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EDITED BY
Heng Luo,
Central China Normal University, China

REVIEWED BY
Thammathip Piumsomboon,
University of Canterbury, New Zealand
Mostafa Aboulnour Salem,
King Faisal University, Saudi Arabia
Rocío Yuste,
University of Extremadura, Spain

*CORRESPONDENCE
David A. Plecher,
plecher@in.tum.de

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Foreign language learning using augmented reality environments: a systematic review

Isabel Schorr, David A. Plecher*, Christian Eichhorn and Gudrun Klinker

FAR Augmented Reality Research Group, TU Munich, Munich, Germany

Augmented Reality (AR) is an advancing technology that has drawn the attention of educational material designers across various academic fields. However, few studies document the successes and setbacks of AR research in the language education sector. This review delves into educational research that employs AR for language training, examining the existing literature on this topic for development trends, benefits, challenges, and success patterns to derive design principles from them. In doing so, the paper covers 40 studies published between 2016 and 2023. The findings suggest that AR is mainly used for vocabulary acquisition with a clear trend toward applying marker-based technology and mobile devices. The design principles derived indicate that the potential of AR lies primarily in contextual learning, and that the technology alone may not satisfy students' needs in all aspects of language learning but should be used in combination with traditional teaching methods.

KEYWORDS

augmented reality, educational technology, language education, systematic review, serious AR

1 Introduction

In recent years, the digital world has made significant advances, with technology shaping every aspect of human life. Augmented Reality (AR) has emerged as a popular technology due to its ability to virtually overlay objects onto the real world and the nowadays relatively low hardware costs for AR systems. So far, AR has been successfully applied in many fields, including medicine, the military, manufacturing, marketing, entertainment, and education (Mekni and Lemieux, 2014). With the proliferation of modern mobile devices such as cell phones and tablets, AR has become accessible to the general public. Although these devices are not typically purchased by their users for AR purposes, they offer a solid hardware foundation with their cameras, sensors, and computing performance (Dörner et al., 2019).

Language learning is a complex and challenging process and requires extensive guidance and discipline. Many factors influence the learning process, which can aid or hamper it. The initial enthusiasm learners feel when starting to learn a new language often fades over time, the learning material can be boring, vocabulary learning can be exhausting, and learners may at times feel like they are not making progress. The potential of AR for aiding language teaching and learning has been recognized by educational researchers who have conducted empirical research on the topic. They have used AR for teaching popular languages such as English (Safar et al., 2016; Topsakal and Topsakal, 2019), French (Perry, 2021), Japanese Plecher et al. (2018) and Chinese (Uiphanit et al., 2020), as well as for niches like sign language (Nazareth et al., 2014) and Egyptian hieroglyphs (Plecher et al., 2020).

Despite its potential, AR is not yet widely adopted in the educational field due to its novelty and the slow pace of change in this area. Therefore, this paper offers a review of empirical studies that have employed AR for language learning, exploring the benefits and challenges of the technology. Additionally, it examines AR-enhanced teaching strategies and their effects, and derives design principles that may assist future researchers and developers in creating effective AR applications. To our knowledge, no comparable study providing design guidelines exists, making this a significant contribution to existing literature on language learning with AR. To achieve its purpose, this literature review considers 40 empirical studies that address the question of how AR systems for language learning can be designed for and implemented in educational contexts. This study systematically reviews and summarizes the literature on AR in language learning from 2016 to 2023, identifying research trends and results in recent empirical research. The following research questions guide the review:

- Question 1. What are trends in terms of publication year, languages taught, content areas, technologies used, target audience, and types of experience?
- Question 2. What are the advantages and challenges of using AR in language learning environments?
- Question 3. What design principles can be drawn from the observed literature that may help future researchers and developers to create AR applications for language learning?

2 Research methodology

To gain an insight into the use of AR systems in language learning and teaching in the period between 2016 and 2023, this literature review follows a procedure inspired by the PRISMA[1] (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram. Figure 1 summarizes the applied procedures for searching and analyzing empirical studies on AR-enhanced language learning.

2.1 Identifying studies on language learning with AR

In the first stage, the following scientific databases were used for obtaining relevant literature: ERIC, IEEE Xplore, Google Scholar, and OPAC Plus. The search terms used for the analysis were ("Augmented Reality" OR "AR") AND ("in language learning" OR "in vocabulary learning" OR "in grammar learning"). The first part of the search term ensured that the search engine looked for publications dealing with the use of AR, while the second part narrowed down the search results to applications using AR for language learning. Occasionally, the second part of the search term included specific languages such as Chinese, English, German, and others. In addition to the articles selected from the scientific databases, this study further includes accessible papers identified by snowballing, a method in which the literature mentioned in reference lists of observed papers is considered for the literature review.

1 http://prisma-statement.org/(last access 07/20/2003).

2.2 Removing duplicates and screening

The next step was to remove duplicates and screen the remaining papers to identify the literature relevant for the systematic analysis. By considering eligibility criteria and by rejecting articles not meeting the defined formal requirements, a dataset of 40 papers remained for the literature review. The inclusion criteria have been the following:

- The researchers deploy AR technologies for teaching or learning.
- The study addresses foreign or second language learning or teaching.
- The research paper is written in English.
- The study is empirical.
- The researchers evaluated their project with students, teachers, professionals, or parents.
- The paper was published between 2016 and 2023.

2.3 Data collection and analysis

For the analysis, the observed manuscripts were scanned for the following information:

- The publication information including title, author, country of origin, and the publication year of the paper.
- The variables considered, which describe the project in the examined publication, encompass the taught language, the target audience (divided into pre-school, K12, higher education, and adult), the devices used to present augmented content, the type of AR marker used for tracking, the type of AR content used for language learning and teaching, and the success variables the authors paid attention to (e.g., perceived motivation).
- Finally, the insights gained from the examined research paper include the research results, which along with the purpose of the study allowed to draw conclusions about the viability of AR in different language learning areas. Exploring suggestions for future research helped to find gaps in the research domain. Figure 2 shows the distribution of selected publications over the time frame under consideration.

The summarized results can be found in Table 1.

After assembling and organizing relevant research data, the information was evaluated to determine the benefits and obstacles of using AR technology for language learning. Furthermore, the extracted data helped to derive design principles, which may facilitate future research aiming to implement AR technology in educational environments.

3 Results and discussion

The following section is divided into two subsections. It will first discuss the results of the literature review with respect to the research questions in detail and then summarize the findings. Table 4 offers an overview of the papers looked at for the analysis results.

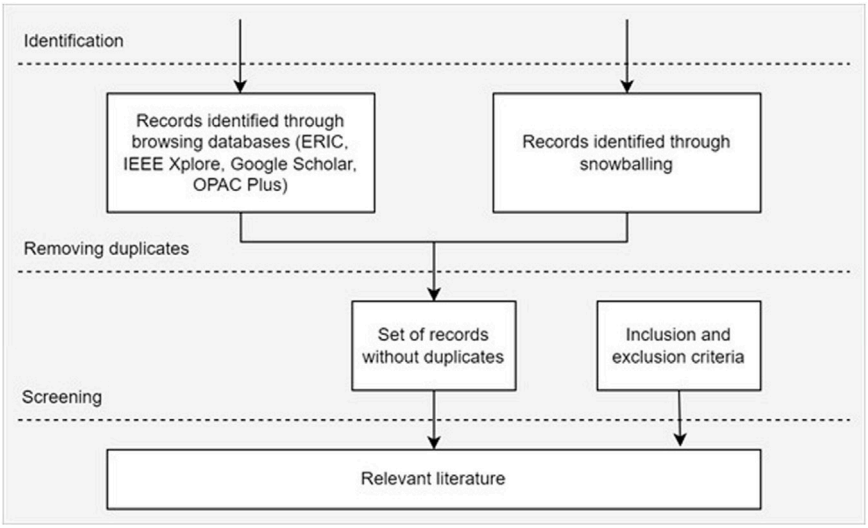

FIGURE 1
Workflow for searching and analyzing empirical studies on language learning using AR.

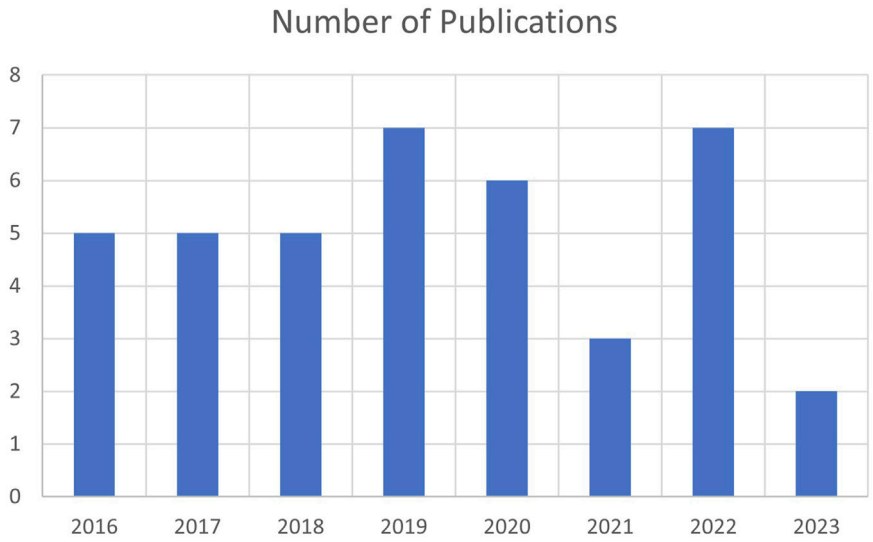

FIGURE 2
Number of publications per year relevant for the literature review.

3.1 Results

Question 1 (RQ1): What are trends in terms of publication year, languages taught, content areas, technologies used, target audience, and types of experience?

Target Language [RQ1]: By far the most common foreign language taught in the reviewed literature is English, with 60% of the 40 studies using AR technology to teach this language. Chinese follows with five (13%), Japanese and German with three (8%) and two (5%) reported uses respectively. The remaining languages are covered in only one study each. Table 2 provides an overview of the target languages and the frequency of their occurrences in the observed research papers.

Content Area [RQ1]: The content area most addressed is vocabulary (70%). On the contrary, only 13% of the observed studies used AR to teach grammar. All content areas and the number of studies using AR to teach them are listed below in Table 3. Some applications taught multiple content areas. Thus, the numbers add up to more than 40 (100%)

Device Used [RQ1]: Eighty-five percent of the surveyed publications used mobile devices for displaying augmented content to language learners. While mobile devices showed a

TABLE 1 Overview.

Author	Year	Language	Target group	Devices used	Type of marker
Dalim et al. (2016)	2016	English	Pre-school	Desktop Computer	Marker-based
Liu et al. (2016)	2016	English	Not specified	Mobile Device	Markerless
Safar et al. (2016)	2016	English	Pre-school	Mobile Device	Marker-based
Santos et al. (2016)	2016	Filipino, German	Various	Mobile Device	Marker-based
Zainuddin and Idrus (2016)	2016	Arabic	Higher Education	Mobile Device	Marker-based
Alizadeh et al. (2017)	2017	English	Higher Education	Mobile Device	Marker-based
Chung and Hsieh (2017)	2017	Chinese	Higher Education	Desktop Computer	Marker-based
Ho et al. (2017)	2017	English	Adult	Mobile Device	Markerless
Lee et al. (2017)	2017	English	Pre-school	Mobile Device	Markerless
Martínez et al. (2017)	2017	English	K12	Mobile Device	Marker-based
Chen et al. (2018)	2018	English	K12	Mobile Device	Not specified
Che Hashim et al. (2018)	2018	English	K12	Mobile Device	Marker-based
Ibrahim et al. (2018)	2018	Basque	Higher Education	Wearable	Markerless
Liu et al. (2018)	2018	English	K12	Mobile Device	Markerless
Tsai (2018)	2018	English	K12	Mobile Device	Marker-based
Chen (2019)	2019	English	K12	Mobile Device	Markerless
Chen and Chan (2019)	2019	English	Pre-school	Mobile Device	Not specified
Montellanos et al. (2019)	2019	Quechua	K12	Mobile Device	Marker-based
Rodríguez-Vizzuett et al. (2019)	2019	English	K12	Mobile Device	Marker-based
Taskiran (2019)	2019	English	Higher Education	Mobile Device	Marker-based
Topsakal and Topsakal (2019)	2019	English	Pre-school	Mobile Device	Marker-based
Vedadi et al. (2019)	2019	English	K12	Desktop Computer	Marker-based
Chang et al. (2020)	2020	English	K12	Mobile Device	Marker-based
Geng and Yamada (2020)	2020	Japanese	Higher Education	Mobile Device	Marker-based
Sani et al. (2020)	2020	Chinese	Higher Education	Mobile Device	Marker-based
Tsai (2020)	2020	English	K12	Mobile Device	Marker-based
Uiphanit et al. (2020)	2020	Chinese	K12	Mobile Device	Marker-based
Wei et al. (2020)	2020	Chinese	Higher Education	Wearable	Markerless
Isaeva et al. (2021)	2021	Not defined	Higher Education	Mobile Device	Not specified
Perry (2021)	2021	French	Higher Education	Mobile Device	Markerless
Wen (2021)	2021	Chinese	K12	Mobile Device	Marker-based
Çelik and Yangın Ersanlı (2022)	2022	English	K12	Mobile Device	Marker-based
Ebadi and Ashrafabadi (2022)	2022	English	Higher Education	Mobile Device	Marker-based
Gu et al. (2022)	2022	German	Higher Education	Mobile Device	Marker-based
Lee (2022)	2022	English	Higher Education	Mobile Device	Markerless
Ustun et al. (2022)	2022	English	K12	Mobile Device	Marker-based
Weerasinghe et al. (2022)	2022	Japanese	Higher Education	Wearable	Marker-based
Yilmaz et al. (2022)	2022	English	Pre-school	Mobile Device	Marker-based

(Continued on following page)

TABLE 1 (*Continued*) Overview.

Author	Year	Language	Target group	Devices used	Type of marker
Geng and Yamada (2023)	2023	Japanese	Higher Education	Mobile Device	Marker-based
Mozaffari and Hamidi (2023)	2023	Persian	Higher Education	Mobile Device	Markerless

TABLE 2 Target languages addressed in the reviewed literature.

Target language	Number of manuscripts
English	24
Chinese	5
Japanese	3
Arabic	1
Basque	1
Filipino, German	1
French	1
German	1
Persian	1
Quechua	1
Not defined	1
Total	40

TABLE 3 Content areas addressed in the reviewed literature.

Content area	Number of manuscripts
Vocabulary	28
Listening	12
Speaking	9
Reading	6
Grammar	5
Writing	3
Cultural Understanding	2
Idioms	1
English Alphabet	1
Not Specified	4

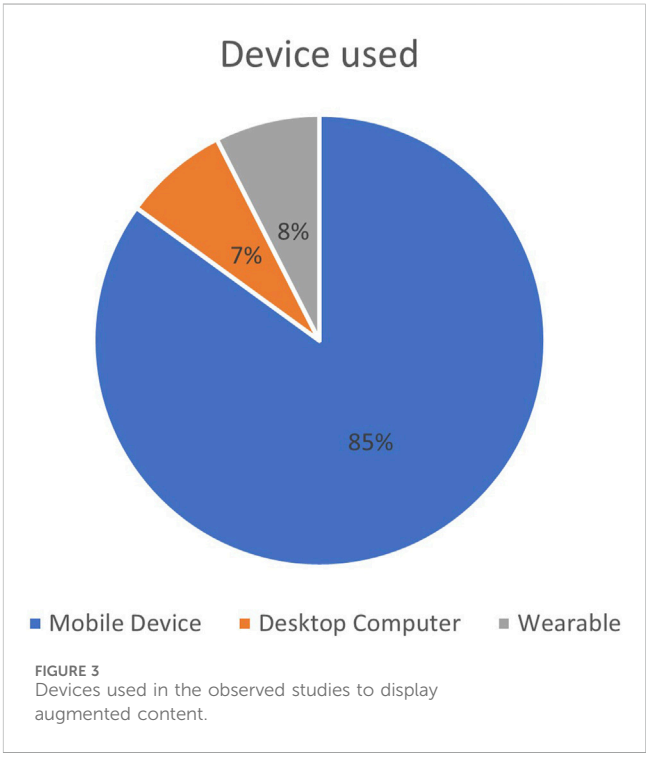

FIGURE 3
Devices used in the observed studies to display augmented content.

high rate of use, few case studies (8%) used wearable AR glasses such as Microsoft's HoloLens (Ibrahim et al., 2018). Figure 3 highlights the distribution of devices used.

Type of Markers [RQ1]: As illustrated in Figure 4, 67% of the 40 studies employed marker-based tracking to trigger augmented content with their AR application. Marker-based tracking, which includes image markers and 2D barcodes, is a reliable and cheap approach for creating AR applications (Santos et al., 2016). Among the ten studies using markerless tracking (25%), six relied on location-based technologies such as GPS for outdoor activities with location-relevant content (Liu et al., 2016; 2018; Ho et al., 2017; Perry, 2021; Lee, 2022; Mozaffari and Hamidi, 2023).

Target Group [RQ1]: The data further reveals that out of the 40 studies conducted between 2016 and 2023, 37% designed and implemented AR-enhanced learning units for K12 learning (Figure 5). The most addressed group are students in higher education (40%). Less commonly taught target groups are, for example, pre-school children, with studies about teaching young children with AR making up only 15% of the found research.

Type of Experience [RQ1]: Three-dimensional objects and animations are the most popular content for AR language learning applications (53%). The next most implemented types of experience are information overlay (38%) augmenting, for example, real objects with their associated vocabulary, and sound, which is often used to teach pronunciation of vocabulary or practice listening comprehension (38%). These and other types of experience conveyed with educative AR applications are listed in Table 4.

Question 2 (RQ2): What are the advantages and challenges of using AR in language learning environments?

Motivation, enjoyment, and reduced anxiety [RQ2]: Among the observed benefits, one of the most frequently mentioned positive effects of AR on language learning is that the technology can motivate learning. Thirty-eight percent of the examined studies

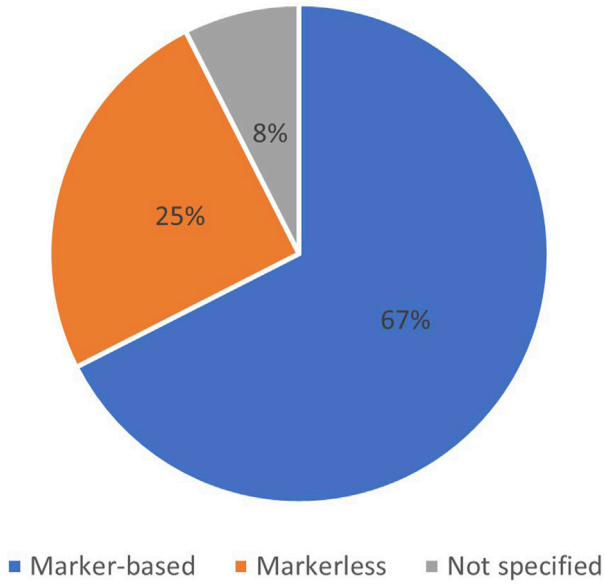

FIGURE 4
Types of markers used in the observed studies for tracking.

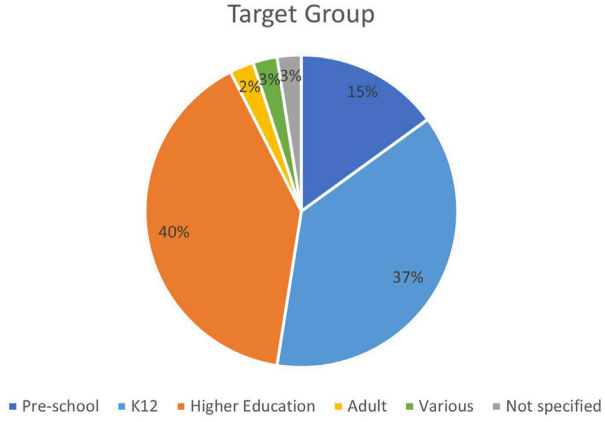

FIGURE 5
Target groups addressed in the found research.

name motivation as a result of using AR for language training (Zainuddin and Idrus, 2016; Martínez et al., 2017; Topsakal and Topsakal, 2019; Weerasinghe et al., 2022; Çelik and Yangın Ersanlı, 2022). While monotonous learning activities involving the same instructional approaches can decrease students' interest and motivation toward the subject matter (Taskiran, 2019), AR provides variety in the learning routine and prevents monotony and boredom (Safar et al., 2016). The literature review findings indicate that learners find AR applications motivating, engaging, and enjoyable when they are implemented in language learning environments and complement instructional materials (Chung and Hsieh, 2017; Chen and Chan, 2019; Taskiran, 2019). AR applications

TABLE 4 Types of AR experience and the number of manuscripts describing projects implementing them for language learning.

Type of experience	Number of manuscripts
3D Object/Animation	21
Information Overlay	15
Sound	15
Video	9
2D Visualization	7
AR Game	8
Gamification	7
Other	3
Not Specified	1

further seem to influence students' emotional states and reduce their stress and anxiety in learning (Wei et al., 2019; Wen, 2021; Ustun et al., 2022). According to Tsai (2020), AR can make the learning process more relaxed and accessible in an enjoyable way.

Immersion, engagement, and student-centered learning [RQ2]: Another benefit of AR, which was found during the literature review, is that AR can create immersive learning environments, especially for young children (Dalim et al., 2016; Wei et al., 2019). Several studies have reported the positive impact of instructional technologies in AR-enhanced learning units on participants' engagement and learning attitude (Dalim et al., 2016; Wei et al., 2020; Ebadi and Ashrafabadi, 2022; Yilmaz et al., 2022). AR applications are interactive and attractive for users (Lee et al., 2017) and thus enrich the learning experience. AR environments seem to outperform traditional and similar digital environments when it comes to students showing positive learning attitudes and consistently focusing on the learning activity as they study with the respective medium (Wei et al., 2020). Safar et al. (2016) indicate that rather than placing learners in a passive role with teacher-led instruction, they should be involved in the learning process. According to educators participating in the study of Liu et al. (2018), AR applications can provide a personalized learning experience and therefore put the learner at the center of activities. When designers create AR-enhanced, student-centered instructional material, they can, for example, allow students to choose between different exercises to practice, reinforce knowledge according to their needs (Wei et al., 2019), and study in their own pace (Geng and Yamada, 2023).

Understanding, retention, and learning performance [RQ2]: Several studies mention that their experimental AR applications have improved the learning performance of participating students (Martínez et al., 2017; Montellanos et al., 2019; Geng and Yamada, 2023). Either researchers observed significant student performance improvement and as a result academic success, when participants studied with AR-enhanced language learning material (Montellanos et al., 2019; Uiphanit et al., 2020), or students themselves reported that the application benefited their language acquisition (Taskiran, 2019). Although not all studies claim that AR is the superior teaching material when comparing the learning gains of AR-enhanced material with traditional teaching methods, researchers

have found both approaches to be at least equally effective for language acquisition. Some studies go further and propose that AR-enhanced learning environments can exceed the success of traditional teaching materials in language learning (Safar et al., 2016; Tsai, 2018; Tsai, 2020). Researchers have drawn attention to AR facilitating understanding and retention, especially in vocabulary learning. Studies emphasize that AR in combination with vocabulary training can deepen students' understanding of words and thus extend vocabulary acquisition beyond rote learning (Chen and Chan, 2019; Tsai, 2020). By allowing multiple accesses to the learning content or providing real-life context, AR-based materials can help learners to understand and memorize the meaning of vocabulary and idioms (Chung and Hsieh, 2017; Ho et al., 2017). Montellanos et al. (2019) further observed that AR content such as 3D objects reduced the time students needed for understanding words. In addition, AR allows intuitive and interactive representations of 3D information (Ho et al., 2017). While many of the observed studies used AR to visualize vocabulary with concrete meanings such as animal names (Chen and Chan, 2019), AR can help learners to understand the meaning of words that describe, for example, emotions (Martínez et al., 2017), spatial relationships (Dalim et al., 2016), and other abstract concepts. Liu et al. (2018) referred to the ability of AR to make the invisible visible as a prominent advantage of this technology.

Affordable technology [RQ2]: Another advantage of AR is its affordability. Interviewed teachers participating in the study of Liu et al. (2018) highlighted that AR provides context-aware learning environments more cost-effectively than fully virtual environments that require dedicated glasses. To develop affordable and compelling AR applications for language learning, mobile devices such as smartphones are viable tools that enable mobile and creative AR learning environments (Wei et al., 2020). However, learning with AR on smartphones or similar devices is only possible if enough students own the required technology and supported platforms (Zainuddin and Idrus, 2016) or if schools can provide them.

Other benefits [RQ2]: If used for group activities and collaborative learning, AR promotes interpersonal communication, during which students support each other or work on tasks together. In this way, they can improve their social skills. Integrating AR in classrooms and other language learning environments can help learners to develop mental and cognitive abilities that differ from those acquired by students through traditional learning materials, such as the understanding of 3D constructs. Lastly, implementing modern technologies like AR in classrooms for young learners provides early access to technology and prepares them for the emerging need for digital skills (Safar et al., 2016).

In addition to the outlined benefits of AR systems in education, the literature review identified obstacles that hamper the adoption of AR technology in classrooms and other language learning environments. Based on the classification of obstacles by Safar et al. (2016), the found challenges and limitations of AR-enhanced instructional design are divided into four categories:

- Human challenges and limitations (teacher)
- Human challenges and limitations (student)
- Technical challenges and limitations
- Physical challenges and limitations

Human challenges and limitations (teacher) [RQ2]: One issue raised in the literature and falling into the human challenges and limitations category is the attitude of teachers toward introducing new technology into their classrooms. Teachers must perceive AR environments as beneficial to their teaching or they might not be easily convinced to incorporate them into their lessons when other technologies and methods are easier to use. Moreover, if there is no clear structure to the learning unit, it can be difficult for the teacher to intervene and guide the class in a meaningful way. In addition, when instructors use AR for language instruction, classrooms can become noisy and the AR elements can distract students (Chen and Chan, 2019). Lastly, to effectively implement AR applications in instructional environments, teachers need to be familiar with the applied technology and possess a rich skill set that empowers them to guide AR-enhanced instructions (Ashley-Welbeck and Vlachopoulos, 2020). Therefore, teachers may find it difficult to adopt AR instructional materials for their classrooms as it is challenging and requires advanced skills in using the technology (Chen and Chan, 2019).

Human challenges and limitations (student) [RQ2]: Most of the reported challenges and limitations posed by AR technology concern the students' learning efficiency. Moving images and animations can distract users and avert their attention (Tsai, 2020). Another problem mentioned by Wen (2021) is that AR systems, due to their novelty, require more time for learners to get used to them than familiar tools. Furthermore, AR technology, like any other instructional approach, is subject to limitations in terms of personal preferences. Non-visual learners may not benefit from using AR technologies as much as visual learners (Chen and Chan, 2019; Tsai, 2020). Instead, it may distract them and prevent effective language learning (Chen and Chan, 2019). In addition, designers of educational AR applications need to consider the physical limitations of users. Young children do not have the same physical capabilities as teenagers and adults. They lack height and their arms are shorter. They also might have trouble holding tablets (Yilmaz et al., 2022). Therefore, designers must take these limitations into account and adapt the learning resource to meet the needs of the target audience (Dalim et al., 2016). Lastly, some researchers reported participants' and parents' concerns about learners' health when interacting with AR technologies (Lee et al., 2017; Tsai, 2020). Learning with AR could strain the eyes and make the learning experience uncomfortable (Tsai, 2020).

Technical challenges and limitations [RQ2]: Among the technical concerns observed are tracking and design issues (Dalim et al., 2016; Lee et al., 2017). Especially children's shaky hands and involuntary movements can cause difficulties for image recognition (Martínez et al., 2017). While technical problems of the AR application can influence the anxiety level of students (Ebadi and Ashrafabadi, 2022), poor quality of images, sounds, animations, and other AR content can reduce user satisfaction and learning efficiency (Zainuddin and Idrus, 2016; Ustun et al., 2022). In addition, developers of AR-enhanced language learning applications need to consider that AR can lead to cognitive overload by presenting too much information (Santos et al., 2016).

Physical challenges and limitations [RQ2]: Bringing AR into the classroom requires consideration of infrastructure, availability of technology, resources needed, and more (Safar et al., 2016). Consequently, developing AR applications adapted to the needs

of schools can be expensive (Liu et al., 2018). Moreover, classrooms can only adopt AR if schools or students own the necessary hardware (Zainuddin and Idrus, 2016).

Question 3. (RQ3): What design principles can be drawn from the observed literature that may help future researchers and developers to create AR applications for language learning?

To support teachers, researchers, and others interested in creating AR applications for language learning, this section highlights design principles derived from the reviewed literature supported by further literature. The following guidelines can aid the creation of educational AR systems designed for foreign language education. Some of these proposals are exclusively useful for classroom use, while others can be applied to autodidactic applications as well.

Avoid cognitive overload [RQ3]: The human working memory has a limited capacity, which means that learners can only absorb a limited amount of knowledge at once. Educational materials that do not consider this constraint may prevent effective learning. According to Santos et al. (2016), overloaded displays reduce the effectiveness of learning, as they hamper the user's knowledge acquisition. In the study of Chen and Chan (2019), a teacher addressed this issue and recommended limiting the number of augmented objects displayed at once to reduce students' cognitive load and promote their retention. Wen (2021) mentioned that an AR system might impose additional cognitive load on users when they encounter the technology for the first time and are not familiar with the User Interface (UI). Therefore, in addition to carefully using AR elements, a simple and intuitive UI may ease the use of the application and reduce the cognitive load imposed on learners. According to Martínez et al. (2017), if developers design an AR application to teach language to young children who are potentially not proficient in reading yet, the latter should be supported with an easy-to-use graphical interface, leaving them with no need to read or interpret it. Regardless of the target group for the AR application, UIs for educational design further require a simple and intuitive structure, consistency between screens, and consistent fonts, as variation may irritate the user. A help feature can facilitate the navigation through the AR application and reduce confusion (Sani et al., 2020). In addition to the graphical representation of the application, the choice of multimedia content influences the user's cognitive load. Moving images and animations can distract and avert the user's attention (Tsai, 2020), especially if they do not contribute to the learner's understanding and learning success. However, thoughtfully combining multimedia elements, for example, using audiovisual learning materials, can lower foreign language students' cognitive load (Ebadi and Ashrafabadi, 2022).

Provide multi-channel sensory experiences [RQ3]: Instructional design that engages multiple senses of learners can enhance their learning experience. In doing so, the multi-sensory experience can support learners with different learning styles and preferences as well as reinforce the understanding of the taught information. According to Felder and Henriques (1995), one of the many challenges of teaching language is to expand verbal activities in the classroom with a visual component to reinforce a good understanding of vocabulary, communication, and the taught topic, a task that is effortlessly fulfilled with AR. In the observed literature, applications employing several of the learner's senses in the learning process have received positive feedback as illustrated later in this section. Especially vocabulary seems to benefit from visualizing and adding auditory information to it to support the learner's understanding and pronunciation. The scope of sensory input for teaching and learning vocabulary with AR primarily mentioned in the observed literature encompasses audios, texts, illustrations, and other visualizations. AR further allows learning with tangible interfaces, addressing users' tactile sense.

Integrating multi-sensory elements into an AR application increases the chance of keeping learners immersed (Wei et al., 2020), attentive (Santos et al., 2016; Wei et al., 2020), interested (Rodríguez-Vizzuett et al., 2019), and motivated (Rodríguez-Vizzuett et al., 2019; Vedadi et al., 2019). It further benefits vocabulary acquisition (Vedadi et al., 2019), knowledge reinforcement (Safar et al., 2016), retention (Santos et al., 2016), and academic success (Safar et al., 2016). In the study on language learning with AR by Vedadi et al. (2019), they investigated whether there is a significant difference between offering images, text, and sound together and dismissing one of those features when using AR for vocabulary teaching. They observed that the AR application variant with image, text, and audio resulted in enhanced vocabulary acquisition and higher perceived motivation compared to the alternatives where each omitted one of the sensory features.

However, randomly combining sensory input may not benefit the learning process and rather hamper it. Cognitive Theory of Multimedia Learning (CTML) by Mayer and Moreno (1998) offers an approach to effectively incorporating multimedia into educational units and was used by several studies to implement AR applications for language education. The success of this approach is illustrated in more detail in the next design principle.

Use multimedia effectively [RQ3]: To use multimedia effectively, studies made use of CTML, an instructional design for combining auditory and visual learning content. According to Gu et al. (2022), it is vital to integrate reading, spelling, listening, and speaking naturally while guiding students' attention during language learning. Martínez et al. (2017) investigated whether using multimedia teaching methods could improve young learners' foreign language proficiency. The researchers considered several aspects of CTML for their didactic unit, including images as markers, narration and song audio, and videos. Overall, the researchers found that the academic success of the young learners significantly increased using their multimedia-based units. However, they annotated that there might be other factors influencing these results. Likewise based on CTML, Santos et al. (2016) developed an application that augmented real objects with sound, text, images, and animations to enhance the understanding of the relationship between the vocabulary and the objects of the learning environment. When evaluating the user experience of an experimental and a control group based on the ARCS model by Keller (1987), the AR multimedia approach resulted in higher levels of attention, perceived relevance, and satisfaction among students than the traditional method. Only confidence scored higher for the traditional learning method. Consequently, the use of established theories for multimedia learning such as CTML can help to design an effective AR application for language learning.

Provide relevant context [RQ3]: Context is important for meaningful language learning. Certainly, a student can learn vocabulary from a dictionary by rote. However, after doing so, they may not know how and in what context to use the words they

have learned. Context can improve the learner's understanding of information beyond rote learning (Kolb, 2014) and facilitates transferring knowledge to real-life situations, as knowledge depends on the context in which it is acquired (Brown et al., 1989). The papers viewed for this research name several means of providing students with relevant context for their foreign language studies. According to Santos et al. (2016), learners profit more from active discussions and relevant texts, in which they might find vocabulary to be useful due to being able to apply it meaningfully, than from translations and definitions alone. They also mentioned that context is gained by offering the learning environment as learning material. Game-based approaches, for example, offer a collaborative and contextual learning experience (Taskiran, 2019). Gamified learning and lessons outside the classroom are strengths of AR, which benefit understanding of taught concepts and allow students to practice the target language in a realistic environment with authentic communication (Mozaffari and Hamidi, 2023).

Inspired by Hawaiian mythology, Liu et al. (2016) designed a collaborative GPS-based puzzle game with a non-linear story combining virtual and physical space in one experience. The exploration of the place-based, open-world language learning game, which gave users opportunities to speak and communicate in a foreign language, received overall positive feedback from the students. However, the application failed to notify the users of any incorrect phrases they used and give them the corresponding support.

Based on the theory by Kolb (2014) of combining learning and real-life environments to achieve meaningful, context-aware learning, Ho et al. (2017) developed a GPS-based AR application teaching English, which supported social interactions and contextual learning. Their system highlighted nearby features of the surrounding outdoor environment to provide relevant, scenery-related information and offered scaffolding instructions and real-time tests. The provided learning materials consisted of context-related vocabulary and phrases considered useful in real-life situations. They concluded that their application enables individuals to learn English in authentic situations, which enhances their understanding of vocabulary and makes the learning experience more engaging.

Foster communication among students [RQ3]: As an educational tool, AR can enable collaborative language learning. It can promote communication, foster entertainment, and facilitate the practice of language skills in authentic environments by incorporating social aspects. The students who participated in the study by Ibrahim et al. (2018) found AR to be more suitable for group learning than individual learning due to its social dimension. When used as a tool for cooperative language learning, AR promotes interpersonal communication, during which students can practice speaking and improve their social competencies by working together on tasks rather than working alone (Safar et al., 2016). In doing so, cooperative AR applications encourage social interactions by providing common goals, which require students to communicate and collaborate (Liu et al., 2016). By allowing students to communicate and collaborate during foreign language learning activities, learners gain the opportunity to support each other and to help peers who do not yet have the same understanding of the educational material or struggle to solve a task. Hence, supporting each other can benefit the learning process of both high-achieving and low-achieving students (Liu et al., 2018).

In addition, collaborative instructional design using AR for language learning promotes entertainment, speaking and listening practice, and the exchange of ideas, which can lead to an acceleration of the learning and problem-solving process. Lee (2022) implemented a location-based AR game for South Korean students majoring in English education. The goal was to solve a murder mystery by investigating the campus and by engaging in group discussions with their peers. After the study, students reported that the collaborative task fostered their enthusiasm and their cognitive engagement. It additionally allowed them to share thoughts and ideas, which facilitated the problem-solving process. However, although they had fun and could use their language skills, the participants indicated that they did not find the game useful for improving their foreign language skills. Therefore, the application, in this regard, needed improvement.

For more insights on the benefits of collaborative design of language learning materials, the authors of this paper review recommend the paper by Long and Porter (1985) on group work in second language acquisition, where the researchers listed five pedagogical arguments for the use of group work in classrooms as an alternative to communication with native speakers. However, as observed by Gu et al. (2022), not all AR applications for language learning require peer learning to be effective.

Provide training and tutorials [RQ3]: Training and tutorials, as they exist in digital games, are equally useful for educational applications. Both learners and teachers can benefit from them. Giving learners the time and opportunity to get used to an AR application with the help of tutorials, for example, makes it easier for them to use the technology when they learn with it later on. Tutorials can help them to become familiar with the controls of the application (Ibrahim et al., 2018; Liu et al., 2018), understand how to use markers (Dalim et al., 2016), clarify how to walk through the learning content, and reduce the novelty effect of the technology (Ibrahim et al., 2018). Therefore, tutorials especially benefit users who have little to no experience with AR technologies (Liu et al., 2018). They allow learners to focus on the learning content instead of being distracted by operating difficulties. Since the usefulness of assistance depends on the proficiency of the user and since students who have mastered the use of AR technology need little or no support (Wei et al., 2019), it may be beneficial to make tutorials skippable. Allowing students to review tutorials afterward, enables them to come back to this support function.

Tutorials can further benefit teachers and their willingness to incorporate AR systems into their teaching. They are the ones who effectively decide whether to implement technologies in the classroom or not (Howard and Mozejko, 2015). Yet, when confronted with unfamiliar technology, teachers face various problems. One of these issues is that teachers may not feel qualified to conduct lessons using AR as, for example, in the study of Chen and Chan (2019). Apart from possibly feeling incapable of carrying out an AR-enhanced learning unit, teachers may fear embarrassment if they have technical problems while using the application, and thus feel less confident about implementing new digital technologies (Oriji and Amadi, 2016). Further, becoming familiar with and implementing new technology in the classroom demands work and time (Howard and Mozejko, 2015). Tutorials

make it easier for teachers to assess the usefulness of the AR application for their classes and reduce their workload, allowing them to become familiar with it in a reasonable amount of time. Training, as suggested by Safar et al. (2016), can prepare teachers to employ novel technology in their teaching, making them feel less anxious about correctly using the application and facing technical issues.

Consult teachers and experts [RQ3]: If appropriate, researchers can involve teachers in the designing process of AR applications for language learning and collaboratively create a technology-enhanced learning unit that is pedagogically valuable, practical, and enjoyable. This can promote a smooth interplay between the teacher, the students, and the learning materials. Teachers may participate in theoretical discussions, actively contributing to the designing process by providing pedagogical and practical insight (Zainuddin and Idrus, 2016; Uiphanit et al., 2020), and evaluate the resulting learning materials before or after testing them in an authentic environment (Liu et al., 2018; Chen and Chan, 2019; Wen, 2021). In doing so, they assist researchers by giving them an idea of how the application will be used and how successful it was once implemented. The idea of involving teachers for pedagogical contributions is supported by Kirschner (2015), who listed three opportunities for teachers to be part of the designing process of technology-enhanced learning, which are stated as follows:

- Suggesting new design features
- Introducing pedagogical requirements
- Providing feedback on design ideas and prototypes

Feedback helps developers and researchers design and improve their applications based on theoretical and empirical evidence. Chen and Chan (2019), for example, found through feedback from teachers that non-visual learners did not benefit from their AR application as much as visual learners. Based on this feedback, the researchers and future developers can improve their systems by considering different learner types. Teachers can further assist researchers and designers by providing teaching material such as documents and exercises, thereby facilitating the topic and task selection for the application. This may ease the integration of AR-enhanced content into existing lecture structures and helps developers consider what students have already learned (Santos et al., 2016). Besides, the success of novel technologies in the classroom heavily depends on the attitude of the teachers implementing the material. According to Kirschner (2015), teachers should not perceive the utilized technology as different from other teaching approaches they usually apply in their classes. After participating in the designing process, teachers are familiar with the features of the application. Furthermore, during the design phase teachers can reflect on how to implement the technology-enhanced learning unit in their classroom (Cober et al., 2015). At the same time, working with teachers and gaining access to their classrooms can help developers to envision how the application will be used in a realistic educational setting (Cober et al., 2015).

The following conditions proposed by Cober et al. (2015) might come in useful for the collaboration between developers of educational applications and teachers:

- Feeling of inclusion
- Feeling of trust and ownership
- A process that feels natural
- Perception of ideas being valued

Provide real-time feedback [RQ3]: Feedback is the response of a system to the interaction of a user with it. It is a crucial element of instructional design and encompasses positive and negative feedback, which indicates whether the learner's understanding of a topic satisfies the expected learning outcome. Feedback usually comes from an external person like a teacher. When using AR applications in an educational environment, the system can adopt the task of providing feedback in real-time. Hereby, it is important to adapt the feedback design provided by the application to the target group. If the target group, for example, is very young, they favor feedback that is easy to understand and does not require the pupils to read or interpret it (Martínez et al., 2017). Real-time feedback assists learners as they complete their tasks (Liu et al., 2018) and shows them whether their understanding of a topic matches what the instructor is trying to convey. A simple method for providing real-time feedback with digital devices is to highlight correct and incorrect answers in different ways or colors, for example, in green and red (Montellanos et al., 2019). Wei et al. (2019) designed an application that allowed users to practice the stroke order of Chinese characters using AR. The system provided feedback by triggering error messages and sounds when the student did not enter the character correctly, so as not to allow them to reinforce the incorrect stroke sequence. It rewarded correct entries with animations that repeated the correct stroke order to strengthen the user's knowledge.

Students benefit from instructional design that provides rewards for successful learning. Feedback is critical for interactive rewards (Wei et al., 2019). When implementing an AR-enhanced application for teaching the Solar System in a foreign language, Liu et al. (2018) rewarded students who reconstructed the correct order of the planets by displaying the complete Solar System. Martínez et al. (2017) designed an AR application using image markers that represented parts of a story. When the children organized the markers correctly, the AR-enhanced application rewarded them by narrating the whole story in one piece.

Track the learner's progress [RQ3]: Monitoring the user's learning progress in an AR application designed for language learning can enable instructors, parents, the software, and the learner themselves to keep track of the learner's interactions with the application and the achieved learning goals. According to Acosta et al. (2019), who created a framework for AR applications for vocational education and training, systems can use monitoring to track the learner's progress in content, their learning results, and the time they spent using the application. Geng and Yamada (2023) encourage developers to incorporate data collection functions into educational systems to facilitate the creation of learning analytics, which can help supervisors, teachers, and students to use the application effectively. In another paper, they emphasize this suggestion by proposing that tracking and visualization of learning behavior can help improve learning and teaching (Geng and Yamada, 2023).

If designers add a feature to monitor and limit a child's use of the AR application, supervisors such as teachers and parents can control the amount of time the child spends on using the mobile device running the educational program (Lee et al., 2017). This can, for

example, address parents' concerns regarding the health of their children, which may be especially important for parents of young learners.

Providing teachers and instructors with statistics about their students' progress in language learning and the general class performance, as suggested by Geng and Yamada (2023), may help them to decide how fast to proceed in the lecture and whether they should repeat content that learners struggle to understand. Hence, presenting data about every student's performance in a comprehensible way, as suggested by Acosta et al. (2019), may ease the supervisor's workload and help them to support their students. Likewise, given the data which represents a learner's progress in the learning content, the application itself can guide the user through the learning material by unlocking more content as the learner's proficiency improves (Montellanos et al., 2019).

By collecting data about a user's learning process, they themselves can benefit from a comprehensible, easy-to-understand visual representation of their improvement and performance in a learning task (Acosta et al., 2019). When communicating the students' progress to them, it is important to do so by fostering motivation and not to discourage them. To motivate them, AR applications for language learning can, for example, apply progress bars and performance graphs, which are elements of the Gamification design. Gamification is an attempt to utilize motivational game design elements in environments that are not games (Deterding et al., 2011) to increase student engagement in a learning unit (Sailer et al., 2013). Wei et al. (2020) proposed that gameplay elements in applications for educational purposes like language learning are necessary to increase the learners' satisfaction. In addition, a monitoring system can enable the development of an AR application that promotes the autonomy of learners. This can, for instance, be realized through an intelligent recommendation system (Wei et al., 2019), which uses collected data to satisfy the learner's need for support and guidance.

Facilitate teacher-student interactions [RQ3]: The way students and teachers interact in the classroom significantly shapes the students' learning experience and can be key to their academic success. Because teacher-student interactions influence learners' language development and are critical to designing effective instructional environments in which meaningful learning occurs (Hall and Walsh, 2002), educational language learning software should promote the communication between instructors and learners. A well-elaborated interface, which supports the communication between teachers and students, can considerably impact the students' learning experience (Safar et al., 2016). As observed in the systematic literature review, an AR application that endorses bidirectional exchanges between instructor and learner can improve the language learning process in the following ways:

- It empowers teachers to properly supervise and analyze the students' state of learning (Santos et al., 2016), their problems, and their questions. Like progress tracking, this allows the instructor to flexibly adjust their teaching pace and learning activities to the needs of students.
- By analyzing their students' performance during learning units and by being aware of their demands, teachers can assess the learners' individual needs. In language learning, these needs could, for instance, concern the translations of phrases or the pronunciation of words, when students desire the affirmation of a real instructor (Tsai, 2020). Chen and Chan (2019) observed that teachers may need to extend the learning material provided by AR systems by other instructional tools if they find that the AR application is not sufficient for students to effectively learn or enjoy the learning process.
- Teachers can help students if they struggle with the technology. Notified teachers can intervene when students have problems with the AR-enhanced teaching method (Chen and Chan, 2019).
- An AR-enhanced application that supports Wi-Fi can allow teachers and students to seamlessly interact outside the classroom and enables remote exchange (Isaeva et al., 2021). This means that teachers can support their students after school and in learning activities at home.

One method for promoting interaction between teachers and learners that is not mentioned in the observed empirical studies on language learning but has been proposed by Acosta et al. (2019), who designed a framework for motivational AR-based teaching materials, is to integrate a Question and Answer (Q&A) system into AR applications.

A target group that could particularly benefit from textual communication options are quiet students. Although they are often mistakenly perceived as unengaged in their classes, they may not deliberately avoid participation in the classroom but instead favor teaching and integration methods that do not require them to draw attention to themselves by raising their hand and by vocally interacting with teachers and peers (Medaille and Usinger, 2019). According to Medaille and Usinger (2019), "[q]uiet students are often more comfortable communicating in written form because it allows them time to think about what they would like to communicate and to carefully craft their responses" (p. 12). Medaille and Usinger (2019) further suggested using instructional technology that assists anonymous participation in classes. In addition to a Q&A system, educational applications can support quiet students' class participation through quizzes, polls, and surveys (Medaille and Usinger, 2019).

Prevent technical issues [RQ3]: Technical problems can diminish the success of AR-enhanced learning units. These issues can affect students as well as teachers. Therefore, it is crucial that computer-assisted language learning allows students to learn undisturbed by technical issues (Chung and Hsieh, 2017). Technical issues can impair the learning experience in several ways. Tracking issues can confuse and irritate learners, which diminishes the learners' enjoyment and satisfaction (Dalim et al., 2016). They can further affect the usability of AR applications and thus the learning experience if users, such as children, have unsteady hands and perform involuntary movements that make tracking difficult (Santos et al., 2016; Martínez et al., 2017). The response time of applications can influence their usability. If an AR system has to display many 3D objects at once, the response time may increase and the application may not react to movement and user input in a reasonable time (Lee et al., 2017). Dalim et al. (2016) noted in their study technical issues with the speech input function of their AR application. If the volume of the learner's voice was not loud enough, the system did not recognize it and therefore did not react.

Teachers are also affected by technical problems as issues with the application may make them anxious about integrating new technologies into lessons. According to Chen and Chan (2019), it can be difficult for teachers to adopt AR-based materials into their classrooms because it is challenging and requires prior knowledge of the technology. Therefore, if developers of educational AR systems consider technical issues and do not use items prone to these problems, they can facilitate the integration of AR into the educational field.

Avoid noise [RQ3]: The acoustic situation in classrooms is an important aspect of learning and can influence the way and the quality of how students acquire knowledge. Listening is critical to various school activities, such as when students follow their teacher's presentations and instructions, communicate with peers during cooperative group work, or participate in auditory learning units like listening comprehension. AR environments teaching vocabulary, pronunciation, and other oral and auditory language abilities can be problematic when sounds interfere with each other and make it difficult for learners to focus on the auditory output of their device. When evaluating an AR environment for foreign language instruction in early childhood education, Martínez et al. (2017) noted that classroom noise caused by multiple sound-equipped AR applications can negatively impact learning activities, especially when multiple students have to simultaneously listen to recordings or provide speech input to be assessed. In the study of Chen and Chan (2019), a teacher mentioned that using AR in education can lead to students making noise if the learning unit lacks structure. Thus, providing clear guidelines and instructions for students to follow and for teachers to supervise may contribute to a more controlled learning environment and reduce noise.

The negative effects of loud learning environments are widely discussed in the literature. For example, uncontrolled noise reduces speech intelligibility in classrooms and impedes communication between students and the teacher (Shield and Dockrell, 2003). Further, it can affect the learners' academic performance (Shield and Dockrell, 2008) and may especially affect students with APD (Auditory Processing Disorder), who can experience "difficulty understanding speech in the presence of competing background noise or in reverberant acoustic environments" (AAA, 2010, p. 9).

Provide a clear structure of the learning material [RQ3]: Designing AR applications with clearly structured instructions can improve the value of technology-enhanced teaching material in various ways. It helps teachers to effortlessly conduct and manage learning units using AR (Chen and Chan, 2019), can reduce distraction, supports cognitive processes (Ho et al., 2017), and prevents classrooms from becoming noisy (Chen and Chan, 2019). Likewise, it empowers autodidacts and independent learners to process material on their own.

Combine traditional and non-traditional teaching approaches [RQ3]: Since not all people learn in the same way, one teaching method cannot satisfy the needs of all learners, as each of them has their individual needs, cognitive style, and preferences (Ho et al., 2017). Depending on the learning situation and content, some may prefer innovative instructional media like AR, while others are more comfortable with traditional learning approaches. Students participating in the study of Lee (2022) on English as a foreign language, for example, preferred print reading over digital reading when learning English. In addition, not all teaching materials are suitable for all learning areas. A participant of the study by Tsai (2020) indicated that, in their opinion, traditional methods were preferable to AR when studying the orthography of words. The researcher concluded that thoughtfully combining traditional and non-traditional learning materials will benefit language learning the most. Consequently, rather than blindly replacing traditional teaching approaches with AR ones, it is important to think about how AR can complement or enhance them. When Weerasinghe et al. (2022) investigated the effects of the keyword method for vocabulary learning and continued it by providing AR visualizations, they found that AR can significantly improve the traditional keyword method. This shows that it is important to investigate which traditional learning approaches work well with AR and can benefit from it. Another reason to combine traditional and non-traditional teaching methods is to make the transition from one medium to the other easier. While some participants of the study by Ibrahim et al. (2018) reported that they enjoyed using AR for learning vocabulary with real-world objects, others preferred flashcards. A reason for this could be that traditional flashcards are a familiar learning method. Adding traditional learning material to language learning lessons using AR may allow learners to feel more comfortable as they become accustomed to the technology-enhanced material (Ibrahim et al., 2018).

3.2 Discussion

This study aimed to capture the current state of research with respect to the use of AR in language education. It explored background information about the educational setting and technical conditions of the studies and investigated the advantages and obstacles observed. Finally, the study presented guidelines for language learning applications using AR, which offer reference points for the creation of new applications. According to the results, AR in language learning can contribute to students' motivation, enhance enjoyment and reduce anxiety, increase immersion with the learning material, offer student-centered learning, foster engagement, improve learning performance, support understanding and retention, visualize difficult to access concepts, and can be implemented using affordable technology. Nevertheless, without external support, teachers may have difficulties implementing AR in their classroom due to personal reasons like being unfamiliar with the technology or because the application does not meet the mental or physical needs of their students. In addition, developers need to mind errors and technical difficulties in their applications and consider the infrastructure into which the educational AR system should be integrated. The presented design principles suggest considering the cognitive limitations and chances of students using the application by avoiding cognitive load and thoughtfully combining sensory input. Additionally, they address the possibilities of AR to enable contextualized learning and to support the exchange between students, which has pedagogical as well as practical value. Finally, the research offers ideas for creating an accessible and user-friendly application. This can be done by providing a clear structure, training and tutorials, real-time feedback, and possibilities for student-teacher communication. Likewise, avoiding technical issues and noise caused by activities using the application contributes to an enjoyable and effective language learning experience with AR. During the creation of an educational AR application, it is advisable to seek support from teachers and experts.

This paper review extends the existing literature on AR and language learning. Fan et al. (2020) investigated the state-of-the-art

of AR for early language learning covering the years between 2010 and 2019. In this context, they analyzed AR learning activities, design strategies applied, and learning gains in a young learners' environment. Huang et al. (2021) reviewed the use of AR as well as Virtual Reality (VR) in studies on language education. The focus of their work is the investigation of the way AR and VR are used for learning, the users who are the main target group in the literature studied, the most significant results, and the effectiveness of AR and VR in the language learning context. Akçayır and Akçayır (2017) conducted a review on the use of AR in educational environments in general, investigating the technology's advantages and challenges. Similar to our study, they found that AR technology enhances students' learning outcomes in terms of performance, motivation, understanding, positive attitude, satisfaction, reduced cognitive load, confidence, and spatial ability. They further observed that AR pedagogically contributes to the learners' enjoyment, level of engagement, interest, collaboration opportunities with peers, student-lecturer interactions, self-study opportunities, and multi-sensory learning, findings that are also present in our study. Finally, similar to our research, Parmaxi and Demetriou (2020) analyzed the literature on AR in language learning from 2014 to 2019, investigating the obstacles and opportunities recorded in empirical research. The results of their literature review are similar to those in this paper, as the authors emphasize the emotional benefits of AR technology such as motivation, satisfaction, attention, engagement, and enjoyment, as well as the educational benefits in terms of learning performance, classroom interaction, and immersion. They further contribute to the literature by connecting the examined research to the KSAVE (Knowledge, Skills, Attitudes, Values, and Ethics) 21st-century skills framework.

This study adds to the literature by considering recently published scientific papers, providing a focus on AR for language learning at all ages, and suggesting design principles that can help in the development of new AR applications for language teaching. For future work, we want to combine the insights and recommendations gained on the implementation of AR applications for language learning with our experiences on the role of AR in serious games (Plecher et al., 2022) in order to achieve synergy effects.

4 Conclusion

This study presents a systematic review of the use of AR in language learning. It provides examples of AR systems used for language learning, discusses advantages and challenges, and presents design principles that help developers and researchers to design effective language learning applications using AR. The selected literature was published between 2016 and 2023 and includes 40 publications discussing empirical research. The findings reveal that the use of AR in language learning has gained attention, especially in the area of vocabulary learning. Consistent with Parmaxi and Demetriou (2020) and the observations by Akçayır and Akçayır (2017), this study further found that smartphones and other mobile devices are a popular hardware choice. These devices facilitate the use of AR for educational purposes due to their high availability. Together with inexpensive tracking methods such as using paper markers, this results in affordable teaching material. Considering the advantages and disadvantages of AR in language teaching, the technology offers a valuable complement to traditional teaching and learning materials in schools and for autodidactic language learners. When AR is used alongside traditional materials in an educational context, it can motivate learners to actively participate in the learning process and engage with the subject matter, as likewise mentioned in the literature review by Parmaxi and Demetriou (2020).

At the same time, AR learning units can help to reduce the pressure to perform in schools, which is consistent with findings of Huang et al. (2021). This can be achieved, for example, by promoting collaborative learning. AR learning can further encourage independent study and provide an enjoyable learning experience. In doing so, it is not inferior to traditional teaching and learning methods. Instead, the effectiveness of the chosen material depends on the anticipated learning effect. As AR is an unfamiliar way of teaching and learning, it can take a while for teachers, students, and autodidacts to become accustomed to it. Afterward, it will be a challenge for developers of educational AR systems to keep the technology interesting for learners as the latter advance in the subject matter and the novelty effect fades. The literature review further established a set of design principles that can help developers to design AR applications for language learning. The 14 identified design proposals consider empirical research findings, suggestions of teachers and educational experts, and student opinions from the observed manuscripts. The scope of principles includes recommendations for UI and content design of applications, suggestions for enhancing the learning experience, and ideas for making the educational AR system attractive to teachers if they implement the technology in schools. Hence, learners benefit from easy-to-understand application design and content that considers their mental capacities. In addition, language learning applications should implement user-centered learning experiences encouraging active learning, for example, by providing them with opportunities to speak and use the language. A sophisticated learning environment can improve language learning performance. Applying suggested design principles can help teachers to feel comfortable and confident using AR technology in classrooms. However, not all design principles are necessary or useful for all learning situations. They are intended to be guidelines for designers and users of AR applications for language learning who are interested in implementation recommendations.

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