured interviews and direct observations	Japanese as the second foreign language	Seven Year-3 university students majored in English language and literature	An AR-based stroke-by-stroke animation guide and mobile computing devices
Yilmaz and Goktas (2017)	Describing the impacts of AR-supported activities on students' narrative skills and creativity	Quantitative, quasi-experimental design using Posttest-only design with a nonequivalent group model	Turkish	100 fifth graders consisting of 46 male and 54 female students in Turkey	Augmented reality technology on flashcards
Yilmaz, Kucuk and Goktas (2017)	Investigating attitudes towards augmented reality picture books (ARPB) and the impacts it has on preschool students	Mixed-method approach, explanatory case study design, using an attitude form, story comprehension test, and interview form	Turkish	92 young learners,49 boys and 43 girls aged 5-6 years old in Turkey	Augmented Reality Picture Books (ARPB)

Table 3: Matrix of the studies

The implementation of AR technology for language teaching and learning in previous studies

Methods and instruments of previous studies

Regarding research design, most of the studies (n = 10) applied a quasi-experimental design combined with either a quantitative approach (n = 6) or a mixed-method approach (n = 4). Various instruments were identified from these studies. For instance, a study by Redondo et al. (2020) adopted a quasi-experimental design to examine the application of AR-supported activities to develop young learners' performance in EFL learning. This study utilized quantitative instruments including a pre-test, a post-test, and a questionnaire. As for Chen and Wang (2016), a combination of a mixed-method approach and a quasi-experimental design was used to examine the impacts of mobile augmented reality-assisted learning on multiple learners' learning styles and language competence levels. For the instruments, the study used both a group embedded figures test and a semi-structured student interview.

Incorporating randomization to select participants for the experiment, five studies adopted a true experimental design (Dalim et al., 2020; Ho et al., 2017; Ibrahim et al., 2018; Wen, 2021; Wu, 2019). Wu (2019), Ho et al. (2017), and Dalim et al. (2020) employed an experimental design using quantitative instruments such as tests and questionnaires. Both Wen (2021) and Ibrahim et al. (2018) used a combination of an experimental design and a mixed-method approach. these two studies used more varied instruments for data collection. Wen (2021) used video-recorded target groups' learning processes, semi-structured interviews, and focus group discussions. For Ibrahim et al. (2018), the study utilized vocabulary tests, a questionnaire, and a short interview.

An uncommon design of study associated with experimental designs is found in Jalaluddin et al. (2020). In this pre-experimental study, a group of low achiever students from two primary schools in Malaysia was involved in a study that incorporated the use of a mobile augmented reality (MAR) application to teach vocabulary. The data were collected through a pretest and a posttest.

A total of five studies employed a case study which was coupled with either a qualitative (Sydorenko et al., 2019; Yang & Mei, 2018), quantitative (Miranda Bojórquez et al., 2016), or a mixed-method approach (Lee & Park, 2020; Yilmaz et al., 2017). Sydorenko et al. (2019) conducted a descriptive case study with a qualitative approach by analyzing video-recorded interactions. As for Yang and Mei (2018), two instruments were used: semi-structured interviews and direct observations. Using a quantitative approach, a case study by Miranda Bojórquez et al. (2016) collected data from the participants through a survey questionnaire. For the combination of a mixed-method approach and case study design, Lee and Park (2020) collected data on students' learning outcomes, post-surveys, and reflection papers to investigate how the students used the physical context and properties in their scenes and how AR technology facilitates language learning. Also, Yilmaz et al. (2017) delved into attitudes toward augmented reality picture books (ARPB) and the impacts it has on preschool students through an explanatory case study design. This study used an attitude form, a story comprehension test, and an interview form.

Lastly, one study adopted a phenomenological design which is fundamentally a qualitative research approach. In this study, Li et al. (2016) developed a model of the English AR classroom which includes five teaching elements (agents, themes, media, operational area, and tutor). They invited six experts (university professors) of technology in language learning in Taiwan in an interview to evaluate and review the practicality of the model.

Participants of previous studies

As the researcher delved into the participants of the reviewed studies, he found a variation in the sample size ranging from 6 to 120 with a total of 1311 participants from 22 studies. The studies were conducted in various countries including Taiwan (n = 7), Turkey (n = 4), Malaysia (n = 2), The United States (n = 2), Singapore (n = 1), Mexico (n = 1), Spain (n = 1), and South Korea (n = 1). Three studies did not specifically mention the origin of the studies.

The reviewed studies delved into the use of AR in multiple levels of education. The majority of the studies (n = 8) were conducted in primary schools (Bursali & Yilmaz, 2019; Chen, 2020; Chen & Wang, 2016; Hsu, 2017; Jalaluddin et al., 2020; Lai & Chang, 2021; Wen, 2021;Yilmaz & Goktas (2017). Seven studies involved college students (Ibrahim et al., 2018; Lee & Park, 2020; Miranda Bojórquez et al., 2016; Santos et al., 2016; Sydorenko et al., 2019; Wu, 2019; Yang & Mei, 2018). Three studies focused on early education (Dalim et al., 2020; Redondo et al., 2020; Yilmaz et al., 2017). Two studies recruited high school students (Koç et al., 2021; Wang, 2017). The last two studies, Ho et al. (2017) and Li et al. (2016), did not specifically mention the target level of AR technology.

Aside from students, the studies also involved teaching practitioners and experts in the domain of educational technology. For instance, Li et al. (2016) invited six experts (university professors) of technology in language learning in Taiwan to review a model of an English classroom setting adopting AR technology. In another study, Ho et al. (2017) investigated the impacts of A Ubiquitous Learning Instruction System with Augment Reality features (UL-IAR) for teaching English as a foreign language. This study involved a total of 90 participants including college students, medical care workers, service industry employees, social workers, and kindergarten teachers aged 18 to 30 years old.

Language focus

Multiple languages were indicated as the main focus of learning and instruction activities. However, the majority of the studies (n = 14) adopted AR technology to teach English as either a second or foreign language. Next, two studies focused on Turkish and two studies focused on Chinese. The review also found

that respectively one study was oriented to Mayo language, Basque, Spanish, and Japanese. In a study by Santos et al. (2016) two languages, German and Filipino, were chosen as the focus of the study.

As the majority of the studies were conducted in the Asia continent, it is not surprising to find English as the focus due to its role as the main second or foreign language taught at almost every level of education. Ghosh (2020) explained that English has been treated in a special way by many non-English speaking countries for its essential role to bridge communication in the global community. Some studies focused on the first language as found in Yilmaz and Goktas (2017) and Bursali and Yilmaz (2019) both of which addressed Turkish. Interestingly, one study examined the Mayo language, which is a Uto-Aztecan language used by approximately 40000 people residing in the northern Mexican states of Sonora and Sinaloa. This language is slowly disappearing as fewer people are using it as a mother language. Another uncommon language included in these studies was the Basque language. This language is used by Basques and other residents of the Basque country which spans the westernmost Pyrenees in adjacent parts of northern Spain and south-western France (What is the Basque language, 2023).

AR application

According to previous studies, there are various applications of AR technology to support language learning and teaching. Several mobile applications have been directed to be educational tools for students to learn the target language. Also, some games adopting AR technology were incorporated into the classroom to facilitate gamified language learning. Furthermore, the application of this technology also enables students to work collaboratively which subsequently helps to increase their language production and practice their language skills. The findings of the previous studies indicated two main categories which cover the overall applications of AR technology using AR-based teaching systems and AR-based mobile games.

The current AR technology can be extensively accessed through the use of mobile devices such as smartphones and tablets. However, the current restriction is the availability of applications or software which can be used to support language teaching. In this review, some studies developed AR systems that were aimed specifically at language learning. This type of study can be found in Li et al. (2016) who developed the AR classroom system model which includes five main graphics elements (Tutor, Theme, Media, Agent, and Operational area). Each of these elements was presented on 2D images and was further enhanced into animated 3D images by AR technology through mobile devices. Similarly, Wen (2021) adopted an AR-supported Chinese character learning game which is specifically developed for learning the Chinese language. while in another study, Jalaluddin et al. (2020) used a platform namely UNITY to design a system for simulation-based concept learning for teaching vocabularies. This cross-platform game enables users to design AR contents that can be transferred to IOS and Android-based devices. Other studies adopting AR-based mobile applications included Wang (2017), Jalaluddin et al. (2020), Li et al. (2016), and Yilmaz and Goktas (2017).

While the majority of the studies relied on the use of mobile devices such as smartphones or tablets, some studies employed different tools to present the technology in the classroom. For instance, a study by Ibrahim et al. (2018) investigated how AR technology affects vocabulary teaching. This study utilized an AR-based flashcard application through a Microsoft HoloLens, an augmented reality head-mounted display. From this device, the participants were able to see the AR-enhanced images from the flashcards and named the objects in the target language. In another study, Dalim et al. (2020) employed TeachAR (an integration of AR and speech recognition technologies). To utilize this system, The workspace setup was prepared by setting up web cameras, Kinect (a line of motion sensing input devices), display monitors, and AR markers.

The adoption of AR for instructional practices has also transformed the format of instruction through the use of AR-based mobile games. The concept of gamification has been addressed in several studies (e. g., Hsu, 2017; Sydorenko et al., 2019; Wen, 2021; Wu, 2019). Gamification itself refers to the application of games in various learning schemes to facilitate engaging and motivating learning and instructional practice (Kapp, 2012; Perry, 2015). For instance, Wu (2019) used the mobile game namely Pokemon Go. In this experimental study, the treatment combined flashcards and the mobile game Pokemon Go to teach English prefixes, roots, and suffixes. There were some activities incorporated into the treatment including tasks to draw simple pictures of the game character and instruct students to listen and repeat the pronounced words. In another study, Hsu (2017) developed two AR educational game systems to teach English vocabulary. Both games presented seven checkpoints each of which provided one vocabulary item. The first system offered more flexibility as it allowed students to start the game at any checkpoint and to freely restart when they flailed the challenge. Meanwhile, the second system required students to pass all checkpoints in the designated order.

The impacts of AR technology on language teaching and learning

The second question of this study addresses the impacts or, more specifically, the affordances of AR technology in language instruction or learning. based on the findings it was reported that the affordances of this technology include the development of language performance, learning satisfaction, situated learning, reduced learning anxiety, and personalized learning. It is important to note that each study might mention more than one affordance. Table 4 summarizes the findings regarding the effects of AR technology.

Effects of AR-assisted instruction on Student's learning performance	Studies
The development of language performance and learning achievement	Bursali & Yilmaz, 2019; Chen, 2020; Hsu, 2017; Ibrahim et al., 2018; Jalaluddin et al., 2020; Koç et al., 2021; Lai & Chang, 2021; Santos et al., 2016; Sydorenko et al., 2019; Wang, 2017; Wen, 2021; Wu, 2019; Yilmaz et al., 2017
Increased learning satisfaction	Bursali & Yilmaz, 2019; Chen, 2020; Chen & Wang, 2016; Dalim et al., 2020; Ho et al., 2017; Huang et al., 2016; Koç et al., 2021; Lai & Chang, 2021; Lee & Park, 2020; Li et al., 2016; Santos et al., 2016; Tan et al., 2018; Wu, 2019; Yang & Mei, 2018; Yilmaz et al., 2017
Reduced learning anxiety	Bursali & Yilmaz, 2019; Chen, 2020; Chen & Wang, 2016; Hsu, 2017; Koç et al., 2021; Santos et al., 2016; Wen, 2021; Wu, 2019
Situated learning	Bursali & Yilmaz, 2019; Chen, 2020; Hsu, 2017; Ibrahim et al., 2018; Jang & Lee, 2019; Li et al., 2016; Santos et al., 2016; Sydorenko et al., 2019; Wang, 2017; Wen, 2021; Yilmaz et al., 2017
Personalized learning	Chen & Wang, 2016; Ho et al., 2017; Ibrahim et al., 2018
Collaborative learning	Chen & Wang, 2016; Ibrahim et al., 2018; Lee & Park 2020; Miranda Bojórquez et al., 2016; Sydorenko et al., 2019; Wang, 2017; Wen, 2021;

Table 4: The effect of AR-assisted instruction on student's learning performance

The development of language performance and learning achievement

The primary affordance of AR technology concerns the students' performance and achievement in learning. Several findings focused on the development of students' language skills specifically writing and reading skills. Also, the analysis of studies showed development in vocabulary and pronunciation skills. However, those findings were drawn in conjunction with the application of suitable learning strategies and teachers' understanding of students' learning characteristics. Additionally, AR-based activities contributed to the development of students' language skills by presenting a more manageable learning process (Chen, 2020; Hsu, 2017).

The findings regarding the development of students' writing skills were highlighted in three studies (Koç et al., 2021; Wang, 2017; Yilmaz et al., 2017;). Yilmaz et al. (2017) indicated an improvement in students' performance regarding writing skills due to the impact of AR technology. Focusing on the use of this technology for young learners, the study found that students were able to produce a more of written language as they were assigned to create stories with AR technology. In a study by Koç et al. (2021), there was an indication of an improvement of particular writing skills at a medium level as a result of employing AR-based materials. Aside from that, the findings revealed improved learning motivation which also contributed to the positive impacts on learning performance. In another study, Wang (2017) explored how AR-supported learning content was utilized to help intermediate-level high school students improve their writing skills. Addressing Chinese as the primary language to learn, this study attempted to accommodate collaborative work between the designers and practitioner teachers. This experimental study indicated that AR-supported learning content was effective to improve students' writing performance in terms of content control, article structure, and wording. The low-achievers were indicated to gain prominent impact from the content as they managed to produce writing more creatively at a faster pace.

As for reading, one study was found to examine the impact of AR technology on this particular skill. In this case, Bursali and Yilmaz (2019) conducted a quasi-experimental study on 89 fifth graders to examine how AR technology could enhance the students' level of reading comprehension. The treatment included presenting students with AR-supported reading and listening content taken from coursebooks. Based on the analysis of reading comprehension tests, the study implied that AR-assisted activities present a more engaging and enjoyable learning experience allowing students to comprehend and memorize the information better from their reading.

Aside from the two language skills, another area that was strongly addressed in the adoption of AR technology is vocabulary. For instance, Wu (2019) supported the idea that adopting AR-based activities encourages students to practice their vocabulary as they practice communicating in English as a foreign language. These activities allowed students to learn in a real-life context which eased them to understand English vocabulary and gain meaningful learning experiences. Also, teaching strategies that utilize a systematic sequence of learning stages and particular presentations of AR through games could lead to more impactful outcomes of learning (Wen, 2021). Sydorenko et al. (2019), as well as Lai and Chang (2021), explained that the use of AR technology helped to enrich students' vocabulary. Their studies demonstrated how this technology could facilitate learning contexts that were useful to explain abstract concepts through audio-visual content and particular story presented via collaborative gameplay. Furthermore, Santos et al. (2016) argued that AR technology could help students enrich their vocabulary. Incorporating a handheld AR system into an authentic and situated vocabulary learning setting in which students were assigned to work in groups and collaborate to complete learning tasks reflecting real-life activities, the AR system was found to work effectively to help students gain better retention of vocabulary and facilitate enjoyable learning circumstances. This technology could expose students to more language input and encourage them to use the language they have learned during the learning process (Ibrahim et al., 2018; Santos et al., 2016;).

Another interesting finding regarding vocabulary development was found in Jalaluddin et al. (2020). This study further claimed that the impacts of AR technology were more significant for low-achiever students. In their study, a mobile AR-based application was used to improve students' vocabulary competence. They recruited 45 low-achiever students and adopted the ADDIE Instructional Design (ID) method to obtain data from the participants. The results indicated that AR could help students' pronunciation skills. Students found it easier to orally pronounce words correctly or produce pronunciation spelling through picture identification. However, this study suggested adopting learning approaches that can help students write the words correctly based on the identified images.

Increased learning satisfaction

Despite the rising interest in technology-assisted learning among students nowadays, (Prensky, 2001), researchers and teaching practitioners are still working on how to optimize learning with technology by incorporating students' active involvement and enhancing learning motivation (Ivanova et al., 2014). However, the success of technology integration relies on the acceptance of technology which is subsequently affected by various factors. For instructional practices, students' acceptance of AR-assisted instruction relies on students' emotions and reasons which determine students' learning satisfaction (Balog & Pribeanu, 2010; Dalim et al., 2020; Lai & Chang, 2021). Learning satisfaction has become the primary affordance of AR technology in this review. A total of 12 studies provided evidence of how AR technology could elevate learning satisfaction among students. Wu (2019) argued that AR applications coupled with suitable learning strategies can develop the learning process which subsequently affects students' learning satisfaction.

Learning satisfaction is indicated by increased motivation which is reflected in students' active participation during the learning process (Chen, 2020; Wu, 2019; Lee & Park, 2020). In Bursali and Yilmaz (2019), it was claimed that AR applications could contribute to students' satisfaction as a result of presenting students with visually transformed objects as attractive media to comprehend the learning content. A similar claim was also mentioned by Huang et al. (2016) and Yang and Mei (2018) who highlighted the impacts of communicative and engaging learning setting through the use of AR for learning satisfaction. Findings also suggested that teachers pay attention to students' feelings and learning intentions due to their effects on the development of language performance (Lai & Chang, 2021; Santos et al., 2016). Moreover, teachers' support is deemed necessary to achieve students' learning satisfaction (Chen & Wang, 2016; Elliot & Covington, 2001; Koç et al., 2021; Li et al., 2016; Santos et al., 2016; Tan et al., 2018). Without proper guidance from teachers, some students might find AR technology too complex to operate and thus lead to overwhelming anxiety and reluctance to use it. A study conducted by Dalim et al. (2020) revealed that students gained a better understanding of the taught materials using AR technology. In this study, 120 Malaysian preschool students (62 females, 58 males) aged 4 to 6 years old also showed their interest in this media leading to higher learning motivation. However, the user interface needs to be developed to optimize the function of this application.

Reduced learning anxiety

AR-supported activities seem to alleviate learning anxiety in students in their language classes by increasing self-efficacy (Bursali & Yilmaz, 2019; Hsu, 2017), supporting better attention, and instilling positive learning behavior while actively engaging students in the language learning process to learn their target language

(Santos et al., 2016). Furthermore, these activities create enjoyable language learning which is essential in the flow experience of the students. Hsu (2017) explained that self-directed learning through AR-based learning media could help students gain a higher flow experience. With guidance and proper strategies adopted by the teacher, students could control their learning and decrease their learning anxiety levels during the use of AR-based learning media. Moreover, the effectiveness of AR facilitates an attractive learning atmosphere that reduces the anxiety level among students and builds positive perceptions of the language learning process (Chen, 2020; Koç et al., 2021). Teachers can harness this technology to offer a more personalized and situated learning experience that alleviates students' learning anxiety (Chen & Wang, 2016). Also, teachers can opt to gamify their classrooms or incorporate AR game-based activities which alleviate students' learning tension (Wen, 2021; Wu; 2019;). However, teachers must consider the intensity that is caused by the elements of competition in some games as well as the suitability of learning contexts to optimize the learning result (Wu, 2019).

Situated learning

The adoption of situated learning can provide a more impactful learning experience that helps students develop their language competence. Anderson et al. (1996), as well as Jang and Lee (2019), asserted that situated learning supports the student-centered learning approach by providing an authentic or virtual learning setting which reflects the real-world situation. Regarding this matter, AR technology possesses elements that can be harnessed to implement a situated learning approach. In these reviews, 12 studies (Bursali & Yilmaz, 2019; Chen, 2020; Hsu, 2017; Ibrahim et al., 2018; Li et al., 2016; Santos et al., 2016; Sydorenko et al., 2019; Wang, 2017; Wen, 2021;Yilmaz et al., 2017) highlighted the impacts of AR technology on facilitating situated language learning for students. These studies concluded that AR technology could be well incorporated into language learning to facilitate situated learning and positively affect students' learning performance in terms of reading comprehension, phonics performance, increased vocabulary, learning motivation, and improved cognitive collaboration. Further studies focusing on the development of AR-based learning applications have been carried out in various teaching settings.

Personalized learning

Another potential of integrating pedagogical technology including AR technology for language learning is the possibility to create personalized learning. Students have their own characters that distinguish them from their peers (Perry, 2015). As a consequence, teachers need to consider the students' prior knowledge, learning preferences, and aptitudes to optimize the use of AR technology (August et al., 2005; Chen & Wang, 2016;). The construct of personalized learning as the affordance of AR technology was mentioned in four studies in conjunction with different emphasis for each study including a focus on students' learning styles (Chen & Wang, 2016), engaging components for young learners (Chen, 2020), incorporation of real-world contexts (Ho et al., 2017), and multicultural backgrounds (Ibrahim et al., 2018).

Collaborative learning

Collaborative learning is a learning approach that highlights the significance of students' active involvement in a group or pair work to construct their own concepts and knowledge. Studies demonstrated how AR technology can be utilized to engage students in collaborative learning. For language learning, engaging students to collaboratively work with their peers can increase their interaction rate, boost their learning motivation, and gain valuable learning experience (Ibrahim et al., 2015; Perry, 2015). Studies addressing collaborative learning for AR technology integration in language classrooms can be found in seven studies (Chen & Wang, 2016; Ibrahim et al., 2018; Lee & Park 2020; Miranda Bojórquez et al., 2016; Sydorenko et al., 2019; Wang, 2017; Wen, 2021). These studies revealed that presenting AR games within a collaborative learning setting provided particular learning contexts that help to explain abstract concepts through images and the game narrative (Sydorenko et al., 2019; Miranda Bojórquez et al., 2016). Students learned to work collaboratively in groups while engaging in an AR-supported learning game (Chen & Wang, 2016; Ibrahim et al., 2018; Wen, 2021). As students found their peers unable to proceed with their game, they tried to support them with necessary assistance. Collaborative work via AR also can greatly affect students' satisfaction (Park et al., 2015; Perry, 2015; Wang, 2017), especially with the adoption of the immersive classroom (Ibrahim et al., 2018).

Barriers to the implementation of Augmented Reality

Despite the rapid development of AR technology, the existing barriers have prevented extensive use of this technology for pedagogical purposes. The third question of this study addresses the barriers to the

implementation of this technology which highlights several variables including technical limitation, inequal technological competence, and health and social issues.

Barriers to AR-assisted instruction	Studies
Technical limitation	Lee & Park, 2020; Wang, 2017
Inequal technological competence	Chen & Wang, 2016; Hsu, 2017; Wen, 2021
Health and social issues	Lee & Park, 2020; Yilmaz et al., 2017

Table 5: Barriers to the implementation of Augmented Reality

Technical limitations

The primary issue related to the integration of technology into the classroom concerns technical limitations. Wang (2017) mentioned the technical issues, the pedagogical considerations, and the gap in technological competence among students which emerged during their use of AR. It was also noted the current limitation of AR technology due to the frequent disappearance of digital objects on the screen when students moved around the camera. It often annoyed students as they used this technology for learning (Dunleavy et al., 2009). In another study, Lee and Park (2020) pointed out other issues in the application of AR including slow internet connections and the need for a large memory capacity for mobile devices to accommodate the large storage size of the AR application. Furthermore, the findings also mentioned the issue of the sensor to precisely pinpoint the location of the AR digital images. All in all, previous studies highlighted the unbalance of the required technology specification of the optimal integration of AR technology and the available resources for classroom application.

Inequal technological competence

Another limitation found in these studies lies in the inequality of students' technological competence. Wen (2021), as well as Lee and Park (2020), found that some students took too much time to adapt to their new AR-assisted class and operate the AR-supported tools. Thus, teachers should carefully manage the time allotment for their classes so that students can have sufficient time to engage in classroom discussion and complete the class assignments. Teachers also need to incorporate students' cognitive engagement in their lesson planning so that students can develop their skills through their efforts (Chen & Wang, 2016) and collaborative work (Wen, 2021). Wen (2021) further indicated cognitive overloading as students initially operated the AR technology. Initially, students found it difficult to optimally use the technology, but the issue was subsequently mitigated as they got used to this technology. This echoes the research results of Hsu (2017) who addressed issues regarding students' inequal technology competence to operate AR-based tools. Hsu (2017) also stated that these tools limited teachers' creativity to develop the learning sequence due to their current less flexible nature of practicability. Teachers cannot expect that students can successfully operate the tools at a similar pace due to their difference in technological competence.

Health and social issues

There are certain risks for students as they are attached to the use of technology. A technology addiction might occur with lead to health and social risks (Plowman et al., 2010; Yilmaz et al., 2017). Yilmaz et al. explained that AR technology should be carefully incorporated into the class due to possible physical, social, health, and ethical issues. The current AR technology requires students to stay steady and mostly immobile to use them properly. Therefore, students will be less physically active and might be at risk of visual disorder due to prolonged use of devices. Another issue is dealing with the lack of interaction among students relies their learning on the content on their device screen (Yilmaz et al., 2017). In another study, Lee and Park (2020) raised their concerns about constructing effective learning activities using AR technology. The authors argued that teachers should also consider the types of activities that actively engage students and yet put a less physical strain on students, particularly concerning their eyesight,. Therefore, teachers should not overlook any possible threats of AR technology dealing with students' health and social interaction due to the lack of physical activities and excessive eyestrain. Additionally, language classroom activities should incorporate learning interactivity which is essential for students to learn a language.

Pedagogical Implications

It is inarguable that the success of AR application relies on various aspects and teachers' ability to predict and identify how students would react to AR technology is one of them. Wen (2021) asserted that teachers have a vital role to plan and organize networked classrooms allowing students to enhance their cognitive ability. For this reason, teachers need to recognize their students' characteristics and determine the

appropriate strategies to incorporate AR technology in their class (Ho et al., 2017; Wu et al., 2013). These strategies can help prevent any possible learning issues or choose the most effective solution to alleviate them. Furthermore, Chen and Wang (2016) also encouraged teachers to understand their students' characters to determine the appropriate instructional tools. They found that the selection teaching strategies strongly influenced the acceptance of AR technology and determined the success of AR integration.

Studies suggested the integration of AR technology for language instruction through various learning schemes. An AR-based game is one of the prominent examples to develop students' language performance. Learning games can potentially develop students' involvement and interaction in a collaborative learning scheme which subsequently increases the frequency of language use (Sydorenko et al., 2019; Sykes et al., 2010; Thorne et al., 2012). Wen (2021) highlighted an influential impact of a sense of competitiveness among students as a result of operating an AR-based game. The author argued that involving students in a competitive game could trigger students' enthusiasm to perform their best and gain particular rewards offered in the game. Also, this improved learning atmosphere could reduce learning anxiety and develop learning motivation (Radu, 2014; Ryu, 2013). Wen (2021) also suggested that schools provide the necessary equipment to help teachers optimally harness AR technology for various schemes of learning activities in particular learning settings.

The application of AR technology can also be applied to develop other learning tools such as e-books and interactive learning boards (Bursali & Yilmaz, 2019; Dunleavy et al., 2009). These tools can help students practice their language during their self-directed learning. There is a possibility that this technology will be utilized in the e-book industry as a substitute for conventional textbooks (Akçayır & Akçayır, 2017). E-books have been deemed as a prospective alternative of a publication format as they offer a lower cost of production, lower prices for consumers, high portability and accessibility, and better support for environmental issues. Using tablets or e-book readers provides a similar experience as paper-printed books. However, adding AR features is likely to provide a different reading experience making it more enjoyable with sounds and interactive images (Akçayır & Akçayır, 2017; Wu et al., 2013). Some studies utilizing AR for developing students' textbooks have shown some positive responses from students.

Furthermore, to optimize the use of AR technology, Yilmaz et al. (2017) suggested a collaboration between parents and teachers to manage the use of AR technology, especially for young learners. Time management is necessary to alleviate harmful risks of using this technology regarding their physical and mental state (Yang & Mei, 2018; Yip et al., 2019).

Research Implications

Based on the previous studies, this review formulates several research implications that can be a reference for future studies on a similar topic. Ho et al. (2017) asserted that the success of AR technology to elevate students' performance cannot be separated from the use of particular learning strategies that suit students' cognitive styles. Thus, they mention the need to investigate the combination of AR technology and particular learning strategies to reveal their effects on students' learning experience.

Wen (2021) highlighted the need for more extensive studies examining students' acceptance and attitudes towards the use of AR technology. These studies can also include a discussion regarding the impacts of this technology based on different variables such as gender, age, and cognitive styles. Similarly, future studies adopting a longitudinal design to explore further the impact of visual and sensory stimuli as students learn through AR technology are necessary to provide in-depth insights regarding the integration of this technology. These types of studies are likely to reveal how the cognitive process takes place and shapes cognitive ability for students with different levels of competence.

Dealing with gamification with AR technology, Sydorenko et al. (2019) encouraged further investigation about the impact of indoor class learning in comparison with outdoor class learning. With different learning atmospheres that subsequently require different strategies from teachers, knowing how gamification through AR technology is integrated into these two different settings might provide insights into the benefits and challenges of AR technology in both settings. Also, future studies adopting gamification through AR technology to achieve particular instructional objectives (enriching students' vocabulary or improving students' oral language skills) are deemed necessary (Sydorenko et al., 2019).

Conclusion

Augmented Reality in education has enormous potential which is yet to be discovered. With the current adoption of mobile technologies and the recent advances in hardware, AR technology is becoming more accessible and more broadly used by education practitioners. Various mobile applications have adopted this

feature to add the value of versatility and attractiveness. In this systematic literature review, the findings of 22 studies from peer-reviewed journals and several databases focusing on the application of AR technology was recorded and analyzed. The analysis was directed at providing answers for the three formulated research questions regarding the application format in the previous studies, the impacts, and the barriers of AR technology in language teaching and learning. The analysis of the findings is summarized as follows:

- Regarding the implementation of AR technology for language learning and teaching in previous studies, the majority of the studies adopted an experimental design involving multiple levels of participants from preschools to higher institutions. Additionally, the studies recruited not only students but also experts and teaching practitioners. In terms of language focus, the majority of studies reported to use the technology to teach English as either a second or foreign language. Other languages reported on other several studies included Turkish, Chinese, Mayo language, Basque, Spanish, Japanese, German and Filipino.
- The application of AR technology for language learning and instructions included AR-based teaching systems and AR-based mobile games.
- Previous studies also identified several impacts of AR technology which included the development of language performance and learning achievement, increased learning satisfaction, reduced learning anxiety, situated learning, personalized learning, and collaborative learning.
- Regarding, the barriers to implementation of AR technology this review indicated several variables including technical limitations, inequal technological competence, and health and social issues.

This review also formulates pedagogical implementation suggesting the support for the development of teachers' technological competence and incorporation of various learning schemes, as well as collaboration between teachers and parents to optimize the utilization of this technology for young learners. Regarding research implications, this review suggests more extensive and longitudinal investigations to examine the effect of this technology on students' acceptance and attitudes towards the use of AR technology. Also, comparative studies examining the impacts of AR-based gamified learning in both indoor and outdoor language classrooms are strongly encouraged.

Limitations

Despite the rapid development of AR technology, studies regarding its application for language instruction are still limited. Due to this reason, several limitations can be extracted from this study. For instance, the criteria to select articles might not be quite rigid to avoid any possible bias. For instance, the review only included empirical studies published in the English language within the last 5 years (2016-2021) and focused on language learning instruction. The search resulted in 22 articles that covered various levels of subjects from different learning backgrounds. Thus, due to the diversities in the characteristics of the study and the limited number of included studies, the conclusion might not be rigid and strongly generalizable for other studies in different learning settings. Additionally, the access to some high-impact journals focusing on language teaching and educational technology are limited which might exclude some quality articles. It might result in the omission of the latest studies on AR applications. Therefore, this study strongly recommends expanding the limitations by including studies outside the area of language instruction. Moreover, the inclusion of non-empirical studies might enrich the findings and provide more detailed description regarding the application of this technology.

References

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, *20*, 1–11. https://doi.org/10.1016/j.edurev.2016.11.002

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational researcher*, *25*(4), 5-11. https://doi.org/10.2307/1176775

August, D., Carlo, M., Dressler, C., & Snow, C. (2005). The critical role of vocabulary development for English language learners. *Learning Disabilities Research & Practice*, *20*(1), 50-57. https://doi.org/10.1111/j.1540-5826.2005.00120.x

Azuma, R. T. (1997). A survey of augmented reality. *Presence: teleoperators & virtual environments*, *6*(4), 355-385. https://doi.org/10.1162/pres.1997.6.4.355

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications, 21*(6), 34–47. https://doi.org/10.1109/38.963459

Balog, A., & Pribeanu, C. (2010). The role of perceived enjoyment in the students' acceptance of an augmented reality teaching platform: a structural equation modelling approach. *Studies in Informatics and Control, 19*(3), 319-330. https://doi.org/10.24846/v19i3y201011

Blevins, B. (2018). Teaching digital literacy composing concepts: Focusing on the layers of augmented reality in an era of changing technology. *Computers and Composition*, *50*, 21-38. https://doi.org/10.1016/j.compcom.2018.07.003

Bronack, S. C. (2011). The role of immersive media in online education. *The Journal of Continuing Higher Education*, *59*(2), 113-117. https://doi.org/10.1080/07377363.2011.583186

Bursali, H., & Yilmaz, R. M. (2019). Effect of augmented reality applications on secondary school students' reading comprehension and learning permanency. *Computers in Human Behavior, 95*, 126–135. https://doi.org/10.1016/j.chb.2019.01.035

Chen, C.-H. (2020). AR videos as scaffolding to foster students' learning achievements and motivation in EFL learning. *British Journal of Educational Technology*, *51*(3), 657–672. https://doi.org/10.1111/bjet.12902

Chen, C.-P., & Wang, C.-H. (2016). The effects of learning style on mobile augmented-reality-facilitated English vocabulary learning. *2015 2nd International Conference on Information Science and Security, Seoul, Korea (South)*, 1–4. https://doi.org/10.1109/ICISSEC.2015.7371036

Dalim, C. S. C., Sunar, M. S., Dey, A., & Billinghurst, M. (2020). Using augmented reality with speech input for non-native children's language learning. *International Journal of Human-Computer Studies*, *134*, 44-64. https://doi.org/10.1016/j.ijhcs.2019.10.002

Diegmann, P., Schmidt-Kraepelin, M., Eynden, S., & Basten, D. (2015). Benefits of augmented reality in educational environments-A systematic literature review. *Wirtschaftsinformatik Proceedings 2015,* 103. https://aisel.aisnet.org/wi2015/103

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology*, *18*(1), 7–22. https://doi.org/10.1007/s10956-008-9119-1

Elliot, A. J., & Covington, M. V. (2001). Approach and avoidance motivation. *Educational Psychology Review*, *13*(2), 73–92. https://doi.org/10.1023/a:1009009018235

Ghosh, I. (2020, February 15th). Ranked: The 100 most spoken languages around the world. *Visual Capitalist*. https://www.visualcapitalist.com/100-most-spoken-languages

Ho, S.-C., Hsieh, S.-W., Sun, P.-C., & Chen, C.-M. (2017). To activate English learning: Listen and speak in real-life context with an AR featured u-learning system. *Educational Technology and Society, 20*(2), 176–187. https://doi.org/10.30191/ETS.201704_20(2).0015

Hsu, T.-C. (2017). Learning English with augmented reality: Do learning styles matter? *Computers and Education, 106*, 137–149. https://doi.org/10.1016/j.compedu.2016.12.007

Ibrahim, A., Huynh, B., Downey, J., Hollerer, T., Chun, D., & O'Donovan, J. (2018). ARbis Pictus: A study of vocabulary learning with augmented reality. *IEEE Transactions on Visualization and Computer Graphics, 24*(11), 2867–2874. https://doi.org/10.1109/TVCG.2018.2868568

Ibrahim, N., Shak, M. S. Y., Mohd, T., Ismail, N. A., Perumal, P. D., Zaidi, A., & Yasin, S. M. A. (2015). The importance of implementing collaborative learning in the English as a second language (ESL) classroom in Malaysia. *Procedia Economics and Finance, 31*, 346–353. https://doi.org/10.1016/S2212-5671(15)01208-3

Ivanova, G., Aliev, Y., & Ivanov, A. (2014). Augmented reality textbook for future blended education. *Proceedings International Conference on e-Learning* 2014, Angel Kanchev University. (pp. 130-136).

Jalaluddin, I., Ismail, L., & Darmi, R. (2020). Developing vocabulary knowledge among low achievers: Mobile augmented reality (MAR) practicality. *International Journal of Information and Education Technology, 10*(11), 813–819. https://doi.org/10.18178/ijiet.2020.10.11.1463

Jang, Y., & Lee, J. (2019). The effects of ideal and ought-to L2 selves on Korean EFL learners' writing strategy use and writing quality. *Reading and Writing, 32*(5), 1129–1148. https://doi.org/10.1007/s11145-018-9903-0

Kesim, M., & Ozarslan, Y. (2012). Augmented reality in education: Current technologies and the potential for education. *Procedia - Social and Behavioral Sciences*, *47*, 297–302. https://doi.org/10.1016/j.sbspro.2012.06.654

Koç, Ö., Altun, E., & Yüksel, H. G. (2021). Writing an expository text using augmented reality: Students' performance and perceptions. *Education and Information Technologies*, *27*, 845-866). https://doi.org/10.1007/s10639-021-10438-x

Lai, J.-Y., & Chang, L.-T. (2021). Impacts of augmented reality apps on first graders' motivation and performance in English vocabulary learning. *SAGE Open*, 11(4). https://doi.org/10.1177/21582440211047549

Lee, S.-M., & Park, M. (2020). Reconceptualization of the context in language learning with a location-based AR app. *Computer Assisted Language Learning*, *33*(8), 936-959. https://doi.org/10.1080/09588221.2019.1602545

Li, K.-C., Chen, C.-T., Cheng, S.-Y., & Tsai, C.-W. (2016). The design of immersive English learning environment using augmented reality. *Universal Journal of Educational Research, 4*(9), 2076–2083. https://doi.org/10.13189/ujer.2016.040919

Miranda Bojórquez, E., Vergara Villegas, O. O., Cruz Sánchez, V. G., García-Alcaraz, J. L., & Favela Vara, J. (2016). Study on mobile augmented reality adoption for Mayo language learning. *Mobile Information Systems, 2016*. https://doi.org/10.1155/2016/1069581

Park, S.-B., Jung, J.-J., & You, E. (2015). Storytelling of collaborative learning system on augmented reality. In D. Camacho, S.-W., Kim, & B. Trawinki, (Eds.), *New trends in computational collective intelligence* (pp. 139–147). https://doi.org/10.1007/978-3-319-10774-5_13

Perry, B. (2015). Gamifying French language learning: A case study examining a quest-based, augmented reality mobile learning-tool. *Procedia - Social and Behavioral Sciences*, *174*, 2308–2315. https://doi.org/10.1016/j.sbspro.2015.01.892

Plowman, L., McPake, J., & Stephen, C. (2010). The technologisation of childhood? Young children and technology in the home. *Children & Society*, *24*(1), 63-74. https://doi.org/10.1111/j.1099-0860.2008.00180.x

Prensky, M. (2001). *Digital game-based learning.* McGraw-Hill.

Redondo, B., Cózar-Gutiérrez, R., González-Calero, J. A., & Ruiz, R. S. (2020). Integration of augmented reality in the teaching of English as a foreign language in early childhood education. *Early Childhood Education Journal*, *48*(2), 147-155. https://doi.org/10.1007/s10643-019-00999-5

Ryu, D. (2013). Play to learn, learn to play: Language learning through gaming culture. *ReCALL, 25*(2), 286–301. https://doi.org/10.1017/S0958344013000050

Santos, M. E. C., Lübke, A. in W., Taketomi, T., Yamamoto, G., Rodrigo, M. M. T., Sandor, C., & Kato, H. (2016). Augmented reality as multimedia: The case for situated vocabulary learning. *Research and Practice in Technology Enhanced Learning, 11*(4). https://doi.org/10.1186/s41039-016-0028-2

Sorrentino, F., Spano, L. D., & Scateni, R. (2015). Speaky notes learn languages with augmented reality. *Proceedings of 2015 International Conference on Interactive Mobile Communication Technologies and Learning, Proceedings. Thessaloniki, Greece.* (pp. 146–150). https://doi.org/10.1109/IMCTL.2015.7359574

Sydorenko, T., Hellermann, J., Thorne, S. L., & Howe, V. (2019). Mobile augmented reality and language-related episodes. *TESOL Quarterly, 53*(3), 712–740. https://doi.org/10.1002/tesq.507

Sykes, J. M. (2018). Digital games and language teaching and learning. *Foreign Language Annals*, *51*(1), 219–224. https://doi.org/10.1111/flan.12325

Sykes, J. M., Reinhardt, J., Thorne, S. L. (2010). Multiuser digital games as sites for research and practice. In F. M. Hult (Eds.) *Directions and prospects for educational linguistics.* (pp. 117-135). Springer. https://doi.org/10.1007/978-90-481-9136-9_8

Thorne, S. L., Fischer, I., & Lu, X. (2012). The semiotic ecology and linguistic complexity of an online game world. *ReCALL, 24*(3), 279-301. https://doi.org/10.1017/S0958344012000158

Tomi, A. B., & Rambli, D. R. A. (2013). An interactive mobile augmented reality magical playbook: Learning number with the thirsty crow. *Procedia Computer Science*, *25*, 123–130. https://doi.org/10.1016/j.procs.2013.11.015

Wagner, D., & Barakonyi, I. (2003). Augmented reality kanji learning. *Proceedings of the Second IEEE and ACM International Symposium on Mixed and Augmented Reality, 2003, Tokyo, Japan.* (pp. 335-336). IEEE. https://doi.org/10.1109/ISMAR.2003.1240747

Wang, Y.-H. (2017). Exploring the effectiveness of integrating augmented reality-based materials to support writing activities. *Computers and Education, 113*, 162–176. https://doi.org/10.1016/j.compedu.2017.04.013

Wen, Y. (2021). Augmented reality enhanced cognitive engagement: Designing classroom-based collaborative learning activities for young language learners. *Educational Technology Research and Development, 69*(2), 843–860. https://doi.org/10.1007/s11423-020-09893-z

What is the Basque language? (2023). Etxepare Basque Institute. Retrieved 21 June, 2023 from https://www.etxepare.eus/en/what-is-the-basque-language

Wu, H.-K., Lee, S. W.-Y., Chang, H.-Y., & Liang, J.-C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers and Education*, *62*, 41–49. https://doi.org/10.1016/j.compedu.2012.10.024

Yang, S., & Mei, B. (2018). Understanding learners' use of augmented reality in language learning: Insights from a case study. *Journal of Education for Teaching*, *44*(4), 511-513. https://doi.org/10.1080/02607476.2018.1450937

Yilmaz, R. M., & Goktas, Y. (2017). Using augmented reality technology in storytelling activities: Examining elementary students' narrative skill and creativity. *Virtual Reality, 21*(2), 75–89. https://doi.org/10.1007/s10055-016-0300-1

Yilmaz, R. M., Kucuk, S., & Goktas, Y. (2017). Are augmented reality picture books magic or real for preschool children aged five to six? *British Journal of Educational Technology, 48*(3), 824–841. https://doi.org/10.1111/bjet.12452

Yip, J., Wong, S.-H., Yick, K.-L., Chan, K., & Wong, K.-H. (2019). Improving quality of teaching and learning in classes by using augmented reality video. *Computers & Education, 128*, 88–101. https://doi.org/10.1016/j.compedu.2018.09.014