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(REVIEW ARTICLE)

Augmented reality in teaching and learning English as a foreign language: A systematic review and meta-analysis

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Abstract

This study provides implications on the application of augmented reality (AR) in education through a review of research papers focused on a type of XR technology, identifying and describing its practical application using examples drawn from different contexts in facilitating learning English as a foreign language (EFL). Specifically, we conducted a systematic review and meta-analysis to bring together information on how available tools employing XR technology can be used to enhance English language learning. This study focuses on providing information for a better understanding of AR-based learning and its integration in both classroom and personal customized learning of EFL. The review aligns with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Statement (PRISMA) guidelines. Literature was searched from ACM Digital Library, IEEE Xplore, PubMed, ERIC, the Cochrane CENTRAL library, and Google Scholar. The studies reviewed identified three major AR game-based strategies used in language learning: augmented word spelling games, card-based word visualization activities, and word annotations or word spelling games. The meta-analysis yielded a random effect size of 8.46 [−1.93, 18.85] at a 95% confidence interval but found no significant effect (z = 1.60 (p = 0.11)). An AR system can effectively teach students of all ages since it enhances engagement in learning. Additional research is necessary to further inform learners and trainers on the full extent of the implementation of AR technology in learning.

Keywords: Augmented Reality; Extended Reality; Word Annotations; Visualization Activities; Card-Based Games; Word Spelling Games; Interactive Storytelling

1. Introduction

Extended reality (XR) refers to several types of technologies based on simulations, such as augmented reality (AR), mixed reality (MR), and holography (HG). These technologies, which blend simulation with the physical environment, have attracted the interest of language experts over the last decades [1]. In recent decades, XR technology has enhanced training and learning in other domains beyond language acquisition. The current study's search process revealed that AR strategies, such as gamification, had existed in various forms as far back as the 1960s when the first digital flight simulators were developed and employed by the world's major airlines and air forces [2]. Since 2012, a developmental shift in the adoption of AR has emerged due to the increasing usage of smartphones [3]. According to them (2011), accessible devices, such as smartphones, offer comfort that can, in turn, arouse learners' interest. Both learners and their teachers have been known to use accessible devices that incorporate AR technology. Along the same lines, the number of teachers and learners that embrace XR technologies in teaching languages has continued to increase.

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The acquisition of a new language is a multilayered process that most language learners do not find easy. Some studies have acknowledged that English language learning is a cognitive process that is complicated and is acquired gradually [4,5]. When learning alphabetic languages in English, learners must understand the ability to change sound phonemes in oral language skills and the rules of how letters correspond to verbal sounds [6]. However, in acquiring the English language, some learners may not master the language's core skills at the same rate but demonstrate different degrees of struggle when reading or spelling [7].

Technological innovation in AR offers a solution for learners who encounter difficulty because it helps make learning attractive to young as well as older learners, primarily through games. In particular, the AR gamification technique represents a game-based mechanism and game thinking that can be used to engage people, motivate action, and promote learning [8,9]. Combining AR with other technological innovations has significantly impacted those who can see and those with sight challenges. Thus, in combination with other mobile technological advances, AR offers tremendous possibilities in language acquisition. Some AR applications include mobile and information learning, games used to support learning, and projects built to enhance self-learning in everyday contexts [10]. The current use of games in learning draws upon research on producing relevant learning in a quickly changing world. Along these lines, AR research at MIT and UW-Madison has created game prototypes and game authoring environments that have explored the use of technology to customize learning, socially constructed and one that extends beyond the classroom [11–13]. In addition to sight-based applications, some AR applications are based on the sense of sound and have been used to augment the sense of sight for blind learners or students with poor vision using audio [14].

Currently, two common types of AR systems are marker and maker-based [15]. Furthermore, the literature reviewed yielded additional terms of interest, including location-aware or place-based AR, as well as image-based AR, also known as vision-based AR [16]. Maker-based AR systems feature the ability to recognize images and markers previously defined as triggers that display AR content during learning. AR simulations can simulate print media by incorporating 3D-rendered models such as books, magazines, and newspapers. When loaded with trigger images, powerful devices with good cameras track AR applications and augment them with social media feeds, hyperlinks, video, audio, and pictures [17]. The material may simply be read in such a case; however, a handheld AR screen can also enable the user to observe three-dimensional models from the pages [18,19]. In 2013, Mahadzir and Phung published research on AR and interactive storytelling (ARIS) [20]. ARIS, an open-source platform, creates GPS-based AR-improved learning storytelling augmented with games. Mahadzir and Phung's report went on to spark the interest of researchers in the development of mobile-based AR in the context of language learning applications [21].

Game-based learning was a significant reference point for most of the reviewed literature. According to Taskiran (2019), mobile AR game-based learning has positively impacted teaching the English language. Specifically, most learners can now afford powerful mobile devices, and educational AR has been impactful and the most widespread technological tool in learning English. Smartphones that work with games like Pokémon have kindled learners' interest in AR used in foreign language learning [22,23]. Furthermore, AR technologies have contributed to the ability to acquire learning material across the globe. Instead of paper-based learning resources, such as textbooks, models, and printed manuals, this technological tool offers portable, less-expensive learning materials [24]. Today, most teens own smartphones with cameras, which can support the use of AR [24,25]. AR drives a highly self-motivated environment, as Majoros and Neumann (2001) discussed [26]. All these advantages have fueled AR's increasing popularity in the context of learning and teaching the English language as a foreign skill to learners from different cultures around the world.

In addition, some studies have proposed the development of improved versions of AR systems to improve language acquisition [27,28]. For instance, TANGO, a system that can detect materials around learners and provide object-related language learning materials, was developed using ARFID technology. HELLO, a 2D barcode created by Liu, Tan, and Chu (2007), is an AR-supported English learning space for enhancing learners' language skills [29]. More specifically, HELLO has an English learning tool and a mobile learning program and is a part of the "My Campus" course [30]. The results revealed that all of the proposed learning activities increased students' motivation for knowledge acquisition and provided enjoyable English learning experiences with speaking skills. Liu and Chu (2008) and Holden and Sykes (2011) presented Mentira, the first AR-based game for foreign language learning [31,32]. Other examples of AR technology implementation becoming increasingly popular are improved textbooks and 3D pop-up books [33].

The literature indicates that simulations in XR have played a key role in motivating and creating interest in English language learning both in class and outside the classroom. Because of the affordability and accessibility of powerful smartphones that can handle AR applications, young people across many contexts have been able to learn English and oral skills everywhere they go. Researchers who seeking to demonstrate the impact of AR on English language learning have placed much emphasis on AR's growing popularity and success. However, additional research focusing on XR technology and AR remains needed, especially investigations that will explicitly examine these technological tools'

efficiency and implications for English language skill acquisition. Furthermore, in-depth evidence is needed to support adequate technology-to-practice, which should be a consequence of XR's efficiency. In addition, some scholars who examined educators' ability to practice most of the adopted new technologies in AR observed the need to improve teachers' knowledge of how to apply AR in teaching, implying the need for more research to provide significant knowledge on how to adopt AR in education. These identified gaps underlie the decision to conduct the review in the current study to boost the available information on AR in English. Therefore, this study entails a systematic review and meta-analysis with the objective of providing further details about the available tools using XR technology and the untapped potential that is currently available to enhance English language learning. The present review will also provide information that supports a better understanding of AR-based learning and its integration in the classroom and personal customization in the learning process of EFL.

1.1. Research Questions and Objectives

The aim of this systematic review and meta-analysis is to describe AR and the use thereof based upon examples derived from various contexts in the development of learners' language skills in learning EFL. The current investigation will achieve this aim by seeking to provide answers to the following research questions:

- How appealing is AR technology when implemented in language learning?
- What AR applications are available for teaching English as a foreign language (EFL)?
- What are the currently available instructional applications and effects of AR designs and strategies in language learning?
- What are the overall impacts of integrating AR technology on students' attitudes toward learning English?
- What were students' and teachers' perceptions of using the technology?
- What technology-to-practice gap can be identified?

2. Methodology

2.1. Study Design

This study took the form of a systematic review and meta-analysis. Thus, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement (PRISMA) guidelines guided this study. This approach governed how the literature search was conducted, determining the inclusion criteria and search questions for the study, and the final study selection process in this investigation.

2.2. Literature Search

The initial search for relevant literature was conducted using ACM Digital Library, IEEE Xplore, PubMed, ERIC, the Cochrane CENTRAL library, and Google Scholar. The search used both keyword combinations and Medical Subject Headings (MeSH) terms. We also used Boolean operators (AND/OR) and field tags (tw/tiab) to narrow the search results. Additional studies were obtained through reference lists of previous systematic reviews and meta-analyses on this topic. In all six databases, detailed searches were performed using the conceptual keywords "XR simulation" OR "AR technology" OR "Extended Reality" OR "Extended Reality" AND "Language learning" AND "Oral Skills. The three keywords were combined with the following MeSH terms: "XR simulation" [Mesh] OR "AR technology" [Mesh] OR "Extended Reality" [Mesh] AND "Language learning" [Mesh] AND "Oral Skills" [Mesh].

2.3. Inclusion and Exclusion Criteria

Two investigators worked independently to analyze all of the studies obtained from the electronic databases. They were guided by the PECO framework (Participants, Exposure, Comparator, and Outcome(s)). The participants (represented by P in PECO) in the eligible studies were within any age group above 13 years old and included both genders, meaning that we did not place any limitations on gender. However, individuals' appreciation of integrating technology in learning was shown to differ between males and females.

Consequently, we sought the effect of XR simulations differently from previous researchers. We required the included studies to be from participants exposed to devices that could operate XR technologies, for example, smartphones, laptops, and iPads. The comparator (C) was not a consideration for this experiment. The review was focused on outcomes (O) and included a single-arm analysis conducted to determine the implications of AR technologies in language learning and teaching oral skills.

2.4. Data Extraction

Selected studies were forwarded to another pair of data extractors. This process employed a standardized Excel sheet, which encoded various variables of interest to the reviewers. First, details for study identification, such as the first author, year of publication, and the study design, were extracted. Participant demographics were also collected, followed by details about interventions. The review was focused on acquiring information about the implications of AR technology in learning EFL. This was specified by one data table depicting the authors' outcomes of interest: the number of participants and interest and attitude effect of utilizing AR in language learning.

2.5. Data Analysis

The extracted data were analyzed in two phases: All qualitative information was synthesized thematically using literary analysis to review the selected literature. In contrast, quantitative data were analyzed using STATA Version 17.0 (STATA V.17.0) to determine each outcome's effect measure and significance. Heterogeneity between the studies was assessed using the I2 statistic. The meta-analysis adopted a random effects model to evaluate both binaries. The effect measure was the risk ratio at a 95% confidence interval. The results of the meta-analysis were represented graphically in forest and funnel plots.

3. Results

3.1. Study Selection Process

The completed search yielded 2340 studies from all databases and reference lists. The selection process began with the elimination of 1359 duplicates. The first screening process dropped 578 studies in an automated process, leaving 403 studies for title and abstract screening. In this phase, we sought to include studies assessing the pertinent participants and exposure. A total of 259 studies were eliminated, leaving 144 studies. These remaining studies were again evaluated via full-text screening to ascertain whether they contained the outcomes of interest and reported the data in a usable manner. In this step, 137 studies did not meet the criterion and were eliminated, as they did not have the outcomes of interest, leaving seven studies for inclusion. Figure 1 presents a PRISMA flow diagram outlining the selection process.

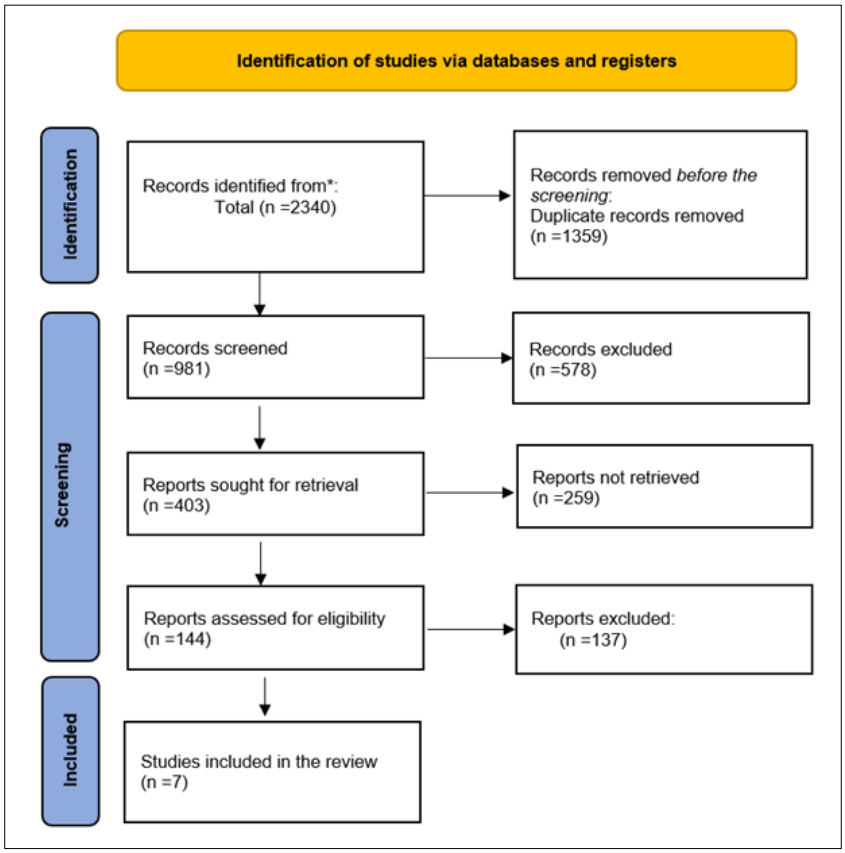

Figure 1 PRISMA flow diagram detailing the selection process

3.2. Study Characteristics

We investigated the interest and attitude effects of using AR in language learning by conducting a meta-analysis to determine the effect size and significance in teaching language. From the data provided in the seven selected and reviewed studies, an overall random effect size of 8.46 [−1.93, 18.85] at a 95% confidence interval was output. No significant difference emerged in terms of the impact of AR on the interest and attitude of students who were learning a new language. This outcome was the result of a test for the overall effect of z = 1.60 (p = 0.11). Figures 2 and 3 display the forest plot and funnel plot representing the meta-analysis and publication bias, respectively.

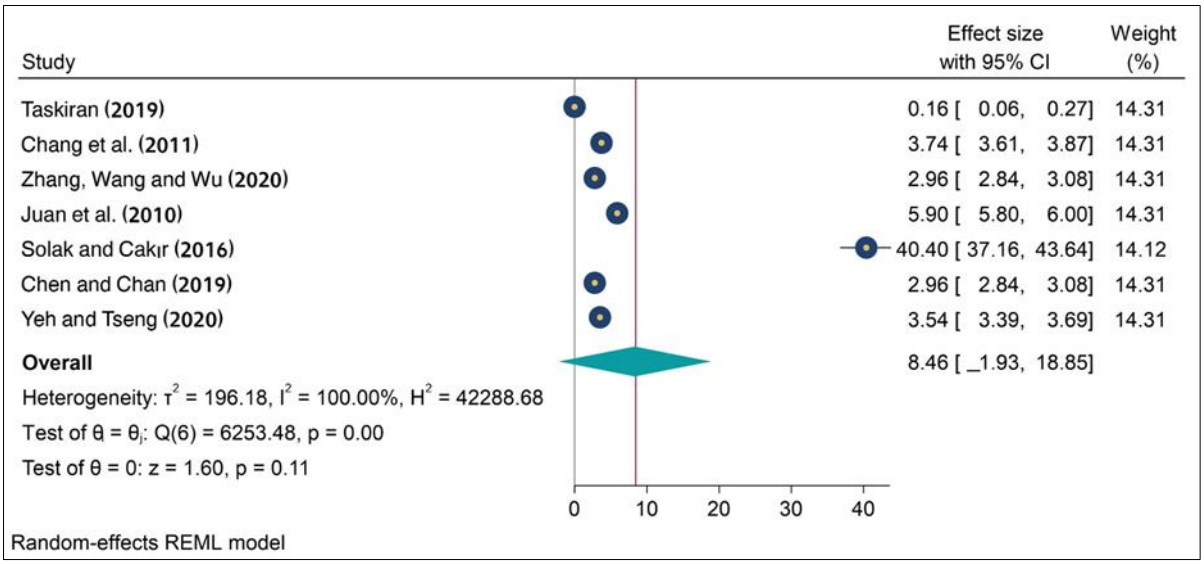

Figure 2 Forest plot of the meta-analysis investigating the interest and attitude effect of using AR in foreign language learning

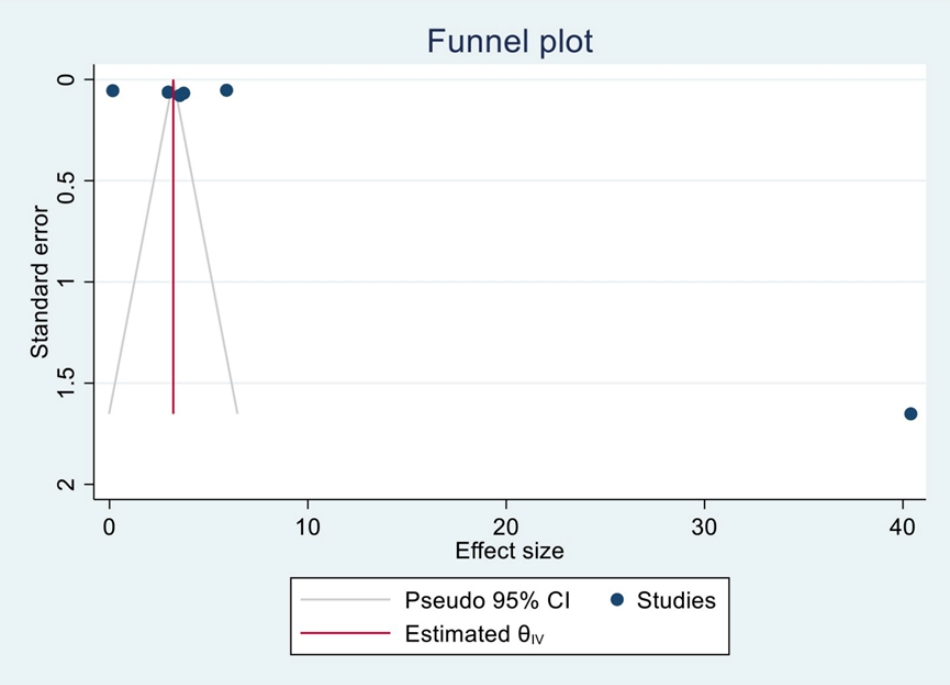

Figure 3 Funnel plot illustrating the publication bias between the studies used in the meta-analysis

Table 1 Study characteristics of the selected studies.Meta-Analysis

Author	Study design	Participants	Setting	Interest and attitude effect of using AR in Learning	Findings
Taskiran (2019) [18]	Survey	83	Four different games with AR technology designed by the authors were used in four diverse language classrooms. The games included the following: Game 1 (Messy room), Game 2 (Let's go to the movies), Game 3 (Treasure hunt), and Game 4 (Fast reporters).	Mean = 0.16430 Standard deviation = 0.50136	The results showed that practically all participants delighted in using learning resources enhanced by AR. Most students found the activities in the AR-learning environment to be highly inspiring and engaging, which is a typical finding in AR research, according to the analysis of items in the questionnaire.
Chang et al. (2011)[34]	Survey	190	An AR-learning system was implemented through the use of a Vizard ARToolKit.	Mean = 3.740 Standard deviation = 0.931	The results of this study concluded that AR-learning technological integration is a potential educational instrument that could improve learning efficacy.
Zhang, Wang and WU (2020) [35]	Factorial research design	196	The authors aimed to provide theoretical insights to facilitate creating and mastering technology-enhanced language learning assignments.	Mean = 2.96, Standard deviation = 0.88	The study's participants demonstrated good motivation for learning and a positive attitude toward engaging in theme-based contextualized EFL learning.
Juan et al. (2010) [36]	Survey	32	The study compared an AR game for learning words to an actual game situation in teaching language to children.	Mean = 5.9, Standard deviation = 0.3	The AR game was positively accepted by the children (81% preferred it) related to the several evaluated aspects. Except for one question, the results demonstrated that the young learners did not find any significant differences between the two games.
Solak And Cakır (2016) [37]	Quasi-experimental	61	The study comprised a quasi-experiment involving predesigned 3D educational materials to use AR technology to create a suitable setting for language learning. The experiment engaged level-appropriate images, text, and voices incorporated into markers to strengthen target vocabulary at the primary level.	Mean = 40.40, Standard deviation = 12.9	The authors concluded that using AR in language classes at the elementary level improves students' academic performance and helps them retain new vocabulary words longer than they would if using a conventional method.

Chen and Chan (2019)[38]	Survey	196	This study used a two-group pre-test and post-test quasi-experimental approach to assess the impact of AR flashcards and conventional flashcards on learning vocabulary.	Mean = 2.96, Standard deviation = 0.88	All learners expressed a positive attitude toward AR-enhanced contextualized learning. There was no considerable difference in the advantage of AR and conventional flashcard approaches; both could significantly enhance children's vocabulary learning. The teachers reported that although the pupils liked the AR-learning exercises, employing AR flashcards in a kindergarten context had several drawbacks.
Yeh and Tseng (2020) [39]	Project-based learning (PBL)	52	PBL was chosen as a framework for education to help students improve their multimodal literacy. Under the PBL approach, students work zwith peers to create artifacts.	Mean = 3.54, Standard deviation = 0.57	The findings showed that students' modes might be divided into visual and aural types. The outcomes also revealed a significant improvement in students' multimodal literacy when the material was created for a location-based AR app using various multimodal media.

4. Discussion

4.1. Observed Intriguing Effects of AR on Learning

The review identified AR as a specific technology type worth investigating and sourced contexts within which it has been used to facilitate teaching and learning EFL, which is in line with the primary objective of this review. AR has evolved significantly with the development of games to support learning English. The aforementioned views coincide with the findings of Taskiran (2019), whose investigation revealed that nearly all participants enjoyed learning English via AR-enriched technology applications. Most of the studies included in this systematic review used questionnaires to collect data. According to the researchers' analyses of the questionnaire items, most students embraced the integration of AR technology into learning English. Furthermore, activities in the AR-learning environment were highly motivating and invoked a positive response during the learning process. These findings indicate that the learners found AR enjoyable, similar to AR research [40–42]. Most of the participants' questionnaire-based scores from the included studies suggested that AR-learning activities drew their attention and generated interest in the learners. Generally, the participants agreed that learning the English language using AR provided a fun experience.

4.2. Available Fields in AR for Teaching English

According to Armstrong and Landers (2017), researchers have recognized gamified learning as a significant application of AR [43]. Game-based education focuses on adding value that goes beyond entertainment in adding value in the classroom [44]. In practice, AR has created many opportunities for teachers to help students grasp abstract concepts. By taking advantage of the interaction and experimentation that AR technology offers, education has been enhanced in both the classroom experience and outside-of-class education. Researchers who have explored game-based learning as one of the main study fields in AR have reported that learners enjoyed learning that integrated their classroom experience with games designed by AR technology developers. One example of the effective use of AR in this context is bringing colored drawings to life for younger learners. The field of gamified learning has gained significant popularity over the past few decades, representing one of the most extensive fields featuring AR inclusion in education.

Coloring books and other study materials allow young learners to be creative, especially in light of the global adoption of technology among learners. AR holds a unique potential to impact learning by providing a bridge between real-world activities and digital enhancements. AR-enabled books and applications can retrieve in 3D formats and satisfy students' preference for visual learning. One practical example is using AR to assign different colors to grammatical errors in order to help second-language learners gain valuable feedback about their grammar mistakes in English. AR has also enabled students to use different colors to connect to other colored materials. For instance, in a color-based spelling game, learners associate certain spelled words with a specific color. Associating spelling mechanics with colors makes learning English both memorable and enjoyable [44].

4.3. Contextual Applications and Effects of AR Designs and Instructional Strategies in Language Learning

One of the objectives of the present systematic review was to investigate the language teaching methods and strategies typically used in simulation with XR technology. Nearly every included study exhibited positive results of learning with AR applications. However, three main combinations of designs and instructional strategies were shown to effectively support language learning and the use of AR games in learning languages. From this review, a clearer view emerged after examining the literature on gaming activities and designs to teach and train English [32]. For example, Safar, Al-Jafar, and Al-Yousefi (2016) described forty-two kindergarten children in Kuwait who received AR instruction that provided 3D animations, augmented sounds, and words on 2D flashcards [45]. The researchers reported that the young learners in the intervention group interacted more often and showed significant learning gains in alphabet tests compared to the learners in the control group. In another study, Barreira et al. (2012) employed an AR game called MOM that was designed for learning English in the classroom setting [46]. The authors observed better results among the learners who used the MOM game in their learning process compared to the group instructed through other traditional means. In 2019, Wu used the handheld AR Pokémon Go game in the context of learning English knowledge of suffixes, prefixes, and word roots and found that the AR-using participants demonstrated better performances than those who experienced the traditional mode of learning [47]. A third game design strategy was discussed in a study by Pu and Zhong (2018) that featured eight children who were four to eight years old [48]. In their investigation, the participants learned English words either by exploring an AR spelling game through the discovery strategy or by playing a physical card game. According to the study results, the AR group displayed more interest and enjoyed learning better than the traditional card group.

Another method that emerged from this systematic review concerns location-based applications in which learners explore a real-world context, allowing them to develop a relationship between the knowledge of words and literature in English. The game concept emphasizes learners' active construction through context visualization in the learning process, continually improving children's ability to memorize words when interacting with the physical environment [49]. In our last reviewed game design strategy, learners were mainly engaged with games of scaffoldings and feedback. Learning motivation was evident through the game under investigation and enabled learners to go through the trial-and-error exploration to gain knowledge. However, previous research showed insignificant learning gains with such an approach with participants of tender age [36,48]. The outcome may be due to young children's attention span needing more time to acquire all the knowledge with proper guidance [38]. Additionally, in the small sample of participants, the majority of the studies only focused on short-term learning gains, therefore with an insignificant number of instances, we were not able to point out with precision to determine the effectiveness of these strategies [50–53] Future research should be done to provide more evidence of their effectiveness.

AR applications are often used as instructional tools to assist trainers in illustrating language knowledge with 3D visualization content [45]. The use of AR in becoming proficient in English communication, conversations, and oral skills has in general, demonstrated high motivation levels, and increased confidence for EFL learners. In addition, several other applications which were reviewed attempted the use of animated cartoon tutors to boost interest in children's learning caused of the importance of social interactions in knowledge acquisition [54,55].

4.4. Students and Teachers' Perceptions and Attitude Effect

Almost all of the participants in the included studies demonstrated positive motivation and a positive attitude toward learning from their interactions with AR-enhanced game-based approaches while learning. Learners seemed attracted by the AR technology during the reviewed experiments, exemplified by their enthusiasm, such as a sense of curiosity and desire to know more about the AR interactions, as well as an increased desire to learn English skills [56]. The synchronization of innovation with challenging reality, as in the case of AR technologies and English learning content, increased students' motivation to achieve English language skills [56,57]. This finding was consistent with a previous argument in the literature reviewed that innovative educational tools and software have proven to stimulate learners' curiosity and motivation.

4.5. Technology-to-Practice Gap

However, the available knowledge from the reviewed articles does not include ways to provide teachers with the ability to use AR technology and apply such tool in classroom teaching. In practical terms, teachers must receive training on using AR game-based applications in education, especially those who work with young learners who wish to help motivate their students to learn English. The knowledge of how to use AR-based gamified learning remains limited in most parts of the world. Most of the teachers instructing the sample groups in the identified studies needed to acquire adequate skills in handling the AR application used during the research [16]. Therefore, the lack of sufficient knowledge on how to maximize the potential of AR implies that developers should consider further research to organize learning resources that will equip teachers with the knowledge they need to use AR in teaching.

Additionally, more cost-effective devices must be developed to increase the accessibility of AR-enabled devices globally. In some parts of the world, especially in developing countries, most of the currently available AR-enabled devices are expensive to acquire. Therefore, researchers need to impart the right attitude and mindset to teachers by creating a game for training teachers. Familiarizing teachers with a game can increase teachers' self-confidence and improve the teaching experience using technology [58].

5. Conclusions

In this review, we identified three major AR game-based strategies used in language learning, including augmented word spelling games, card-based word visualization activities, and word annotations or word spelling games. The preferred design strategy, which combined 3D multimedia content integrated with sound, 2D physical flashcards, and gamification, was the most selected in light of the already tremendous yet still growing development in ICT tools, apps, and services. In addition, their impact on the effectiveness of both teaching and learning based on the outcomes of the current study suggests that AR technology and its related apps represent an ideal approach at the primary stage of education, in particular, as well as in advanced learning levels. The authors of the reviewed studies strongly recommend increasing the educators' awareness of adopting AR technologies in teaching and learning environments. The researchers uniformly endorse offering training courses and workshops for teachers at different levels of education to train them on how to use and implement AR apps in learning. Furthermore, in this paper, we highlighted an AR system that teaches young children who were non-native English speakers English terms using primary colors on 3D shapes.

Our findings reveal that our AR system could effectively teach young and older students, as it enhances engagement in the learning process and increases knowledge gain.

Limitations

The literature search showed that only a few studies are available that properly probe the specific area of interest that was the focus of this systematic review and meta-analysis. This factor limited the amount of data and information we could access for our investigation. Additionally, most of the studies surveyed had no control group in their evaluation of AR applications. A limited number of studies complicated our efforts to identify the effectiveness of AR instruction in the learning process, along with potential gains, compared to other traditional approaches, such as using tangible textbooks or other computer instruction-based applications. Therefore, more evidence is needed to identify the specific design features of the AR applications that have been used in helping learners gain English language skills. Almost all studies compiled learning outcomes immediately after using AR techniques but included no consideration of follow-up learning gains. The age of the participants in some studies also served as a limitation. For instance, in Barreira et al.'s (2012) investigation, the seven- to nine-year-old participants did not exhibit different attitudes toward using AR as a learning tool and simply played games for fun. Another area for improvement was the need for proper knowledge by trainers and teachers to handle AR applications and incorporate AR into their teaching designs, as AR is an emerging technology. Additionally, most of the studies did not measure the participants' cognitive load while learning via an AR-enhanced approach and lacked a follow-up to measure the learners' application of the knowledge gained.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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