

Article

“Wow! This Is So Cool”: Learning Spanish with Augmented Reality

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Abstract: Augmented Reality (AR) enables users to see or interact with virtual objects in real-world environments. This case study examines three AR lessons integrated into a beginner-level Spanish course at a university. The participants were 18 undergraduate students enrolled in this class. The AR lessons portrayed a classroom, a coffee shop, and a family setting aimed at improving students' retention of Spanish vocabulary related to each AR environment. The research data included pre-test and post-test scores, in-class observations, and interviews. Paired-sample *t*-tests were conducted before and after the AR sessions to examine vocabulary retention. The quantitative findings revealed significant differences in test scores among all three interventions, suggesting the efficacy of AR-based learning methods. A thematic analysis was conducted on qualitative data, encompassing interviews with six students and in-class observations. Students shared that the AR-based lessons made learning more engaging and enhanced vocabulary recall. Student interactions increased, and the AR-based lessons inspired students to transition from technology users to designers. This study addresses the need for more AR learner-centered empirical studies in learning Spanish and provides implications for AR educational application design and implementations.

Keywords: augmented reality (AR); Spanish learning; instructional design; instructional technology; emerging technology; case study



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1. Introduction

Augmented Reality (AR) is a technology that enables users to see or interact with virtual objects in a real-world environment (Azuma, 1997). Common examples of AR can be found during football broadcasts in the form of yellow “first down” lines. With the rapid growth of technology, AR development has significantly accelerated, leading to profound transformations in its visual affordances. Besides deploying AR in physical spaces, computer engineers have developed innovative AR applications (e.g., SLART ToolKit) that allow computers with webcams and mobile devices with embedded cameras to project 3D materials over the Internet.

A preliminary survey of AR educational applications suggests that AR educational applications are primarily related to health, engineering, and natural sciences (Avila-Garzon et al., 2021; Matuk, 2016; Yilmaz, 2021). Although integrating emerging technologies into language education has become increasingly popular, the applications of AR language research primarily focus on English (Majid & Salam, 2021; Parmaxi & Demetriou, 2020;

Schorr et al., 2024), indicating a need to explore AR usage in other languages. AR educational application discussions tend to be more technology-centered, focusing on topics related to computer programming and less on the design of the interventions (Weng et al., 2024). When discussing learning gains, the advancements in learning are not sufficiently evaluated by empirical evidence. Furthermore, the impact of AR focused on learners is also less explored, including the influence of AR on students' learning experiences and their reactions to technology.

These observations from the current literature on AR educational applications indicate that (a) there is a need to extend the use of AR to non-science subjects, and (b) there is a need to research the educational applications of AR, emphasizing its implications. Furthermore, understanding learners' experiences with AR is crucial for assessing its educational value and developing meaningful AR applications. Echoing these two critical arguments, the goals of this study are to (a) experiment with AR in a language course, more specifically in Spanish, (b) focus on the influence of AR on students' learning experience and the instructor's teaching experience, and (c) create AR applications that adhere to instructional design strategies to ensure the applications are easy to implement and replicate.

2. Literature Review

2.1. Educational Affordances and Challenges of Augmented Reality

Research has examined the educational affordances of AR across various subject areas in K–12 and higher education settings (Avila-Garzon et al., 2021; Ibáñez & Delgado-Kloos, 2018; Li et al., 2017; Parmaxi & Demetriou, 2020). Key educational affordances of AR noted in the literature include its capacity to transform or enhance real environments with contextually relevant virtual objects; create authentic, immersive, spatially oriented visualizations of abstract or invisible phenomena; provide multisensory experiences while allowing users to maneuver objects in ways that defy physical laws; and recreate events that would otherwise be dangerous, risky, or impossible in the real world, such as historical occurrences or hazardous weather conditions (Challenor & Ma, 2019; Dunleavy et al., 2009; Stefan et al., 2019; Woods et al., 2004; Y. Yang et al., 2019). These affordances have generated novel learning opportunities with reported benefits across multiple disciplines, including science, engineering, and languages. In the sciences, for example, AR has allowed learners to visualize and manipulate invisible scientific phenomena such as electromagnetic fields, molecular structures, internal organs, and geological processes, helping students to better understand these concepts in ways that are challenging to achieve through traditional teaching methods (Dunleavy & Dede, 2014; Furió et al., 2013; Ibáñez & Delgado-Kloos, 2018; Yilmaz, 2021; Yuen et al., 2011). Similar possibilities can be observed in other STEM-related fields, such as engineering, where AR has been effectively employed for teaching concepts in areas such as electronics, technical drawing, assembly, and robotics (Álvarez-Marín & Velazquez-Iturbide, 2021; Sen et al., 2018).

AR has also impacted language learning in significant ways by providing unique opportunities for learners to acquire new vocabulary through dynamic and interactive tasks; contextualizing grammar and vocabulary acquisition within authentic cultural settings, providing authentic practice opportunities; scaffolding sentence construction through enhanced text, word, and sentence organization; and promoting focus and engagement during reading tasks (Godwin-Jones, 2016; Liu et al., 2016; Parmaxi & Demetriou, 2020; Wang, 2017; M. T. Yang & Liao, 2014). Across studies on AR's educational impact, findings indicate that AR enhances knowledge retention, engagement, learner satisfaction, motivation, and collaboration (Akçayır & Akçayır, 2017; Ibáñez & Delgado-Kloos, 2018; Parmaxi & Demetriou, 2020). In language learning, more specifically, AR has been shown to improve student's performance across various language skills, including writing, reading, speak-

ing, and comprehension, while also impacting non-language outcomes such as motivation and engagement (Cai et al., 2022; Parmaxi & Demetriou, 2020; Richardson, 2016).

Despite reported benefits in education and language learning, there are challenges associated with AR's implementation. Technical difficulties have been widely reported in literature resulting from imprecise AR tracking systems, AR's incompatibility with certain devices, issues with network stability and Wi-Fi connectivity, and poor user interface designs (Holden & Sykes, 2011; Kim et al., 2017; Reinders & Lakarnchua, 2014; Steffen et al., 2019). Such challenges can hinder students' experiences, decrease satisfaction, and foster disengagement from tasks (Lau & Wen, 2021; M. T. Yang & Liao, 2014). Moreover, developing AR content for language learning can be time-consuming, and instructors have limited time to implement exploratory and inquiry-based AR experiences within the short lesson periods typical of standard-based educational systems (Cheng, 2021; Clarke-Midura et al., 2011; Klopfer & Squire, 2008; Santos et al., 2016). Other notable challenges with incorporating AR into education and language learning specifically include poor implementation strategies stemming from teachers' limited skills in developing or implementing AR content in line with sound and effective pedagogical principles, limitations related to monitoring and feedback functionalities in AR systems, as well as limited access to AR learning apps tailored to specific foreign languages (Cheng, 2021; Lau & Wen, 2021; O'Shea et al., 2009; Parmaxi & Demetriou, 2020).

2.2. AR and Language Learning

AR's integration into higher education language learning has been the subject of ongoing research and interest. Research in this area usually focuses on either language-specific skills (such as reading, writing, speaking, and listening), non-language outcomes (such as interest, collaboration, and motivation), or both (Majid & Salam, 2021; Parmaxi & Demetriou, 2020). For example, in a study by Ebadi and Ashrafabadi (2022), which investigated both language and non-language-related outcomes from undergraduate EFL students in Iran, students who learned with AR demonstrated significantly higher reading comprehension levels than students who learned the traditional way. The same study reported that students enjoyed learning with AR over traditional reading comprehension approaches and expressed their interest and willingness to further engage with AR-enhanced reading comprehension tasks. However, scholars such as Lee (2022) have emphasized the importance of evaluating technology's efficacy in language learning through direct, empirical measurements of learning outcomes rather than relying solely on students' perceptions, given the mixed evidence regarding technology's effectiveness in language learning.

Moreover, while several studies have investigated AR's application in higher education language learning, many of them have focused predominantly on English, especially in contexts where English is taught as a foreign language or second language (Majid & Salam, 2021; Parmaxi & Demetriou, 2020; Schorr et al., 2024). AR's application in foreign languages such as Chinese, Turkish, and Spanish has also been explored in the literature, although to a lesser extent when compared to English (Parmaxi & Demetriou, 2020; Xie et al., 2024). For the Spanish language, in particular, related studies have typically involved usability and evaluation studies for AR-based interventions designed for Spanish language learning. For instance, Scrivner et al. (2016) evaluated the use of the Aurasma AR app in a beginner-level Spanish language course and found it to be user-friendly, engaging, and effective for student learning. However, the study did not conduct any pre-post comparisons to measure learning outcomes or achievement, and important details such as sample size and participant demographics were not elaborated. Other related studies include design cases and conceptual papers for AR-based Spanish language learning interventions. For example, Holden and Sykes (2011) described a design case for Mentira, a game-and-

location-based AR experience for teaching intermediate-level Spanish pragmatics, while [Hajahmadi et al. \(2024\)](#) presented a conceptual paper describing the learning affordances of an AR-based, Chat-GPT-3.5 integrated Spanish language learning mobile app. While these studies are valuable for expanding current approaches to Spanish language learning, they provide limited empirical evidence of AR's impact on Spanish language learning, especially in the area of vocabulary retention. Hence, this paper bridges an essential gap in the literature by providing additional empirical evidence of AR's efficacy in the previously underexplored context of Spanish language learning through a holistic evaluation of learning gains and students' learning experiences.

2.3. Theoretical and Pedagogical Considerations for AR Integration in Language Learning

[Huang \(2023\)](#) demonstrated the importance of grounding the design of AR resources in instructional design principles and learning theories to enhance learner engagement and promote deep learning. [Sommerauer and Müller \(2018\)](#) also emphasized the need to consolidate evidential data and theoretical frameworks to enhance the effective integration of AR in education. Commonly cited theories that advocated for developing AR learning applications include constructivism and sociocultural learning and the cognitive theory of multimedia learning ([Dunleavy & Dede, 2014](#); [Krüger & Bodemer, 2022](#); [Parmaxi & Demetriou, 2020](#); [Piriyasurawong, 2020](#); [Sommerauer & Müller, 2018](#); [Zhang et al., 2020](#)). These theoretical frameworks will guide this study's evaluation of AR's impact on Spanish language learning.

2.3.1. Constructivism and Sociocultural Learning Theory

Constructivist and sociocultural learning theories underscore the critical roles of context, social interaction, and active participation in effective learning ([Bandura, 1977](#); [Lave & Wenger, 1991](#); [Vygotsky, 1978](#)). These theories suggest that learning is inherently context-specific, with individuals applying prior knowledge to construct new meanings through social interactions and collaborative inquiry ([Zhang et al., 2020](#)). AR language learning applications align with these principles by immersing learners in environments that approximate real-life situations while maintaining the environment's physical and social attributes. This setup enables learners to engage in authentic inquiry, active observation, and interactive activities ([Dunleavy & Dede, 2014](#)). AR also offers realistic conversational contexts, facilitating language acquisition by allowing learners to practice new vocabulary in authentic communicative settings ([Kernan et al., 2018](#); [Xu, 2023](#)). This approach aids learners in developing and applying contextual knowledge effectively ([Zhang et al., 2020](#)). Furthermore, AR applications often incorporate cultural contexts and multimedia elements, enriching learners' understanding of language within its cultural and historical dimensions ([M. T. Yang & Liao, 2014](#)).

2.3.2. Cognitive Theory of Multimedia Learning

According to the Cognitive Theory of Multimedia Learning (CTML), individuals actively process information through sensory, working, and long-term memory via dual channels: auditory-verbal and visual-pictorial, each with limited capacity ([Mayer, 2002](#)). This aligns with cognitive load theory, which postulates limitations in working memory capacity ([Sweller et al., 1998](#)), highlighting the need to design instructional materials that avoid overloading these cognitive channels. There are three types of cognitive processing during learning: extraneous, essential, and generative processing ([Mayer, 2002](#)), corresponding to three types of cognitive load: extraneous, intrinsic, and germane cognitive loads ([Krüger & Bodemer, 2022](#)). Extraneous cognitive processing involves expending mental effort on non-essential elements, whereas the intrinsic process contributes directly to the learning goal. The germane processing depends on the learner's level of motivation

(Krüger & Bodemer, 2022). An effective learning design is to limit extraneous cognitive processing to foster intrinsic and germane processing. The CTML theory is well-suited for designing AR learning resources and environments, as AR systems integrate visual, textual, and auditory information.

CTML has been suggested as the most widely applied framework for designing and evaluating AR-based learning resources (Buchner et al., 2022; da Silva et al., 2019; Garzón et al., 2020; Sommerauer & Müller, 2018). Specifically, the spatial contiguity principle (placing related text and visuals in close proximity) and the coherence principle (minimizing extraneous and unnecessary materials) have been suggested as applicable in enhancing the design of AR resources (Altmeyer et al., 2020; Krüger & Bodemer, 2022). However, further research is needed to evaluate the suitability of applying CTML principles in the design of AR for language learning.

2.4. Research Questions

In this case study, we explored the use of AR in a Spanish language learning course. The overarching research question is: How effective were the AR learning sessions in improving students' language acquisition and learning experience in a beginning-level Spanish undergraduate class?

Individual research questions:

1. Did the AR learning sessions improve students' Spanish vocabulary retention? Did students achieve higher scores on the post-tests compared to the pre-tests?
2. What were students' learning experiences within the AR learning sessions?

3. Materials and Methods

We used a case study methodology to explore the effectiveness of using AR technology in enhancing Spanish language learning. A case study allows for the detailed examination of a situation involving a group or organization in order to understand a phenomenon in its real-world context (Yin, 2018). Here, the beginning-level Spanish undergraduate class was our unit of analysis with a finite number of participants. This study was conducted to produce an "in-depth description and analysis" of the bounded system (Merriam & Tisdell, 2016, p. 39), where the phenomenon's variables cannot be separated from the context (Yin, 2018). In this case study, we studied a bounded system of 18 students enrolled in a 100-level Spanish language course taught by a female assistant professor who had been the instructor for this class for more than three years when this study took place. As the primary instructor, she designed and developed all the learning activities and assessments for this class. Data for this case study were collected from multiple sources (Creswell & Creswell, 2022), including pre-tests, post-tests, interviews, and observations.

3.1. Research Site

This case study was conducted in a beginner-level Spanish class at a regional university with IRB approval in the Spring of 2011. The Spanish class occurred in a technology-rich learning and teaching environment with hardware and software, including computers and webcams, which were essential technological equipment to execute AR learning sessions. In addition, the physical environment of this classroom, where students share their learning space at big tables that seat four to five students per table, made it convenient to conduct group activities. This learning space made it possible for the researchers to explore how students interacted with each other.

3.2. Participants

Students enrolled in the Spanish class participated in this study. Overall, 18 students aged between 18 and 25 were enrolled in this class. Eight of them were female, and ten were male. Additionally, the researchers recruited six students for one-on-one interviews (see Table 1). All participants were from different disciplines at the university, but they all chose to register for this class due to the general education course requirement. Five participants had learned Spanish in high school before taking this class.

Table 1. Demographic Information of the Interview Research Participants.

Name	Gender	Academic Status	Major	Reasons for Enrolling in This Class	Former Foreign Language Learning Experience
Jack	Male	Sophomore	Science	Required	Learned Spanish in high school
Jennifer	Female	Freshman	English	Required	Learned Spanish for two years in high school
Tony	Male	Senior	Business	Required. Good for future career	Learned Spanish for three years in high school
Mike	Male	Sophomore	Transfer student; Undecided	Required	Learned Latin for four years in high school
Rachael	Female	Sophomore	Occupational Therapy	Required	Learned Spanish for two years in high school
Dona	Female	Sophomore	Criminal justice	Required	Learned Spanish for two years in high school

3.3. Research Procedure

Figure 1 presents the research and instructional design processes comprising design, development, and implementation. We collected students' inputs about their learning experience with AR in the form of post-tests, interviews, and observations. The seven-stage process is explained below.

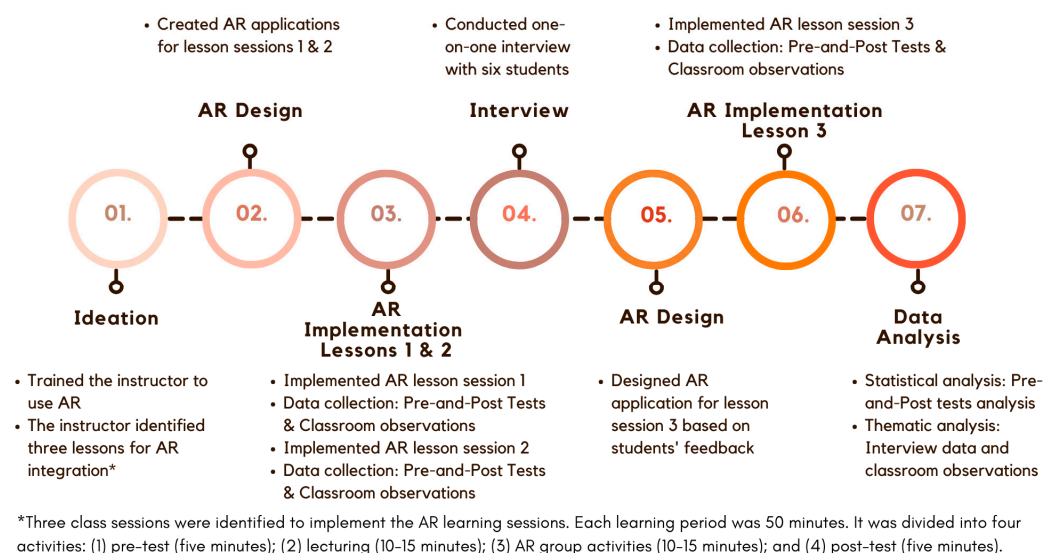


Figure 1. Research Procedure.

Step 1—Ideation

The researchers, who are also instructional designers at the university, met with the Spanish language instructor several times to discuss how and when to integrate AR learning content in the class to engage all the students. The discussions served multiple purposes. First, it allowed the instructor to understand how AR worked to ensure the instructor was comfortable implementing this new technology in the classroom. Second, both parties discussed the potential educational benefits that AR could deliver. Third, they identified the class periods and lesson units where the AR learning content would enhance students' learning. Based on her previous teaching experiences, the instructor decided it would be best to integrate AR learning materials in the middle of the semester when students would be more comfortable learning the language. The concern was that it would add anxiety or be a barrier to students if they needed to learn a new language through a new technology. Finally, it was decided that three AR learning sessions would be integrated into three separate class periods.

Step 2—AR Design

The instructor suggested that the design and research team replicate the textbook learning content to align the AR learning sessions with the textbook content. In other words, the AR learning materials would be an “enforcer” of the learning process. The three lessons were: (1) A Classroom—students learn how to tell the names of physical items often found in a physical classroom (e.g., chairs, tables, doors) in Spanish; (2) A Coffee Shop—students learn how to have casual conversations at a social environment (e.g., a coffee shop) by introducing themselves (e.g., their ethnicity) in Spanish; and (3) A Family—students learn Spanish words that described family members and relationships.

The research and design team started by identifying resources to develop the AR learning materials. They used Google Sketchup, a 3D modeling platform, to design the 3D models for the lessons. They also adhered to cognitive load theory (Sweller et al., 1998) and Mayer's (2002) principles of multimedia educational application in their design to prevent unnecessary extraneous load. The BuildAR viewer application was chosen to deploy the AR applications. It is essential to note that the team utilized an iterative process when designing the AR applications. They considered the initial AR applications as a pilot to understand and assess user experience and improve their design further.

Steps 3 and 4—AR Implementation and Data Collection

As shown in Figure 2, in Step 3, the first two lessons were implemented one after another. Each learning period was 50 min long. It was divided into four activities: (1) pre-test (five minutes); (2) lecturing (10–15 min); (3) group activities (10–15 min); and (4) post-test (five minutes). The AR learning sessions were integrated into the group activities.

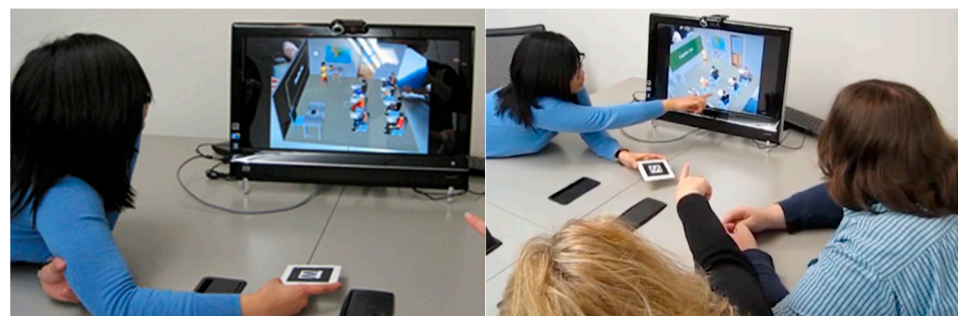


Figure 2. Examples of AR Applications and Group Activities.

For each lesson, the instructor created ten fill-in-the-blank questions for the pre-test and post-test to evaluate students' vocabulary retention ability. Based on the instructor's previous experiences, the difficulty levels of these questions were consistent. The questions were embedded as quiz question banks on the course site of the university's learning management system. The system randomly generated five questions from the question bank each time for the pre-test and post-test.

The research and design team participated in the class sessions to (1) provide the instructor and the students with technical support, (2) implement the AR learning sessions, and (3) observe and document students' learning experiences. The researchers observed and documented the interactions between the students and the AR material and their interactions with each other. This process was repeated for lessons one and two. After implementing lesson two, the researchers conducted one-on-one interviews with six participants.

Step 5—AR Design

The feedback data collected from the students in the previous steps was analyzed. The findings were used to design the Lesson 3 AR application.

Step 6—AR Implementation

Following a procedure similar to Steps 3 and 4, lesson 3 AR learning materials were implemented in the classroom. A pre-test before the lesson and a post-test after the lesson implementation were conducted. Students' interaction with one another and the AR material was also observed and recorded. Figure 2 shows one of the AR applications and group activities.

3.4. Data Analysis

Data included pre-test and post-test results from the three AR sessions (labeled as AR lesson sessions 1, 2, and 3 in Figure 1), individual interviews ($n = 6$), and classroom observations. Paired sample *t*-tests were used to analyze the pre-test and post-test quantitative data. For the qualitative data, we used thematic and inductive analysis (Bingham & Witkowsky, 2022) to analyze the interview data and field notes. The process started with reviewing and coding each interview transcript. The first phase of the coding revealed several themes emerging from the interview data, including motivation for learning Spanish, learning preferences, learning with technology in general, first reaction toward the AR application, learning with AR, learning in groups (e.g., interaction with peers), ideas for future AR applications, etc. A thematic analysis of the field notes revealed themes about students' learning with AR and learning in group settings. Table 2 shows the research questions, data sources, and data analysis methods.

Table 2. Research Questions, Data Sources, and Data Analysis Methods.

Research Questions	Data Sources	Data Analysis Methods
RQ1. Did the AR learning sessions improve students' Spanish vocabulary retention? Did students achieve higher scores on the post-tests compared to the pre-tests?	• Pre-test and post-test	Paired sample <i>t</i> -tests
RQ2. What were students' learning experiences within the AR learning sessions?	• Individual student interviews • The design and research team's classroom observations	Thematic and inductive analysis.

In this case study, we established external validity and transferability by explicitly explaining the steps that were followed while implementing and evaluating the AR-based learning interventions (Yin, 2018). We believe this and the research design can inform similar endeavors in future studies. We collected both quantitative and qualitative data through surveys, interviews, and observations to establish data triangulation and coherence (Denzin, 1978; Lincoln & Guba, 1985). Semi-structured interviews (Merriam & Tisdell, 2016) with the participants covering their learning experiences, technology use, and other aspects of instructional design provided a rich source of qualitative data. The first and the fourth authors collected and analyzed the interview data independently and met several times to compare findings, control for bias, and build consensus (Denzin, 1978; Patton, 2015). We have provided participants' own words as quotes without paraphrasing to enable readers to connect directly with participants' opinions (Erickson, 2012).

4. Results

In this section, we present the quantitative and qualitative data findings to provide insights into students' perceptions of the effectiveness of the AR learning sessions and their learning experiences with AR.

4.1. Learning Effectiveness

To answer research question 1, which is about the effectiveness of the AR learning sessions, pre-tests and post-tests were implemented in each AR learning session to assess students' vocabulary retention. Table 3 shows the descriptive statistics for students' pre- and post-test scores for the three AR learning sessions. A paired sample *t*-test was performed to compare students' pre-test and post-test scores before and after each AR learning session. The statistical analysis showed significant differences in students' test scores before and after every AR learning session. There was a significant difference in students' scores before ($M = 3.70$, $SD = 1.32$) and after ($M = 4.77$, $SD = 0.53$) the first AR learning session, $t(14) = -3.51$, $p = 0.003$. There was a significant difference in students' scores before ($M = 3.67$, $SD = 1.3$) and after ($M = 4.67$, $SD = 0.49$) the second AR learning session, $t(11) = -3.07$, $p = 0.001$. There was a significant difference in students' scores before ($M = 2.04$, $SD = 1.51$) and after ($M = 4.08$, $SD = 0.76$) the third AR learning session, $t(12) = -4.79$, $p = < 0.001$.

Table 3. Descriptive Statistics for Pre-Test and Post-Test Scores.

AR Learning Session	Pre-Test <i>M</i> (<i>SD</i>)	Post-Test <i>M</i> (<i>SD</i>)
AR Session 1 (<i>N</i> = 15)	3.70 (1.32)	4.77 (0.53)
AR Session 2 (<i>N</i> = 12)	3.67 (1.30)	4.67 (0.49)
AR Session 3 (<i>N</i> = 13)	2.034 (1.51)	4.08 (0.76)

Note: The highest possible score for the pre-test and post-test, respectively, was 5.

4.2. Learning Experience

Participants' learning experiences were investigated based on the individual interviews conducted after the second AR learning session and the observations captured by the design and research team. The data were evaluated using a thematic analysis approach. Several themes evolved from the data, which are discussed below.

4.2.1. AR vs. Textbooks: More Dimensions; More Engaging

All participants indicated that they liked the AR learning experiments and believed those sessions helped them learn better. They shared a variety of reasons why AR was helpful. One commonly agreed reason for why they found AR helpful was that it is a more interactive and engaging medium compared to other learning resources or mediums such as textbooks or video clips. One student commented, “When you read a textbook, you kind of go through it, scan it. You don’t really get into it ... the [AR] model is more exciting.” Another shared this comment. “The textbook is boring [it] is always flat in front of you, and I’ll pay attention more, you know, on the computer plus the little people were there, and there were like little dogs and stuff [the participant was describing the AR 3D models]. It was just cool. I loved it.” Additionally, the AR applications fit these students’ learning preferences well since most participants favored learning with multimedia elements. One student commented, “I just like to learn visually. I think it is awesome that you can do it now.” Another student specifically commented on how valuable it was to them: “I think putting it [the AR application] with a picture helps me remember things. So, I liked that aspect a lot.”

Another student also shared a similar reaction to the medium. Still, she went further to point out how AR (the technology) stimulated or impacted the interactivity between students and their peers. “Well, I think it was more memorable than just staring at a picture in the book because you could manipulate it [the AR application]. Mm hmm. Then, there was more conversation at the table because we were trying to figure out the different characters in the picture ... I think it helped me to remember vocabulary a little better.” This participant went on to share more on why AR was memorable and effective compared to the textbook: “I still remember what the screen looked like when we did the first one. The classroom. I don’t remember the pictures from the book.”

4.2.2. Excitement About, Yet Fear of, the Unknown and New Technology

“Wow! This is so cool.” The first time we conducted the AR experiment, students were blown away by what they saw on the computer screens. What was important from this first AR session was that it served as an introduction to AR for the students. None of the students had heard of or seen AR applications operated through a cardboard marker and a webcam before the session. One student chuckled while sharing his reaction when seeing the AR application for the first time: “The little thing ... it’s like a cube. I have never seen anything like that.” Another student said, “It shocked me at first. Really? What is this imaging coming from?”

The students were surprised and, to some extent, intrigued by what they saw; however, they only interacted with the AR applications a little initially. When asked, some students indicated they did not quite understand what AR was and did not know what to do with it. One student shared that “you explained what it was, but we still didn’t understand it.” This lack of understanding of the technology seemed to be an obstacle for the students in the beginning when using it. One student indicated: “We didn’t mess with it too much because if we touch it too much, the picture went away. But we did spin it and turn it so we could see the other things in the picture.”

Some students admitted that they were worried the 3D model on the monitor would disappear if they moved the marker too much. One student mentioned, “It would kill your arm if you keep holding the marker.” This student continued to share that their group figured out a way to prop the marker at a certain angle so that they could see the complete 3D model without moving the marker. He added proudly, “I actually was the one that figured out how to set it down. Everyone was holding it up. But I landed it on the desk.”

Fear existed among the students when using new technology for the first time. However, our observations suggested that students became at ease with the technology during the second AR session as they could freely use the AR marker to engage in the lesson and converse with their peers.

4.2.3. Beyond Learning Spanish—Being Inspired by AR

All six interview participants agreed and shared that AR applications could be implemented in various courses, such as history, mathematics, and nursing, to enhance learning. In addition to sharing how they felt about using AR for education, some participants mentioned that they were curious about the technology and took the initiative to explore it right after the first AR learning session. One student shared: “It just really shocked me at first. I was, like, really? Where’s the image coming from? ... It made me curious.” Another was interested in learning about the design process and the tools used to create the AR applications. During the interview, she asked several technical questions, such as “How does the marker work?”; “How did you create the 3D model?”. A student was so fascinated by the learning effect that she shared her experience with her mother, an elementary school teacher who was into technology, shortly after the first AR learning session. She said in an excited tone, “I went home and told my mom about it. She teaches fourth grade. She thought it was really neat!”

The research team was surprised by this phenomenon, given that none of the interviewees were from the field of education or technology. Nevertheless, the experience prompted them to reflect on their learning experiences and the technology (i.e., AR).

5. Discussion

The quantitative phase of this case study showed a significant difference in students’ learning before and after each AR learning session, indicating that the AR learning sessions improved students’ language acquisition in the beginning-level Spanish undergraduate class. The qualitative phase provided supporting evidence on why this was so. Additionally, it highlighted how the collaboration between learning design and learning theories fosters an improved educational environment for students, as well as what is required to assist both instructors and students in adapting to new learning technologies.

5.1. Learning Effectiveness and Experience

The quantitative data analysis showed that the AR-based intervention produced significant learning gains for all students. Although any learning intervention would produce learning gains, the qualitative findings clearly showed that students had better learning experiences and outcomes owing to the features of AR that immersed them in the learning environment. The interactive elements of the AR environment with the 3D models brought to life the passive elements in textbooks that are “flat” and “boring,” according to the students. The AR environment was attention-grabbing, and the virtual elements were attractive, as in prior studies where overlaying visual, verbal, and interactive virtual objects on the learning material enhanced learning (Chin et al., 2020; Xu, 2023).

In this case study, an interactive, authentic learning environment immersed students in their learning and made it “memorable,” as one student said. Students were trying to figure out the different characters in a coffee shop environment and learned to express different ages or ethnic groups in Spanish during session 2. In session 3, students learned Spanish words that described family members and relationships. In this study, the visualization properties of AR benefited students in language learning as it provided students with an awareness of the cultural contexts (Godwin-Jones, 2016; M. T. Yang & Liao, 2014). Furthermore, AR, similar to some other interactive media, was used to provide

real-time visual and sensorimotor feedback (Hedley, 2003), creating a sense of immediacy (Chang et al., 2022), thereby increasing student engagement and improving presence and immersion.

In prior studies, AR has also been found to promote motivation in language learning (Cai et al., 2022; Chang et al., 2022; Parmaxi & Demetriou, 2020), especially when the interventions were for longer periods. Other studies have highlighted how higher levels of engagement and interest were recorded due to the challenging yet enjoyable tasks that were provided using AR (Fan et al., 2020; Perry, 2015; Richardson, 2016; Taskiran, 2019; Vedadi et al., 2019). This was evident in the present case study as well and was attributed to the highly interactive learning experience that AR could provide, which was much more engaging than other mediums, such as textbooks or videos.

The feedback from the students after sessions 1 and 2 helped us make some changes in session 3. Students preferred that visual and textual information appear closer together so that they could connect the images to the corresponding words directly. Suitable edits were made to the AR environment, aligning with the spatial contiguity principle and the coherence principle based on the cognitive theory of multimedia learning (Krüger & Bodemer, 2022; Mayer, 2002).

5.2. Peer Collaboration

Social interactions have long been associated with accomplishing learning tasks (Bandura, 1977; Lantolf & Zhang, 2015; Prior, 2006; Vygotsky, 1978), including language learning (Aljohani, 2017; Zhang et al., 2020). In this case study, students participated in group activities such as finding the various characters and objects in the AR applications and practicing new Spanish vocabulary with each other based on what they saw on the AR screen. As shared by the interview participants, this learning design strategy enhanced their interactions with their peers, improved peer collaboration, and made learning more memorable. This finding reflected what was reported in prior studies on AR's capacity to foster shared engagement and collaboration between learners (Bacca Acosta et al., 2014; Dunleavy et al., 2009; MacCallum & Jamieson, 2017).

To explore this observation further from the Cognitive Theory of Multimedia Learning (CTML) perspective, peer collaboration likely reduced the cognitive load, or the total working memory resources needed to carry out a learning task, as it was divided among students to improve their learning and recall (Buchner et al., 2022; Kirschner et al., 2018; Leahy & Sweller, 2011; Sweller, 2010). In addition, it was suggested by the participants that peer collaboration also helped them deal with the new technology and its challenges found in this case study.

5.3. New Technology

It was not easy at first for students to interact with the new technology. They were surprised, worried, and realized that it was physically too much effort, as was found in other studies about usability issues, technical problems, and technology acceptance (Ajit et al., 2021; Wu et al., 2013). Although some students in this case study were hesitant to interact with the AR environment at the beginning and were overwhelmed with the new technology, they were also curious about AR. Using AR was another obstacle because students had to hold the physical marker and point it toward the camera, which hurt their hands. Similar problems with AR technology have been noted in prior studies (Kim et al., 2017; Steffen et al., 2019). However, this obstacle prompted creative problem-solving in this study context. Students soon figured out a way to place the marker in a specific position so that they did not need to hold it, which made interactivity among students easier.

The researchers' observations showed that fear gave way to confidence following the second session. The new AR learning environment inspired curiosity and problem-solving concerning the technology, which went beyond learning the subject matter. AR encouraged peer collaboration in subject learning, problem-solving, and sharing new experiences with others outside the classroom. Similar to learning through collaboration, this case study showed that collaborative problem-solving helped reduce the extraneous cognitive load attributed to the technology (Mayer, 2002; Sweller et al., 1998). These findings should encourage more instructors to experiment with emerging technologies in their classrooms.

5.4. Instructional Design Support

Prior research has shown that it is challenging for teachers to first master the technology, create a curriculum, manage the learning process, and ultimately assess student learning (Cheng, 2021; Lau & Wen, 2021). Our experience in guiding the teachers through the steps of implementing an AR environment was successful. It is possible that the presence of experienced instructional designers who were familiar with the technology was instrumental to this successful implementation. We believe that an active collaboration between instructional designers and instructors will provide a meaningful solution.

This type of collaboration will also help ensure that all instructors and instructional designers understand the affordances of AR and align its potential for meaningful application in educational contexts (Steffen et al., 2019). We recommend that for optimizing the use of AR, it is necessary to intentionally incorporate learning theories and a diverse set of instructional strategies (Cai et al., 2022; Parmaxi & Demetriou, 2020) in the design of AR-based learning environments.

6. Limitations and Future Research

Although the results indicate that AR learning sessions were effective, this study does have some limitations. The sample size of this study is small ($N = 15$), which makes the findings less generalizable. There was no control group, making it difficult to determine whether the positive outcomes were due to AR activities or other activities students engaged in during the sessions. The research took place in 2011, and since then, there have been significant advancements in AR technology. Future studies could explore how to apply the materials created in this study, such as the 3D models, and incorporate them into various emerging technology platforms, such as VR, to assess differences in learning effectiveness. While the one-on-one interviews conducted with six participants offered some insights into learning experiences, the interview protocols could be improved as well. The researchers might have incorporated further assessments, such as verbal language tests, to better gauge what the students genuinely retained, presenting a chance for future research. Furthermore, an upcoming study could involve the use of pre- and post-AR learning experience surveys to gain a comprehensive understanding of the students' learning experiences.

7. Conclusions

This case study investigated how AR learning sessions influence undergraduate students' learning experiences and outcomes in a beginning-level Spanish class. Three different AR learning sessions were integrated into the Spanish class. The findings suggested that the AR learning sessions improved students' vocabulary retention and enhanced their learning experiences. Collaboration among peers helped alleviate technology anxiety, and students creatively solved problems related to technology handling. When reviewing the study as a whole and reflecting on its implications, the authors took a holistic perspective to examine the implications of the study, starting from the design of the AR sessions. It is chal-

lenging for teachers to master emerging technologies (e.g., AR, VR), create a curriculum, and ultimately facilitate the learning process (Cheng, 2021; Lau & Wen, 2021). In this case, the instructor worked with the research and design team, familiar with AR and learning design, to implement the AR learning sections. The positive learning experiences observed in this case study suggest that supporting instructors interested in implementing emerging technologies (e.g., AR) to enhance learning is essential. Secondly, the design of the AR sessions was integrated into the regular sessions with social interaction learning theories in mind that aim to promote learning through interaction. This implies that connecting to learning theories (Parmaxi & Demetriou, 2020) and implementing different instructional strategies (Cai et al., 2022) are recommended to make learning with AR effective.

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References

- Ajit, G., Lucas, T., & Kanyan, R. (2021). A systematic review of augmented reality in STEM education. *Studies of Applied Economics*, 39(1), 1–22. [\[CrossRef\]](#)
- 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. [\[CrossRef\]](#)
- Aljohani, M. (2017). Principles of “constructivism” in foreign language teaching. *Journal of Literature and Art Studies*, 7(1), 97–107. [\[CrossRef\]](#)
- Altmeyer, K., Kapp, S., Thees, M., Malone, S., Kuhn, J., & Brünken, R. (2020). The use of augmented reality to foster conceptual knowledge acquisition in STEM laboratory courses—Theoretical background and empirical results. *British Journal of Educational Technology*, 51(3), 611–628. [\[CrossRef\]](#)
- Avila-Garzon, C., Bacca-Acosta, J., Duarte, J., & Betancourt, J. (2021). Augmented reality in education: An overview of twenty-five years of research. *Contemporary Educational Technology*, 13(3), 37.
- Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators & Virtual Environments*, 6(4), 355–385.
- Álvarez-Marín, A., & Velazquez-Iturbide, J. A. (2021). Augmented reality and engineering education: A systematic review. *IEEE Transactions on Learning Technologies*, 14(6), 817–831. [\[CrossRef\]](#)
- Bacca Acosta, J. L., Baldiris Navarro, S. M., Fabregat Gesa, R., & Graf, S. (2014). Augmented reality trends in education: A systematic review of research and applications. *Journal of Educational Technology and Society*, 17(4), 133–149.
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191–215. [\[CrossRef\]](#)
- Bingham, A. J., & Witkowsky, P. (2022). Deductive and inductive approaches to qualitative data analysis. In C. Vanover, P. Mihas, & J. Saldaña (Eds.), *Analyzing and interpreting qualitative data: After the interview* (pp. 133–146). SAGE Publications.
- Buchner, J., Buntins, K., & Kerres, M. (2022). The impact of augmented reality on cognitive load and performance: A systematic review. *Journal of Computer Assisted Learning*, 38(1), 285–303. [\[CrossRef\]](#)
- Cai, Y., Pan, Z., & Liu, M. (2022). Augmented reality technology in language learning: A meta-analysis. *Journal of Computer Assisted Learning*, 38(4), 929–945. [\[CrossRef\]](#)

- Challenor, J., & Ma, M. (2019). A review of augmented reality applications for history education and heritage visualisation. *Multimodal Technologies and Interaction*, 3(2), 39. [\[CrossRef\]](#)
- Chang, H. Y., Binali, T., Liang, J. C., Chiou, G. L., Cheng, K. H., Lee, S. W. Y., & Tsai, C. C. (2022). Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact. *Computers & Education*, 191, 104641. [\[CrossRef\]](#)
- Cheng, H.-J. (2021). Integrating augmented reality and virtual reality technology into Chinese education: An observation from nine cases. In Y. J. Lan, & S. Grant (Eds.), *Contextual language learning. Chinese language learning sciences*. Springer. [\[CrossRef\]](#)
- Chin, K.-Y., Lee, K.-F., & Chen, Y.-L. (2020). Effects of a ubiquitous guide-learning system on cultural heritage course students' performance and motivation. *IEEE Transactions on Learning Technologies*, 13(1), 52–62. [\[CrossRef\]](#)
- Clarke-Midura, J., Dede, C., & Norton, J. (2011). Next generation assessments for measuring complex learning in science. In *The road ahead for state assessments* (pp. 27–40). Rennie Center for Education Research & Policy.
- Creswell, J. W., & Creswell, J. D. (2022). *Research design: Qualitative, quantitative, and mixed methods approaches* (6th ed.). Sage Publications.
- da Silva, M. M., Teixeira, J. M. X., Cavalcante, P. S., & Teichrieb, V. (2019). Perspectives on how to evaluate augmented reality technology tools for education: A systematic review. *Journal of the Brazilian Computer Society*, 25, 3. [\[CrossRef\]](#)
- Denzin, N. K. (1978). *The research act: A theoretical introduction to sociological methods* (2nd ed.). McGraw-Hill.
- Dunleavy, M., & Dede, C. (2014). Augmented reality teaching and learning. In *Handbook of research on educational communications and Technology* (pp. 735–745). Springer Science+Business Media.
- 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, 7–22. [\[CrossRef\]](#)
- Ebadi, S., & Ashrafabadi, F. (2022). An exploration into the impact of augmented reality on EFL learners' Reading comprehension. *Education and Information Technologies*, 27(7), 9745–9765. [\[CrossRef\]](#)
- Erickson, F. (2012). Qualitative research methods for science education. *Second International Handbook of Science Education*, 1451–1469.
- Fan, M., Antle, A. N., & Warren, J. L. (2020). Augmented reality for early language learning: A systematic review of augmented reality application design, instructional strategies, and evaluation outcomes. *Journal of Educational Computing Research*, 58(6), 1059–1100. [\[CrossRef\]](#)
- Furió, D., Juan, M.-C., Seguí, I., & Vivó, R. (2013). Mobile learning vs. traditional classroom lessons: A comparative study. *Journal of Computer Assisted Learning*, 29(5), 471–480. [\[CrossRef\]](#)
- Garzón, J., Baldiris, S., Gutiérrez, J., & Pavón, J. (2020). How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and research synthesis. *Educational Research Review*, 31, 100334. [\[CrossRef\]](#)
- Godwin-Jones, R. (2016). *Augmented reality and language learning: From annotated vocabulary to place-based mobile games*. University of Hawaii National Foreign Language Resource Center.
- Hajahmadi, S., Clementi, L., López, M. D. J., & Marfia, G. (2024, March 16–21). ARELE-bot: Inclusive learning of spanish as a foreign language through a mobile app integrating augmented reality and ChatGPT. 2024 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW) (pp. 335–340), Orlando, FL, USA.
- Hedley, N. R. (2003, August 10–16). *Empirical evidence for advanced geographic visualization interface use*. International Cartographic Congress, Durban, South Africa.
- Holden, C. L., & Sykes, J. M. (2011). Leveraging mobile games for place-based language learning. *International Journal of Game-Based Learning (IJGBL)*, 1(2), 1–18. [\[CrossRef\]](#)
- Huang, W. (2023). Deep learning becomes a reality when emerging technologies meet learning design. *TechTrends*, 67, 178–188. [\[Cross-Ref\]](#)
- Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, 123, 109–123.
- Kernan, W. D., Basch, C. H., & Cadorett, V. (2018). Using mind mapping to identify research topics: A lesson for teaching research methods. *Pedagogy in Health Promotion*, 4(2), 101–107. [\[CrossRef\]](#)
- Kim, K., Maloney, D., Bruder, G., Bailenson, J. N., & Welch, G. F. (2017). The effects of virtual human's spatial and behavioral coherence with physical objects on social presence in AR. *Computer Animation and Virtual Worlds*, 28(3–4), e1771. [\[CrossRef\]](#)
- Kirschner, P. A., Sweller, J., Kirschner, F., & Zambrano R, J. (2018). From cognitive load theory to collaborative cognitive load theory. *International Journal of Computer-Supported Collaborative Learning*, 13, 213–233. [\[CrossRef\]](#)
- Klopfer, E., & Squire, K. (2008). Environmental Detectives—the development of an augmented reality platform for environmental simulations. *Educational Technology Research and Development*, 56, 203–228. [\[CrossRef\]](#)
- Krüger, J. M., & Bodemer, D. (2022). Application and investigation of multimedia design principles in augmented reality learning environments. *Information*, 13(2), 74. [\[CrossRef\]](#)
- Lantolf, J. P., & Zhang, X. (2015). Response to pienemann's critique of Zhang and Lantolf (2015). *Language Learning*, 65(3), 752–760. [\[CrossRef\]](#)

- Lau, S. Y., & Wen, Y. (2021). A systematic literature review of augmented reality used in language learning. In *Contextual language learning: Real language learning on the continuum from virtuality to reality* (pp. 171–186). Springer.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.
- Leahy, W., & Sweller, J. (2011). Cognitive load theory, modality of presentation and the transient information effect. *Applied Cognitive Psychology*, 25(6), 943–951. [\[CrossRef\]](#)
- Lee, S. M. (2022). A systematic review of context-aware technology use in foreign language learning. *Computer Assisted Language Learning*, 35(3), 294–318. [\[CrossRef\]](#)
- Li, W., Nee, A. Y., & Ong, S. K. (2017). A state-of-the-art review of augmented reality in engineering analysis and simulation. *Multi-modal Technologies and Interaction*, 1(3), 17. [\[CrossRef\]](#)
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage.
- Liu, Y., Holden, D., & Zheng, D. (2016). Analyzing students' language learning experience in an augmented reality mobile game: An exploration of an emergent learning environment. *Procedia-Social and Behavioral Sciences*, 228, 369–374. [\[CrossRef\]](#)
- MacCallum, K., & Jamieson, J. (2017, October 2–4). *Exploring augmented reality in education viewed through the affordance lens*. Proceedings of the 8th Annual Conference of Computing and Information Technology Education and Research in New Zealand (pp. 114–120), Napier, New Zealand.
- Majid, S. N. A., & Salam, A. R. (2021). A systematic review of augmented reality applications in language learning. *International Journal of Emerging Technologies in Learning*, 16(10). [\[CrossRef\]](#)
- Matuk, C. (2016). The learning affordances of augmented reality for museum exhibits on human health. *Museums & Social Issues*, 11(1), 73–87.
- Mayer, R. E. (2002). Multimedia learning. *Psychology of Learning and Motivation*, 41, 85–139.
- Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.
- O'Shea, P., Mitchell, R., Johnston, C., & Dede, C. (2009). Lessons learned about designing augmented realities. *International Journal of Gaming and Computer-Mediated Simulations (IJGCMS)*, 1(1), 1–15. [\[CrossRef\]](#)
- Parmaxi, A., & Demetriou, A. A. (2020). Augmented reality in language learning: A state-of-the-art review of 2014–2019. *Journal of Computer Assisted Learning*, 36(6), 861–875. [\[CrossRef\]](#)
- Patton, M. Q. (2015). *Qualitative research and evaluation methods* (4th ed.). Sage.
- 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. [\[CrossRef\]](#)
- Piriyasurawong, P. (2020). Scaffolding augmented reality model to enhance deep Reading skill. *TEM Journal*, 9(4), 1760–1764. [\[Cross-Ref\]](#)
- Prior, P. (2006). A sociocultural theory of writing. In C. A. MacArthur, S. Graham, & J. Fitzgerald (Eds.), *Handbook of writing research* (pp. 54–66). The Guilford Press.
- Reinders, H., & Lakarnchua, O. (2014). Implementing mobile language learning with an augmented reality activity. *Modern English Teacher*, 23(2), 42–46.
- Richardson, D. (2016). Exploring the potential of a location based augmented reality game for language learning. *International Journal of Game-Based Learning (IJGBL)*, 6(3), 34–49. [\[CrossRef\]](#)
- Santos, M. E. C., Lübke, A. I. 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. [\[CrossRef\]](#) [\[PubMed\]](#)
- Schorr, I., Plecher, D. A., Eichhorn, C., & Klinker, G. (2024). Foreign language learning using augmented reality environments: A systematic review. *Frontiers in Virtual Reality*, 5, 1288824. [\[CrossRef\]](#)
- Scrivner, O., Madewell, J., Buckley, C., & Perez, N. (2016, December 6–7). *Augmented reality digital technologies (ARDT) for foreign language teaching and learning*. 2016 Future Technologies Conference (FTC) (pp. 395–398), San Francisco, CA, USA.
- Sen, A., Chuen, C. L., & Zay Hta, A. C. (2018). Toward smart learning environments: Affordances and design architecture of augmented reality (AR) applications in medical education. In *Proceedings of first international conference on smart system, innovations and computing: SSIC 2017, Jaipur, India* (pp. 843–861). Springer Singapore.
- Sommerauer, P., & Müller, O. (2018, June 23–28). *Augmented reality for teaching and learning—A literature review on theoretical and empirical foundations*. European Conference on Information Systems 2018 (Vol. 2, pp. 31–35), Portsmouth, UK.
- Steffen, J. H., Gaskin, J. E., Meservy, T. O., Jenkins, J. L., & Wolman, I. (2019). Framework of affordances for virtual reality and augmented reality. *Journal of Management Information Systems*, 36(3), 683–729. [\[CrossRef\]](#)
- Sweller, J. (2010). Element interactivity and intrinsic, extraneous, and germane cognitive load. *Educational Psychology Review*, 22, 123–138. [\[CrossRef\]](#)
- Sweller, J., Van Merriënboer, J. J., & Paas, F. G. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, 10, 251–296. [\[CrossRef\]](#)

- Taskiran, A. (2019). The effect of augmented reality games on English as foreign language motivation. *E-Learning and Digital Media*, 16(2), 122–135. [\[CrossRef\]](#)
- Vedadi, S., Abdullah, Z. B., & Cheok, A. D. (2019, April 8–11). *The effects of multi-sensory augmented reality on students' motivation in English language learning*. 2019 IEEE Global Engineering Education Conference (EDUCON) (pp. 1079–1086), Dubai, United Arab Emirates.
- Vygotsky, L. S. (1978). The role of play in development. In *Mind in Society*. Harvard University Press.
- Wang, Y. H. (2017). Exploring the effectiveness of integrating augmented reality-based materials to support writing activities. *Computers & Education*, 113, 162–176.
- Weng, Y., Schmidt, M., Huang, W., & Hao, Y. (2024). The effectiveness of immersive learning technologies in K–12 English as second language learning: A systematic review. *ReCALL*, 36(2), 210–229. [\[CrossRef\]](#)
- Woods, E., Billinghamurst, M., Looser, J., Aldridge, G., Brown, D., Garrie, B., & Nelles, C. (2004, June 15–18). *Augmenting the science centre and museum experience*. Proceedings of the 2nd International Conference on Computer Graphics and Interactive Techniques in Australasia and South East Asia (pp. 230–236), Singapore.
- 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 & Education*, 62, 41–49. [\[CrossRef\]](#)
- Xie, X., Gong, M., Qu, Z., & Bao, F. (2024). Exploring augmented reality for Chinese as a foreign language learners' reading comprehension. *Immersive Learning Research-Academic*, 246–252.
- Xu, D. (2023). Research on the development and application of English teaching resources based on augmented reality. *Open Journal of Social Sciences*, 11(7), 21–31. [\[CrossRef\]](#)
- Yang, M. T., & Liao, W. C. (2014). Computer-assisted culture learning in an online augmented reality environment based on free-hand gesture interaction. *IEEE Transactions on Learning Technologies*, 7(2), 107–117. [\[CrossRef\]](#)
- Yang, Y., Wu, S., Wang, D., Huang, Y., & Cai, S. (2019, December 2–6). *Effects of learning activities based on augmented reality on students' understanding and expression in an English class*. ICCE 2019: The 27th International Conference on Computers in Education, Kenting, Taiwan.
- Yilmaz, O. (2021). Augmented Reality in science education: An application in higher education. *Shanlax International Journal of Education*, 9(3), 136–148. [\[CrossRef\]](#)
- Yin, R. K. (2018). *Case study research and applications* (6th ed.). Sage.
- Yuen, S. C.-Y., Yaoyuneyong, G., & Johnson, E. (2011). Augmented reality: An overview and five directions for AR in education. *Journal of Educational Technology Development and Exchange*, 4(1), 119–140. [\[CrossRef\]](#)
- Zhang, D., Wang, M., & Wu, J. G. (2020). Design and implementation of augmented reality for English language education. In *Augmented reality in education: A new technology for teaching and learning* (pp. 217–234). Springer.

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