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Review

Towards Sustainable Education with the Use of Mobile Augmented Reality in Early Childhood and Primary Education: A Systematic Mapping

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Abstract: Over the years, educational institutions have faced significant difficulties in the teaching process at all educational levels, due to lack of motivation, concentration, attention, and confidence, among other aspects. In this sense, information and communication technologies can be the answer to transform educational models. One of the most promising and accessible technologies in recent years is mobile augmented reality (MAR), which allows students to visualize content through a mobile device combining the real environment with a virtual environment, providing an interactive and digital vision of the physical world in real time. The appropriate use of digital technologies in early childhood and primary education can promote socialization, comprehension, learning, language development, attention, and other educational benefits. However, due to the novelty of this technology, there is limited research and a gap in the literature on the use of MAR at these educational levels. This research work, through systematic mapping, aims to give an overview of how AR and mobile devices have been used in the last decade, which academic areas have benefited from the use of this innovative academic approach, and the main benefits and problems of using this technology in early and primary education. The findings are encouraging and show that AR technology, together with mobile devices, can be used to support the teaching of science, mathematics, reading, language, geography, etc.

Keywords: mobile augmented reality; smartphone; mobile learning; active learning; sustainable learning

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1. Introduction

In recent years, educational institutions have faced many difficulties in the teaching process, due to multiple educational needs, as well as the lack of basic competencies, attention, concentration, motivation, and confidence among students [1,2]. The new generations of students, due to the exposure and use of technologies from a relatively young age, have developed new ways of learning and can reach great learning potential with innovative educational methodologies [3]. Education, according to the United Nations, is the key to achieving several of the Sustainable Development Goals (SDGs) [4]. When all people have access to quality education, they can escape the cycle of poverty [4]. For this reason, information and communication technologies in education should be used to transform educational models to improve the learning experience and equip students with skills that will help them in their professional and daily lives [5].

Digital technologies can be used to support students in both formal and informal settings, generating positive results in the teaching process [6]. An example of this is gamification, which promotes the use of game elements to improve engagement and motivation in academic activities [7]. With the proliferation of mobile devices, it has been possible to find new alternatives for the use of technology for education such as mobile augmented reality (MAR) [7]. There is evidence showing that the use of MAR in the educational model improves students' comprehension, memory, and imagination skills [8]. MAR is a field of computer science that combines real-world data with virtual objects, which can be superimposed on real images and dynamically coexist in the same space [9]. Furthermore, it allows students to visualize content through a mobile device, providing a digital view of the physical world in real-time [10]. Among the aspects that are most enriched by MAR are spatial skills, practical skills, concept understanding, conceptual change, collaborative work, long-term knowledge retention, and student motivation [11,12]. However, there are also negative effects, such as usability issues, distraction, and deployment and integration in the classroom effectively [12,13].

The use of MAR in early and primary education has been successful because users at these educational levels see it as something fun, which generates an intention to use it and motivation to learn [7]. For students at these levels, entertainment is paramount, because if they do not find this factor, they get bored and begin to look for another medium with which to interact [14]. MAR as a technology has been used to support the teaching of a variety of subjects in early and primary education such as STEM (science, technology, engineering and mathematics) [6], health [15], biology [16], astronomy [6,17], animal names and sounds [18,19], painting and reading [20], and language [14,21]. The motivation for the implementation of MAR, in the subjects described above, was that students innovatively receive teaching, with the use of digital technologies to improve the practical process of learning [22].

Although the use of MAR in the field of early and primary education could be highly convenient, there are not enough research studies that identify how this technology is being used in the different subjects, and in which ones it is not being used yet. Therefore, this paper aims to give insight to teachers, educational institutions, and other researchers on how to involve MAR technology in early education for the benefit of students. In this context, the objective of this work is, through a systematic mapping (SM), to identify the different ways of using MAR in early and primary education. To this end, the aim is to explore and find uncovered spaces in order to create opportunities for new lines of research for the improvement and innovation of education with the use of MAR. The research objectives are detailed in Table 1.

Table 1. Research objectives and questions.

Research Objectives (RO) & Research Questions (RQ)
RO1. To identify the use of AR technology vs. academic areas RQ1. Which academic areas have benefited from the use of MAR?
RO2. To identify the benefits and problems related to the use of MAR in early and primary education. RQ2. What are the benefits and main problems in the use of MAR in early and primary education?

This section is used to introduce the reader to the main topic of this research. The rest of the article is composed as follows. Section 2 presents the use of MAR technology in early and primary education, Section 3 shows the methodology used to conduct this research, Section 4 exposes the main results, Section 5 describes the discussion of the findings, Section 6 indicates the limitations of the systematic mapping and, finally, Section 7 contains the conclusions and future work.

2. Use of MAR Technology in Early and Primary Education

The constant evolution of digital technologies and their progressive inclusion in early and primary education is a generalized reality [23]. Today, educational methodologies and technology complement each other, to offer students new tools to access educational content in a playful, ubiquitous, and formative way [24]. However, the knowledge and applicability of this digital tool in primary-level teaching are still scarce [24]. Thanks to the continuous advancement of mobile technologies, the development of educational applications and tools has gained relevance in recent years [25]. Features such as flexibility, availability, and affordability are three elements that allow this technology to be deployed in a variety of educational environments [26]. In particular, the potential in the synergy between MAR and mobile devices (smartphones and tablets, even some laptops) for use in the gamification of education is appreciated [27].

Over the last few years, several initiatives have been developed that use new digital technologies to innovate the way of teaching in early and primary education [6,13,28]. Tools such as e-learning, mobile learning, AR, Virtual reality (VR), and videoconferencing, among others, have become options that can be used in the educational model to help motivate and enrich the knowledge of students [29]. With the accelerated growth of digital technologies in recent years, the traditional teaching and learning model has not been able to be maintained and educational institutions seek to innovate their academic proposal [5]. MAR is a widely versatile technology that has been used in early childhood, primary, secondary, and higher education, and is even useful in job training, video games, and continuous learning [9,28,30,31]. Early childhood education is a learning process in which children have the desire to know and begin to be curious about their environment; if the teaching method does not attract their attention, they can easily become bored [19]. Therefore, MAR in education has been used to improve the learning of children at an early level in subjects related to vowel and number recognition [21]. This tool has been used as a strategy to improve children's attention and motivation to learn the names, shapes and characteristic sounds of animals [19]. Furthermore, this technology is used to teach English vocabulary to early childhood [19]. For the development of this application, the researchers integrated real-time monitoring so that parents can control the use, access, start, and end of use of the application [32]. This was done to control the problems that may arise from the continuous use of mobile devices by children [32].

On the other hand, in primary education, MAR together with gamification has been integrated into a playful application that serves to improve the socialization, communication skills, and emotional intelligence of students [7]. This technology has also been used to improve reading comprehension levels [24], improve chemistry learning [33], and in natural sciences [34], etc.

Nowadays, the use of mobile devices is part of the daily lives of children, youth, and adults [28]. The new generation of digital natives is multi-tasking, they work on a laptop while watching a program on their tablet, listen to music on audio streaming applications, and chat at the same time [35]. Therefore, taking advantage of students' mastery and familiarity with technology, educational institutions should explore the opportunities of using digital technologies to innovate learning [36].

3. Methodology

3.1. Systematic Mapping

To conduct this research, an SM was used to find articles in a specific time interval (2012–2022) and categorize them according to the issues raised. The SM allowed finding trends, limitations, and benefits in a summarized and ordered manner. All researchers participated in an organized manner in the different stages of the SM to find the greatest number of articles and meet the stated objectives. The search string used was modified according to the database of scientific articles used. The databases used were IEEE Xplore, Web of Science, Scopus, and ScienceDirect. These databases were chosen because of their ample content in high quality and impact journals in various disciplines which include the use of technology in education.

3.1.1. Search String

The search string used is presented below; this was adapted to be used in each of the databases.

((“Document Title”:”education” OR “Document Title”:”student”) AND (“Document Title”:”augmented reality” OR “Document Title”:”AR”) AND (“Abstract”:”mobile” OR “Abstract”:”mobile learning” OR “Abstract”:”mobile devices” OR “Abstract”:”mobile-learning” OR “Abstract”:”m-learning” OR “Abstract”:”mlearning” OR “Abstract”:”mobile app”)).

3.1.2. Four-Step Method

A 4-step method was applied because it was used in a previous investigation and the results were adequate [37]:

- First step: The search string was used.
- Second step: The article exclusion criteria was applied to the different scientific databases.
- Third step: Each document was read and the articles that did not deal with the proposed research topic were eliminated.
- Fourth step: A filter was applied to identify the educational level of the articles found.

In the initial search, applying the search string, all articles related to the use of MAR in early and primary education were obtained. After this, exclusion criteria were applied, which consisted of eliminating repeated articles, articles that were not written in English, and articles that were not related to education. Each of the final articles was read to further refine the search and, finally, the results were filtered only to research that contributed to the objectives of the SM.

- The data that were obtained from each article are as follows:
- Article information: Title, first author, first author’s country of affiliation, year, journal and educational area.
- Context: Points referring to the type of education and subject in which the MAR was used.

4. Results

4.1. Systematic Mapping and Literature Review

The 4-step method allowed us to obtain the greatest number of articles relevant to the research topic.

- **First step:** The total number of articles was 503.
- **Second step:** The total number of articles was 364.
- **Third step:** The total number of articles was 164.
- **Fourth step**: The total number of articles was 40. The four-step method used to carry out this work can be seen in Figure 1.

Forty articles were included to perform the SM, of which 18 were found in Web of Science, 12 in Scopus, 7 in IEEE Xplore, and 3 in ScienceDirect. Table 2 shows the results of the research found in the last 10 years (2012–2022). The use of emerging technologies (ET) as a support in education is not a completely new research trend as several initiatives exist that were published in the years 2017, 2018, and 2019. In 2021 there is a spike in research on this topic, this could be due to the pandemic and isolation by COVID-19. On the other hand, 2012 is the year in which no publication was found on the topic of MAR in early and primary education.

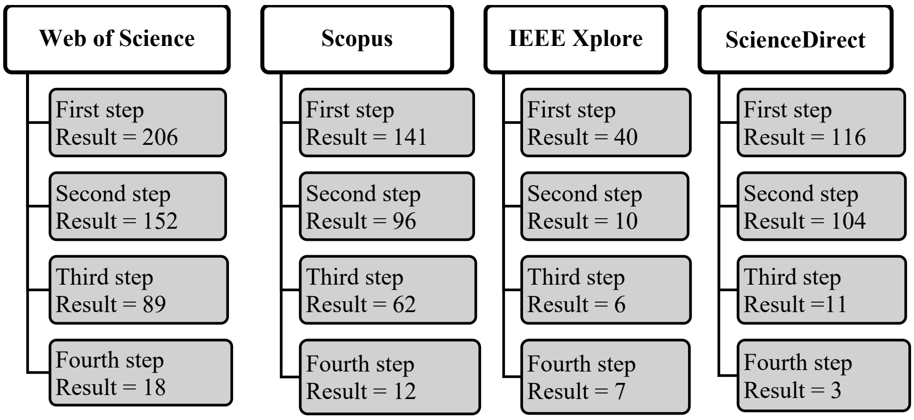

Figure 1. Four-step method for systematic mapping.

Table 2. Corpus of articles found in systematic mapping.

Source	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	All
Total articles	0	1	3	2	1	6	6	5	5	7	4	40

4.2. Research Objectives

4.2.1. Objective 1

Table 3 shows the educational level and subjects that have benefited from the use of MAR in education. There are six research papers dealing with early education and 34 papers showing the use of MAR in primary education.

Table 3. Corpus of Articles Found in Systematic Mapping for objective one.

References	Author	Country	Year	Education Level	Subject	Publication
[20]	Hou, Shou-Ming	USA	2013	Early Childhood	Painting, reading, listening to stories	Conference
[32]	Lee, L.-K.	Taiwan	2014	Early Childhood	Language	Conference
[21]	Cieza, Edwin	Croatia	2014	Early Childhood	Language	Conference
[19]	Nainggolan, Esron	Malaysia	2014	Early Childhood	Types of animals	Conference
[28]	Korenova, Lilla	Bulgaria	2015	Early Childhood	3D objects	Journal
[38]	Ye, Zhufeng	Italy	2015	Early Childhood	Reading and educational games	Conference
[13]	Bressler, D.M.	Taiwan	2016	Primary	Natural Science	Journal
[8]	Chiang, T.H.C.	Chile	2017	Primary	Natural Science	Journal
[22]	Delic, Alen	China	2017	Primary	Geography	Conference
[39]	Yusoff, Zarwina	Brazil	2017	Primary	Natural Science	Journal
[34]	Stoyanova, D.	China	2017	Primary	Natural Science	Journal
[27]	Petrucco, Corrado	Finland	2017	Primary	History	Conference
[40]	Hwang, Gwo-Jen	France	2017	Primary	Ecology	Journal
[41]	Joo-Nagata, Jorge	Indonesia	2018	Primary	Road safety culture	Journal
[42]	Mohd, C.K.N.	Peru	2018	Primary	Language	Journal
[5]	Rezende, Walter J.	China	2018	Primary	Mathematics, science, and geography	Conference

Table 3. *Cont.*

References	Author	Country	Year	Education Level	Subject	Publication
[16]	Alakarppa, Ismo	Greece	2018	Primary	Natural Science	Conference
[23]	Remmer, Melanie	Indonesia	2018	Primary	Geometry	Conference
[14]	Rahmat, R.F.	Colombia	2018	Primary	Language	Conference
[11]	Chen, Chien-Hsu	Taiwan	2019	Primary	Natural Science	Journal
[43]	Chen, Liyan	Malaysia	2019	Primary	Reading	Conference
[17]	Antoniou, Panagiotis	Portugal	2019	Primary	Astronomy	Journal
[24]	De la Gala Quispe, K.	Perú	2019	Primary	Reading	Conference
[44]	Pombo, L.	China	2019	Primary	Science	Conference
[45]	Ibarra, M.	Slovakia	2020	Primary	Mathematica and communication	Conference
[33]	Jin, Jing	Portugal	2020	Primary	Chemistry	Conference
[6]	Costa, M.C.	China	2020	Primary	Science, mathematics, and technology	Conference
[46]	Zhang, Luyue	Philippines	2020	Primary	Memorization	Conference
[47]	Garcia, Manuel B.	Ecuador	2020	Primary	History	Journal
[7]	López-Faican, Lissette	Slovakia	2021	Primary	Emotions	Journal
[48]	Tometzová, Dana	South Korea	2021	Primary	Geography	Conference
[12]	Hassan, Syed Ali	Thailand	2021	Primary	Language	Journal
[49]	Hsieh, Min-Chai	Taiwan	2021	Primary	Natural Science	Journal
[50]	Khan, Haymontee	Bangladesh	2021	Primary	Geography and history	Conference
[51]	Chen, Zheng	China	2021	Primary	Poetry	Book section
[52]	Afnan, Afnan	South Korea	2021	Primary	Mathematics and reading	Journal
[53]	Palazón, Belén	Spain	2022	Primary	Programming	Conference
[54]	Mueller, Lea Marie	Germany	2022	Primary	Mathematics	Conference
[55]	Hashim, Nurhazarifah	Malaysia	2022	Primary	Vocabulary	Journal
[56]	Pasalidou, Christina	Greece	2022	Primary	Robotics	Conference

The use of MAR in early childhood education is very limited; only six research initiatives were found that have used this technology to support the teaching and learning model in a decade. On the other hand, the largest number of research initiatives found (34) in the SM are on the use of MAR in primary education to support the teaching and learning model. Figure 2 shows the subjects that have benefited from the use of MAR as support in their teaching-learning methodology. Science teaching is where the most research initiatives are found, followed by reading, mathematics, language, geography and history.

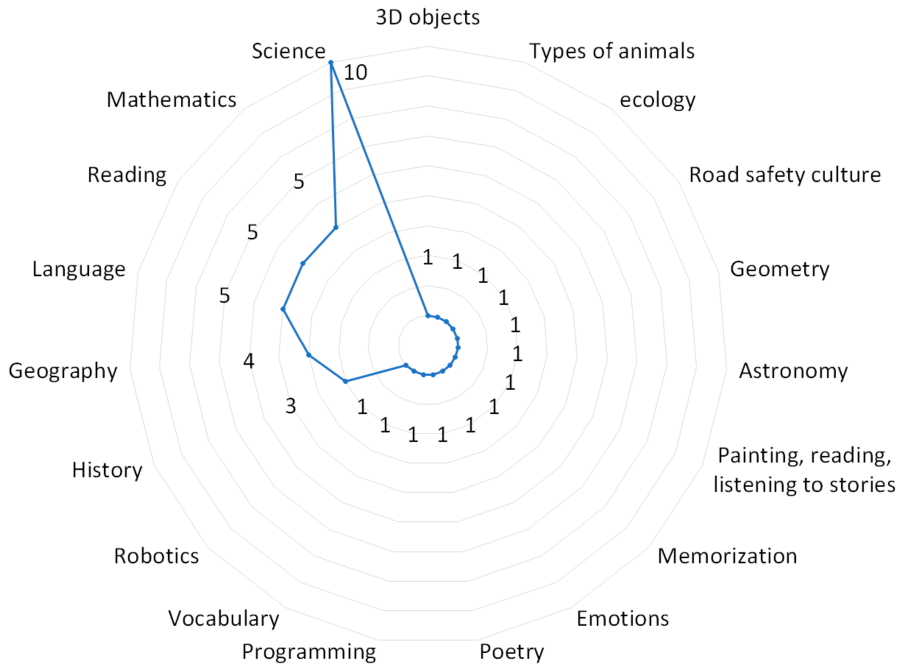

Figure 2. Academic areas that benefit from the use of AR in early and primary education.

4.2.2. Objective 2

In the present study, it was also possible to observe the advantages and benefits, as well as the problems and possible limitations of the use of MAR identified in early and primary education. The main benefits found are:

- Arouses interest and motivation [6,7,12,13,19,22,27,33,34,40,47,49,52]
- Improves understanding [6,11,12,23,27,33,47,52]
- Promotes collaboration [7,11–13,27,41,49]
- Improves student participation [7,13,23,27,52]
- Generates fun in learning [7,13,27,34,40]
- Creates learning experiences [6,16,27,33]
- Generates a sense of discovery [13,33,52]
- Improves and enhances performance [6,13,52]
- Improves perception [11,22,47]
- Promotes cognitive activity [23,34,40]
- Personalizes learning [12,27,47]
- Promotes competence [23,40,41]
- Enhances interactivity [7,11]
- Facilitates teamwork [6,13]
- Enables co-construction of knowledge [27]
- Generates enthusiasm and curiosity [7]

On the other hand, the SM identifies many of the barriers and problems encountered in the use of MAR at this educational level. The following is a list of the most common problems to be faced in the use of digital technologies in early and primary education:

- Low accuracy of GPS on mobile devices [8,12,22]
- Application design without iterations [13,23]
- Applications without performance testing [22,23]
- Costly creation of didactic classrooms for MAR use [11,27]
- Poor quality of mobile device cameras [12,32]
- Difficulty experienced by children when using MAR [43,47]
- Usability of apps with MAR [12,47]
- Application design without feedback from teachers and students [22]

- Limited real-world application contexts [27]
- Academic curriculum reformulation [27]
- High cognitive loads due to a lack of pedagogical strategies [40]
- Use of technologies in early childhood education can be detrimental to children's learning, health, and development [32]
- Use of markers to visualize the MAR scene [16]
- The Vuforia platform is not recommended for personalized educational MAR [16]
- Slowness in apps with older versions of Android OS [21]
- Extra technological knowledge burden for the teacher [47]
- Mobile devices with limit resources for MAR scenes [12]

In addition, this research found several learning strategies that can be used when using MAR as a support in education, these are:

- Constructivist pedagogical learning (participation, reflection, teamwork, and willingness to learn) [6,13,23,27]
- Formal learning combined with fieldwork (Informal) [16,41]
- Experiential-based learning [16,32]
- Cooperative learning [7,13]
- Learning from learning scenarios with relevant materials (images, text, videos) based on the principle of spatial and temporal continuity of multimedia design theory [8,11,23]
- Project-based learning [27]
- Game-based digital learning [40]

5. Discussion

Sustainable education implies adopting practices and approaches that ensure the continuity, quality, and positive impact of education over time, without compromising the needs of future generations. This is why the use of AR technology and mobile devices can be an answer to improving and innovating an educational model attractive to new generations of students. The Sustainable Development Goal (SDG) 4 for 2030 focuses on "ensuring inclusive, equitable and quality education and promoting lifelong learning opportunities for all" [4]. The use of mobile Augmented Reality (AR) technology can play a key role in achieving this goal by generating universal access to education by overcoming geographical and economic barriers, enabling ubiquitous learning experiences for students, reducing the access gap. Also, MAR can be adapted to meet diverse needs and learning styles by catering to different abilities and preferences. By providing more interactive and visual learning experiences, mobile AR can improve educational quality and active student participation, promoting deeper understanding. Finally, by adopting sustainable practices in the use of technology, such as the development of energy-efficient applications and the consideration of their environmental impact, it is possible to contribute to a responsible use of technology, aligning with the principles of sustainable development [57–59].

Of the research papers obtained for the SM, 23 were published in scientific conferences, 16 were published in Journals indexed in Scopus, and there was one published as a book chapter. This shows that the academic community considers that this technology has the potential to improve the learning process at these stages. Articles in journals are usually peer-reviewed, which implies a level of quality control in the research, and they tend to be more complete and mature research. Papers presented at scientific conferences may indicate ongoing research or pilot projects. In addition, papers presented at conferences are often a mixture of ongoing research and preliminary work. This can provide valuable information on the future direction of research in the field.

The results indicate a strong interest in the use of MAR in early and primary education in several regions of the world. The high number of MAR initiatives in education in China suggests a strong commitment to research and application of this technology at this educational level. This could be due to several factors, such as the size of the population, investment in educational technology, or the culture of innovation present in this country. Although China leads in the number of articles published, it is interesting to note that

Taiwan and Malaysia have also contributed significant research in this field. Despite their smaller number of publications, these countries may be making valuable contributions in terms of quality or focus. In addition, the distribution of research papers in scientific conferences and journals indexed in Scopus shows that MAR research in early and primary education is an active and diversified field.

5.1. Objective 1

The research initiatives found in this SM on MAR in various areas of early and primary education suggest a growing interest in taking advantage of this technology to improve teaching and learning in these specific fields. For example, 10 initiatives on the use of MAR were found, which have shown this technology can be especially valuable for science teaching [6,8,13,44,49]. It was used to simulate experiments, visualize abstract concepts, and make students interact with scientific phenomena in a more hands-on way by providing immersive experiences [5,11,16,34,39].

In language [12,14,21,32,42], reading [20,24,38,43,52], and mathematics [5,6,45,52,54], MAR was used to provide more immersive learning experiences. An example of this is the visualization of stories, the creation of interactive games to enhance vocabulary, and the practice of mathematical problem-solving skills through visual and immersive interactions.

The applications used for teaching geography enhanced the learning experience by providing detailed and contextual information about different locations. Students explored interactive maps, discovered geographic data, and better understood the relationship between different geographic regions [5,22,48,50].

In history teaching, MAR was used to recreate historical events, places and relevant characters. This allowed students to immerse themselves in historical contexts and better understand the chronology of key events, thus contributing to a deeper understanding of history [24,47,50].

Even though for support in subjects such as chemistry [33], animal types [19], ecology [40], astronomy [17], memorization [46], poetry [51], programming [53], vocabulary [55], and robotics [56], there is only one publication for each of these subjects, the presence of MAR suggests an interest in applying this technology in diverse educational areas. In each of these fields, augmented reality was used to provide hands-on and visual experiences, facilitating the understanding of abstract concepts and encouraging student participation.

5.2. Objective 2

5.2.1. Benefits

In early childhood education, research initiatives use the three main directions of MAR in the development of early childhood education, which are: children's books, educational games, and classroom practice [28,32,38]. It is important to point out that at this educational level, learning based on sounds, images, and multimedia content predominates, for which the use of MAR can be very beneficial [20].

The use of MAR in early and primary education has been shown to offer a wide range of benefits that positively impact the learning process [7,12]. MAR catapults student engagement and collaboration by transforming the learning environment into an interactive and engaging experience. Collaboration has been identified as a key 21st-century skill that is included in most current educational models [7]. By introducing virtual elements into the real world, MAR creates a novel environment that captures students' attention, arouses their curiosity, and, consequently, motivates their interest in learning. Interacting with MAR content often requires collaboration among students, which fosters teamwork and enhances social skills while reinforcing joint learning, allowing them to actively engage and increase their attention to the educational material.

The ability to explore objects and concepts three-dimensionally through MAR creates a sense of discovery, stimulating children's natural curiosity and facilitating the understanding of abstract concepts [28]. The combination of visuals and interactive practices through

MAR has been shown to contribute significantly to students' academic performance and achievement by facilitating a deeper understanding of subjects [17,19]. By tangibly visualizing abstract concepts, AMR facilitates the understanding of complex and abstract ideas, making learning more accessible and meaningful [8]. This technology promotes collaboration and teamwork by allowing students to interact with the same virtual content at the same time, fostering communication and joint problem-solving [5]. The introduction of playful elements through MAR makes the learning process a fun experience, which in turn contributes to a more positive and stimulating educational environment [7,27,40]. The ability to visualize concepts in 3D enhances spatial perception and understanding of relationships between objects, contributing to students' cognitive development [33]. Furthermore, the interactivity of MAR stimulates cognitive activity by challenging students to think critically, solve problems, and practically apply concepts [20]. MAR in early and elementary education not only enriches the learning process but also transforms the way students interact with content, providing benefits that go beyond simple knowledge acquisition [18,20].

5.2.2. Barriers and Problems

Alternatively, the main problems encountered in the use of MAR should be addressed before its use and deployment in the educational model [32]. The omission of these can lead to final products that do not fit the real educational needs and could limit the effectiveness of the application built for learning. In addition, some hardware elements in mobile devices may affect the quality, experience, and accuracy of location-based MAR experiences [8]. This may exclude some learners from accessing MAR experiences due to hardware or software limitations. On the other hand, lack of end-user participation and input may affect the relevance and effectiveness of the application which may limit the applicability of MAR in various topics and areas of study. This could result in errors or malfunctions during actual use in the educational environment [22].

The use and deployment of MAR may require changes to educational programs to effectively integrate MAR, which may be met with resistance or logistical challenges. Moreover, it may be prohibitively expensive to implement learning environments fully equipped for MAR [27]. It is important to consider that a lack of pedagogical guidance may result in overwhelming learning experiences for students, which may limit the flexibility and spontaneity of MAR-based educational experiences [40].

The lack of usability in MAR applications may hinder the widespread adoption of MAR applications in educational settings, which may negatively affect the learning experience if children find it difficult to interact with the technology. It is important to consider the potential impact on children's health and development when introducing advanced technologies at an early age [32]. This is why it is crucial to choose appropriate platforms to ensure the effectiveness and adaptability of educational applications.

To address these issues, it is essential to conduct thorough testing, involve teachers and students in the design process, and provide adequate training for both educators and students. Finally, careful consideration must be given to pedagogical and logistical issues when integrating MAR into the educational curriculum.

5.2.3. Learning Strategies

It is important to use strategies that promote student participation, collaboration, and meaningful learning [47]. For this purpose, cooperative learning through games and activities is an appropriate strategy for students to interact with each other [13]. In addition, students can be provided with information and resources that they can use to collaborate on projects [7].

Constructivist pedagogical learning is a strategy that is based on the idea that students construct their knowledge through experience and interaction [6]. MAR can be used to provide students with opportunities to experiment and manipulate virtual objects. It can also be used to create activities that students can complete independently. MAR technology, coupled with a problem-solving strategy using projects, can create immersive learning experiences that help students better understand concepts related to their group work [27].

On the other hand, AR together mobile devices can create various activities that are engaging and stimulating for students [40]. These activities can help students learn concepts and skills in a fun and meaningful way. Furthermore, the portability and ubiquity of mobile devices mean that AR can be used to create activities that students can complete informally outside of the classroom [41]. It can also be used to provide students with information and resources that they can use to explore their environment. MAR can also be used to create experiences and to provide students with opportunities to interact with real-world objects and phenomena [16].

6. Limitations

An SM is a snapshot of the scientific literature at a particular moment in time [37]. Although the literature search followed a rigorous process, it is possible that there were articles that were not considered. Furthermore, a challenge was the availability of data as not all studies publish data in an accessible manner or compatible formats. The date range chosen may exclude relevant studies before 2012 or after 2022 that could have valuable information. Besides, only scientific initiatives written in English were included. This linguistic bias limits the number of possible additional investigations and may lead to a variation in the result.

7. Conclusions and Future Work

The SM of research on the use of MAR in early and primary education reveals a strong global interest in this technology, with a notable number of papers published in scientific conferences and journals indexed. Research in this field is active and diverse, addressing mainly children's books, educational games, and classroom practices for early education [38].

The implementation of MAR in early childhood and elementary education offers notable benefits, such as increasing student participation and collaboration [13], creating interactive and engaging learning environments, and fostering social and teamwork skills [40]. The technology facilitates the understanding of abstract concepts by enabling three-dimensional exploration and 3D visualization [28], thus improving academic performance [47]. These characteristics show that MAR should be used in early childhood and primary education because of its great benefits for student-centered learning.

However, challenges are identified that need to be addressed before the widespread implementation of MAR in educational environments. Issues such as hardware quality [8], lack of end-user involvement [13,22], resistance to change in educational programs [8], costs [11], and lack of pedagogical guidance are critical. In addition, the usability of MAR applications and their potential impact on child health and development must be carefully considered.

Overcoming these challenges requires thorough testing, active participation of teachers and students in the design of educational experiences, as well as adequate training for all involved. The integration of MAR into the educational curriculum must consider pedagogical and logistical aspects to ensure its effectiveness and adaptability. Although MAR in early and primary education offers significant benefits, its successful implementation requires a comprehensive approach and careful consideration of the associated challenges.

It would be important for future research to report on the challenges and opportunities identified in the studies. For example, mention should be made of technological or access barriers. In addition, it is important to discuss the pedagogical implications and risks associated with their misuse. These aspects are crucial to fully understanding the current and future state of MAR in early and primary education.

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