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Review Article

Augmented Reality and Student Motivation: A Systematic Review (2013-2024)

Zuo Ruijia[1], **Li Wenling**[2], **Zhang Xuemei**[1]

[1]Department of Preschool Education, School of Music and Dance, Xihua University, Chengdu, Si Chuan, China
[2]School of Education Science, GuangXi Minzu Normal University, Chongzuo, Guang Xi, China

Abstract

This study investigates the impact of Augmented Reality (AR) technology on K-12 students' learning motivation. AR, as an innovative instructional tool, integrates virtual objects into real-world settings, creating immersive and interactive learning environments. Learning motivation is a critical factor influencing students' academic achievement, and AR technology provides autonomous and personalized learning experiences that enhance capabilities, reduce cognitive load, and improve learning outcomes. A systematic literature review methodology was adopted, analyzing 44 high-quality research articles published between 2013 and 2024 that examine the relationship between AR and learning motivation. The analysis revealed that AR technology is widely implemented in educational contexts, particularly in subjects such as mathematics, science, and art, offering authentic and engaging learning experiences. The findings highlight that AR significantly enhances students' learning motivation by fostering autonomy, promoting interactive activities, and visualizing abstract concepts in intuitive ways. These features reduce cognitive load and improve comprehension, leading to better academic performance. Additionally, the novelty of AR stimulates students' curiosity, driving sustained engagement and making learning more appealing and effective. The study underscores the potential of AR to transform traditional education by creating engaging and interactive learning experiences. Educators are encouraged to integrate AR into their instructional practices to foster students' curiosity, motivation, and academic success. Future research should explore the long-term effects of AR technology and address challenges such as accessibility and teacher training to maximize its impact in educational settings.

Keywords: Augmented Reality, K-12, Motivation

Correspondence
Li Wenling
liwenling@gxnun.edu.cn

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1. INTRODUCTION

From traditional textbooks and chalkboards to a variety of multimedia materials, numerous multimedia and computer-assisted learning systems have been developed that provide interactive and effective learning materials (Djamas et al., 2018).

Multimedia learning materials have become an integral part of education, and various multimedia technologies can be utilized to develop learning systems, such as videos, e-learning websites, virtual reality, and augmented reality (Wolf et al., 2017). Augmented reality (AR), derived from the advancements in these technologies, is a technology that allows for the interaction between real and virtual objects simultaneously (Kavanagh et al., 2017). It is an extension of virtual reality (VR), where virtual objects are superimposed onto real images. In other words, through these applications, an object that does not physically exist is perceived as being present through the display of a mobile device (del Cerro Velázquez & Morales Méndez, 2021). With the advancements in mobile devices, AR technology has been applied in various domains, including health, marketing, education, film, advertising, and design (Georgiou & Kyza, 2018; Khowaja et al., 2020; Lin et al., 2021; Salmi et al., 2017). Augmented reality (AR), as an interactive technology that enables direct interaction with virtual objects in the real world, has recently garnered significant attention.

AR has created new opportunities for education, offering a seamless interface that combines the real and virtual worlds compared to traditional VR (Chen et al., 2016; Lai et al., 2019). Users can interact with virtual objects integrated into the surrounding real environment, resulting in the most natural and authentic human-computer interaction experience (Cai et al., 2014).

AR learning applications in the field of education have been widely utilized as interactive digital learning platforms for complex and abstract concepts in certain courses, such as mathematics and geometry, science, geography, and art (Bistaman et al., 2018). The use of AR allows students to immerse themselves in authentic scientific learning experiences, stimulating their learning motivation and achievement, while enhancing the flexibility and interactivity of learning activities (Estapa & Nadolny, 2015; Lu et al., 2020; Wang et al., 2022). Researchers have confirmed the advantages of AR as it enables students to interact with virtual objects in the real world. Furthermore, numerous studies have proposed AR learning activities, demonstrating that AR systems not only provide foundational knowledge to students but also offer flexibility and innovation, actively enhancing students' motivation to learn (Djamas et al., 2018). Chen et al. (2016) conducted a quasi-experimental study based on Keller's motivation model, aiming to enhance students' mathematics learning motivation and alleviate math anxiety. Through this research, it was determined that learning mathematical objects proved more effective than teacher drawings or verbal descriptions, and students faced no difficulties in visualizing objects in three-dimensional space. In the context of mathematics education, the use of AR in the classroom is quite significant as traditional teaching materials such as paper, pencils, and rulers are insufficient to achieve three-dimensional visualization of geometric shapes in students' minds (Djamas et al., 2018; Kavanagh et al., 2017).

Learning motivation refers to the intrinsic drive that initiates, sustains, and directs learners' engagement in academic activities, playing a vital role in determining academic performance and success (Hwang et al., 2016). Understanding what motivates learners to engage in learning activities can assist educators in designing effective instructional approaches to facilitate student learning (Sarkar et al., 2020). Several factors influencing learning motivation have been identified, including personal characteristics such as personality, self-efficacy, and academic self-concept. Additionally, environmental factors such as teacher behaviors, classroom atmosphere, and peer relationships also impact motivation (Bistaman et al., 2018). Traditional learning approaches often rely on textbooks, lectures, and handouts as conventional instructional resources, which may present challenges in terms of the abstract nature of the learning content and the lack of tangible experiences, potentially resulting in dull and difficult learning experiences (Kul & Berbe, 2022). AR technology can empower students by providing opportunities for autonomous learning and customized learning experiences (Yousef, 2021). Furthermore, augmented reality can enhance capabilities by facilitating interactive and engaging activities that promote skill development (Djamas et al., 2018). Through AR technology, learners can interact with virtual objects, combining learning content with the real environment, creating immersive and sensorial learning environments (Astuti et al., 2019). Additionally, AR technology can foster relevance through facilitating collaboration and social interaction among students. By providing visual and interactive representations of abstract concepts, AR technology can reduce cognitive load, which can be challenging. By alleviating cognitive load, AR technology can enhance students' motivation and learning outcomes. The emergence of AR technology injects new vitality into learning motivation (Tarng et al., 2015). This novel learning approach stimulates learners' curiosity, exploratory drive, and agency, thereby increasing the appeal and effectiveness of learning. Understanding the factors influencing AR learning motivation can assist educators in designing effective AR learning environments to promote learning outcomes (Hajiali, 2020).

1.1. Research Structure

The subsequent sections of this paper are organized as follows: Section 2 provides a detailed outline of the systematic approach and research methodology utilized, along with the research questions. Section 3 presents the study's findings. Section 4 outlines the discussion and conclusions. Lastly, Section 5 offers suggestions for future research endeavors.

2. METHODOLOGY

A systematic literature review (SLR) is a comprehensive and rigorous process aimed at identifying and synthesizing high-quality evidence related to a specific research topic (Boell & Cecez-Kecmanovic, 2015). This process involves a detailed description of the review scope, research questions, and methods, followed by thorough searching and selection of relevant evidence. The selected evidence is then critically assessed for quality, and data extraction and synthesis are conducted. Finally, the review findings are reported and disseminated. Disseminating the results of an SLR is crucial for providing information to decision-makers and practitioners. In this review, an extensive search of relevant databases was conducted to identify all literature related to VR and motivational analysis.

To mitigate potential reporting bias, we employed the following strategies:

Double-Blind Procedures: Both participants and evaluators were blinded to the study hypotheses to reduce subjective influences during data collection and interpretation.

Cross-Checking of Data: Independent researchers reviewed the raw data and analytic processes to identify discrepancies and ensure accuracy.

2.1. Definition of the Scope and Questions

In this study, we analyzed all of the research studies related to AR and motivation from 2013 until 2024. This time frame was chosen to focus on the most recent decade, a period that reflects the latest advancements and emerging trends in the field. By limiting the scope to the past ten years, we aim to ensure that our analysis captures contemporary perspectives and developments, which are particularly relevant to current research and practice. While earlier publications laid important groundwork, the selected period aligns with our study's objective to highlight the evolution and state-of-the-art contributions within this timeframe. The purpose of this article is to answer the following questions: Documentation dimension, Methodological dimension, Pedagogical dimension.

Documentation dimension

RQ1. What is the extracted concept network from the literature and what are the article themes based on the journal categories in the database?

RQ2. What is the geographic distribution of these publications?

Methodological dimension

RQ3. What methodological approaches and research methods were employed in the selected studies?

RQ4. What were the sample sizes and durations of each study?

Pedagogical dimension

RQ5. Under what circumstances were AR instructional processes implemented?

RQ6. What impact does the use of AR have on learning motivation?

RQ7. What other variables were investigated in the selected studies?

RQ8. Which specific academic disciplines in the K-12 domain have incorporated AR applications?

In conclusion, this paper focuses on AR, student motivation, and the K-12 field, aiming to review the application of AR in student motivation in basic education over the past decade. The study explores the characteristics and evolving trends of instructional design, teaching strategies, and assessment in AR teaching processes, aiming to summarize existing experiences and promote the application of AR technology in basic education.

2.2. The Searching and Paper Selection Process

A systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards, which included defining inclusion criteria, information sources, search strategies, study selection process, data collection process, and data presentation and synthesis. The systematic review process in this study involved different stages:

Phase 1: Research Questions (RQ). These questions were organized into three dimensions, as shown in Table 1: (1) Literature dimension (RQ1-RQ2) to identify the knowledge domains and geographical distribution of researchers, as well as the impact of journals where the studies were published; (2) Method dimension (RQ3-RQ4) to address the applied approaches and methods, sample sizes, and time frames of the studies; (3) Instructional aspect (RQ5-RQ8) to identify the various K-12 educational contexts involved in AR use, educational levels and subject areas studied, instructional methods identified in the analyzed teaching practices, the impact on student motivation, and finally, the identification of other instructional, psychological, sociological, or technological variables used in the studies.

Table 1. Domains, Research Questions, and Initial Coding Criteria

Areas	Research Questions	Initial Coding
Documentation Dimension	RQ1. What is the extracted concept network from the literature and what are the article themes based on the journal categories in the database?	Co-occurrence map by keywords.
	RQ2. What is the geographic distribution of these publications?	Countries involved in the research.
Methodological Dimension	RQ3. What methodological approaches and research methods were employed in the selected studies?	Approaches: Quantitative, qualitative, mixed methods. Methods: Quasi-experimental, experimental research, instructional design, case study, survey research, exploratory data analysis, descriptive research, observational study.
	RQ4. What were the sample sizes and durations of each study?	Sample: <25/25–50/51–100/101–150/151–200/ >200 subjects Time Range: 7 days or less/1-4 weeks/1-6 months/7-12 months/over 1 year
Pedagogical Dimension	RQ5. Under what circumstances were AR instructional processes implemented?	Inside the physical classroom/Outside the physical classroom/Blended Learning
	RQ6. What impact does the use of AR have on learning motivation?	Motivation: Improved/Not improved
	RQ7. What other variables were investigated in the selected studies?	Attitudes towards learning: critical thinking disposition/group self-efficacy/situation interest/self-efficacy/learning value/learning anxiety/learning attitude; Learning abilities: memory capacity/creative thinking/problem-solving skills; Learning methods: flipped learning; Psychological states: psychological burden/cognitive load/self-regulation/spatial ability.
	RQ8. Which specific academic disciplines in the K-12 domain have incorporated AR applications?	Foundational Disciplines: science/ geometry/ art/ physics/chemistry/ biology/English/reading/natural sciences Environmental Education: environmental science/ marine education/plant education. Creative Courses: communication technology/ learning materials/ creative courses/social skills. Other: STEM education/ maker education.

Phase 2: Inclusion Criteria and Information Sources. The literature included in this review consisted of articles published in journals from 2013 to 2024. The search was conducted from the commencement date to June 2024. The following descriptors from the Education Resources Information Center (ERIC) were used: "AR," "AR applications in education," "learning motivation," and "AR and learning motivation." Empirical studies employing quantitative, qualitative, and mixed methods were also included.

Phase 3: Search Strategy. Seven electronic databases (Google Scholar, Springer Link, Scopus, Web of Science, IEEE, Elsevier, and CNKI) were searched using a combination of keywords. The following keyword combinations were used in each database: ("learning motivation" OR "motivation" OR "academic motivation" OR "learning incentive" OR "learning intention" OR "learning enthusiasm" OR "learning interest" OR "learning drive" OR "learning goals" OR "desire" OR "aspiration" OR "exploration desire" OR "interest" OR "drive") AND ("augmented reality" OR "AR" OR "immersive technology" OR "simulated reality" OR "extended reality" OR "wearable augmented reality") AND ("k-12" OR "basic education" OR "elementary education" OR "secondary education" OR "kindergarten to twelfth grade" OR "early years to high school" OR "basic education"). Additionally, a supplementary search was conducted using Google Scholar. To ensure a comprehensive retrieval of publications, studies meeting the criteria were selected from previous systematic reviews. In this stage, we identified 231 articles from journals, conferences, books, and other sources.

Based on the research objectives, a further selection was made from the initially screened literature, following these steps: (1) The study context had to be in K-12 education (kindergarten, primary, middle, and high school), excluding higher education, special education, vocational education, and other contexts. (2) Only empirical research (quantitative, qualitative, design, and mixed methods) was included, excluding reviews and theoretical articles. (3) The focus had to be on AR technology, excluding studies related to VR and MR. (4) Peer-reviewed journal articles were selected, excluding monographs and conference papers. Finally, 44 empirical studies were included, originating from 27 different journals, including Journal of Computer Assisted Learning, Computers & Education, and Computers in Human Behavior.

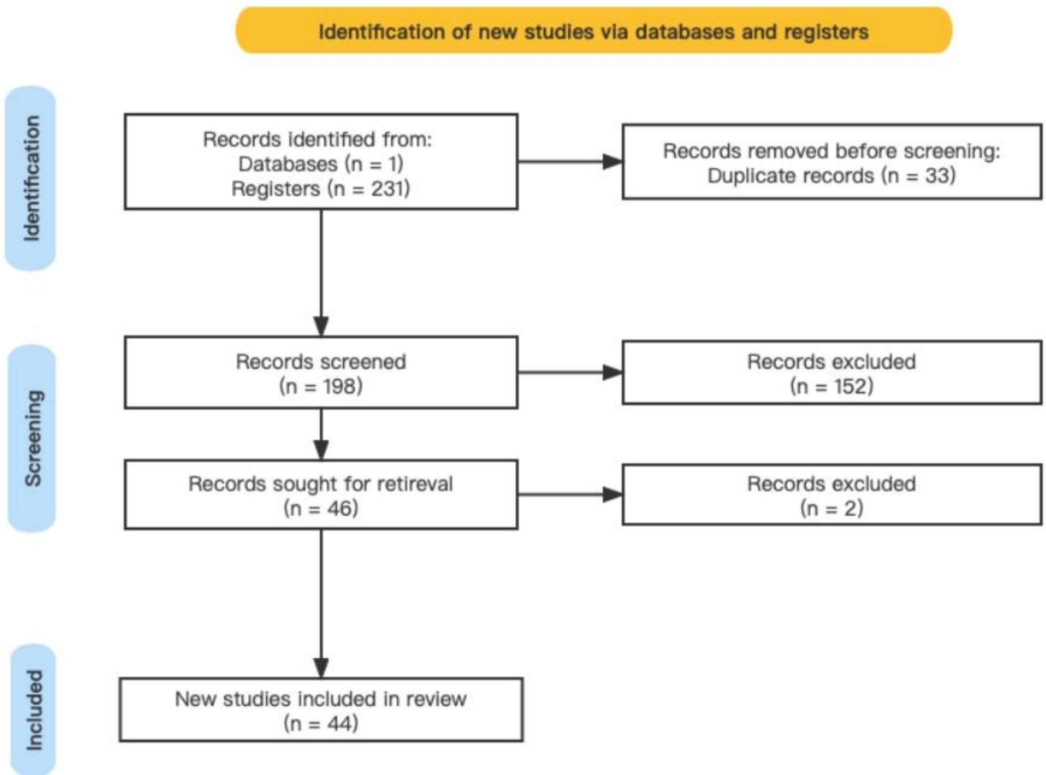

Figure 1. Flow Chart of the Study Selection Process

Phase 4: Study Selection Process. The initial search yielded 231 articles, of which 33 were duplicates. Based on the inclusion-exclusion criteria, an analysis of the titles and abstracts of the remaining 198 articles was conducted. Once consensus was reached, 152 articles were excluded. The remaining 46 articles were independently analyzed and, after consultation, 2 articles were excluded. The final sample for the systematic review consisted of 44 articles (see Figure 1).

Stage 5: Data Coding and Synthesis. Zotero reference management software was utilized for data collection. Data synthesis was conducted using a coding table with 29 fields (LibreOffice Calc). VOSViewer was employed for conceptual network analysis. Three researchers independently and subsequently collaboratively participated in the selection process at different stages, based on predetermined inclusion criteria and explicit inclusion review.

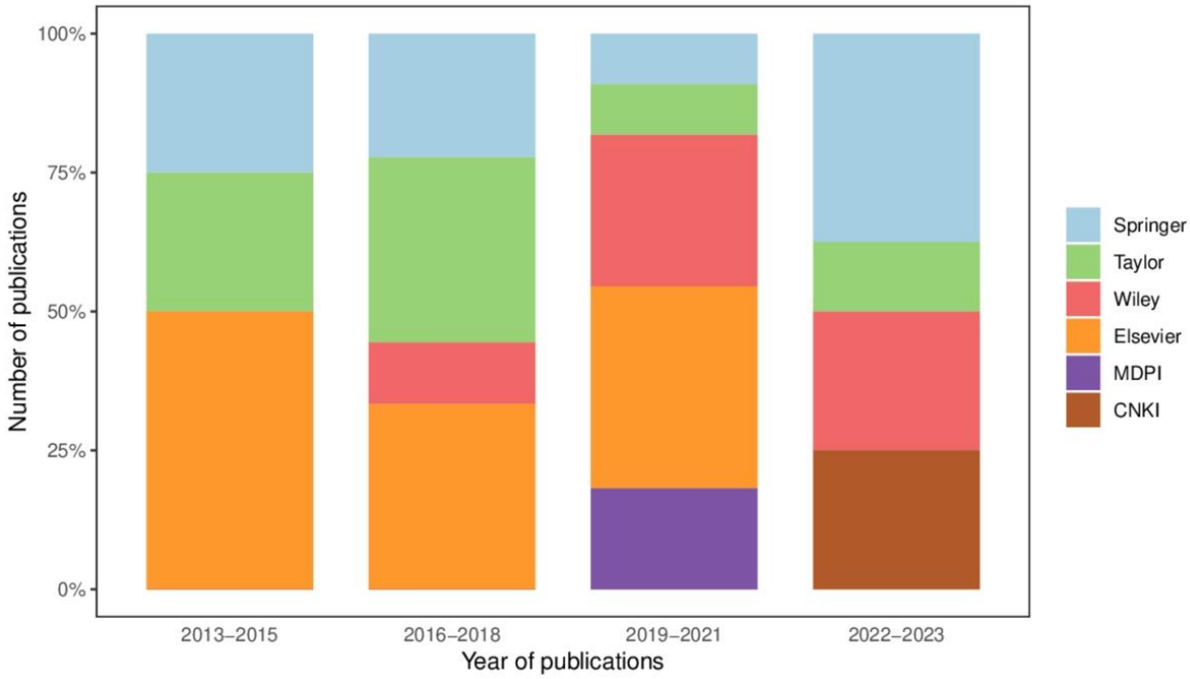

Figure 2. Distribution of Articles by Publisher

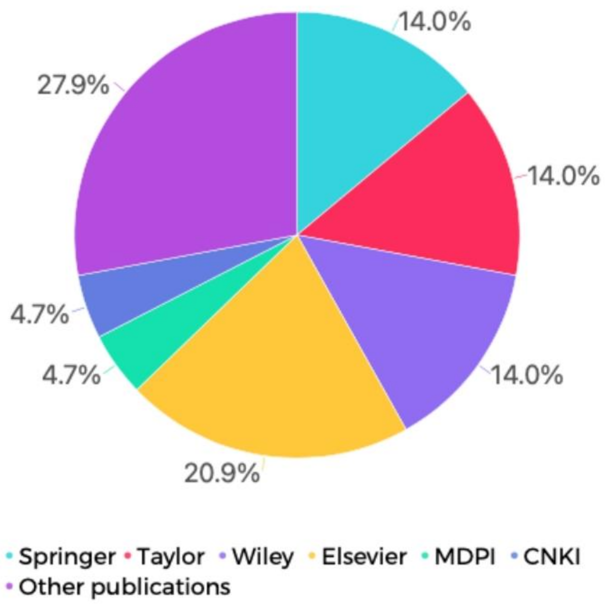

Figure 3. A Pie Chart of the Percentage by Different Publishers

2.3. Data Extraction, Synthesis, Reporting, and Dissemination

At this stage, the remaining 44 articles were categorized based on the publisher's name and publication year, and a brief overview of these articles is presented in Figure 2. Figure 3 displays the percentage of papers for each publisher. A meticulous analysis of these articles was conducted, highlighting their strengths and limitations. It is evident that prior to 2005, there was only one article in this field. Furthermore, the majority of articles published in 2018 belonged to Springer and IEEE. This evidence indicates that the topic of AR and learning motivation is a newly discussed subject on a regular basis. Hence, a comprehensive study on this topic is necessary. The next section will provide a comprehensive analysis of the selected articles.

3. RESULTS

RQ1. What is the extracted concept network from the literature and what are the article themes based on the journal categories in the database?

By examining the co-occurrence of keywords in the articles, we obtained a series of clusters for analyzing conceptual networks. In Figure 4, the first cluster (15 items) is represented in red, forming a conceptual network related to augmented reality, encompassing elements such as student performance, learning motivation, and technology. The second cluster (12 items) appears in green and represents a conceptual network concerning learning motivation, analyzing the research impact on corresponding populations. The third cluster (10 items) is depicted in blue, displaying a conceptual network centered around the applications of augmented reality in animal studies and animal experiments.

In summary, the key concept network extracted from the articles included in this systematic review consists of two primary nodes: augmented reality and motivation. Among the analyzed articles, 73% were published in journals with relevant index categories, primarily falling under the "Education" category (67%), followed by "E-Learning" (4%) and "Educational Communication" (2%). Additionally, 8% of the articles were associated with journals categorized as "Mathematics (Miscellaneous)," while 7% were categorized as "Interdisciplinary." The remaining articles covered various topics related to natural sciences (4%), health (2%), social psychology (2%), language and linguistics (1%), and computer technology (3%).

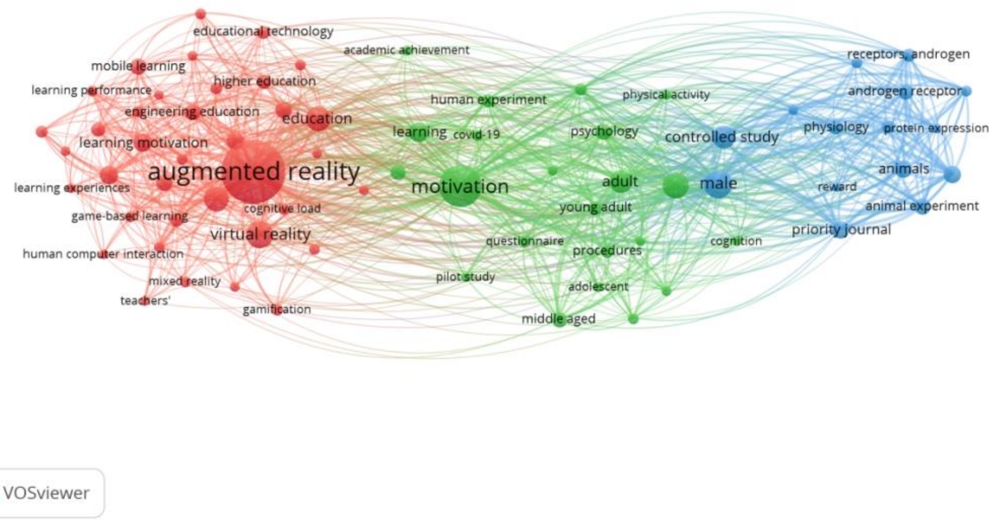

Figure 4. Map of Co-occurrence by Keywords of the Articles Reviewed. Source: Prepared with VosViewer

a. Link Length Between Nodes

In the VOSviewer visualization, the link length between nodes represents the strength of the relationships between the terms or entities. Shorter links indicate stronger associations or higher co-occurrence frequencies, suggesting that these terms are more likely to appear together in the dataset. Conversely, longer links suggest weaker associations or less frequent co-occurrence. For instance, in the figure, the terms "augmented reality" and "virtual reality" are closely linked, reflecting their strong conceptual or contextual relationship within the analyzed publications.

b. Size of Nodes

The size of the nodes reflects the importance or frequency of the terms in the dataset. Larger nodes represent terms with higher occurrence frequencies or greater relevance in the network, indicating their central role in the research landscape being analyzed. For example, "augmented reality" is depicted as one of the largest nodes, signifying its prominence and frequent discussion in the analyzed studies.

RQ2. What is the geographic distribution of these publications?

The geographical locations investigated in this review were determined based on the countries associated with the first authors of the articles. The results indicate that 52% of the research was conducted in China (including China Taiwan). The subsequent leading countries were Turkey, Spain, and Malaysia, accounting for 18% each. The remaining countries, such as the United States, France, Finland, and Portugal, collectively constituted 30% of the analyzed studies.

RQ3. What methodological approaches and research methods were employed in the selected studies?

These studies were categorized based on their methodologies as quantitative (64%), qualitative (6%), and mixed methods (30%). Among the selected studies, quasi-experimental designs were the most frequently employed (62%), followed by experimental research (26%). Exploratory research constituted 2% of the total, while case studies were utilized in 2% of the research. Surveys as a research method were less prevalent, accounting for 6% of the studies, and other approaches, such as factor research design and observational research, each accounted for 1% of the total.

In terms of the analytical methods employed, ANCOVA and t-test were the most frequently utilized, comprising 30% and 34%, respectively. Following these, MANCOVA and ANOVA accounted for 9% each. Additionally, a portion of studies utilized SEM path analysis and Kendall's W test, each constituting 5% of the methods applied. Moreover, regression analyses, cluster analysis, and thematic analysis were each employed in 3%, 3%, and 2% of the studies, respectively.

RQ4. What were the sample sizes and durations of each study?

In this systematic review, 39% of the studies utilized samples ranging between 25 to 100 participants. 25% of the studies involved sample sizes exceeding 100 and below 200. 9% of the studies used samples smaller than 25, and the remaining 4% did not report the sample size. The majority of the reported studies (51%) had a research duration ranging from 1 to 6 months. Studies with a duration between 6 months and 1 year accounted for 26%. 7% of the studies reported a research duration of less than 1 month. Approximately 14% of the studies were conducted within a period of less than one week. Furthermore, 2% of the articles did not report the duration of their research.

RQ5. Under what circumstances were AR instructional processes implemented?

In the analyzed studies, nearly three-quarters of AR instructional practices were conducted in traditional classroom settings (73%). Blended learning accounted for 23% of the research. Finally, the employment of AR for instructional practices outside the classroom constituted 3% of the reported studies.

RQ6. What impact does the use of AR have on learning motivation?

In general, 90% of the research indicates a positive relationship between students' learning motivation and the use of Augmented Reality (AR). Besides enhancing students' learning motivation, the utilization of AR also shows potential in reducing cognitive load and improving academic performance. However, 10% of the studies report a negative association between the implementation of AR in educational practices and students' learning motivation, with no evident positive facilitating effect or only indicating potential impact of AR on students' learning motivation.

RQ7. What other variables were investigated in the selected studies?

In addition to learning motivation, this review also analyzed other variables across different domains, as follows:

a. Learning attitude-related variables: critical thinking disposition, group collective efficacy, situational interest, self-efficacy, learning value, learning anxiety, and learning attitude.

b. Learning ability-related variables: memory capacity, creative thinking, and problem-solving ability.

c. Learning approach-related variable: flipped learning.

d. Psychological state-related variables: psychological burden, cognitive load, self-regulation, and spatial ability.

RQ8. Which specific academic disciplines in the K-12 domain have incorporated AR applications?

The application of Virtual Reality (VR) in the field of basic education is primarily concentrated in three domains: fundamental disciplines (e.g., science, geometry, fine arts, physics, chemistry, biology, English, reading, natural sciences, etc.), environmental education (including environmental science, marine education, and botanical education), and creative courses (such as communication technology, learning materials, creative curriculum, and social studies). Other subjects encompass informal disciplines represented by STEM education and maker education. However, at the primary and middle school levels, Augmented Reality (AR) technology is predominantly employed in the fundamental science subjects to enhance students' learning motivation.

4. CONCLUSION AND DISCUSSION

This study aimed to explore the relationship between learning motivation and augmented reality (AR) through a systematic review of 44 high-quality studies. The findings provide valuable insights into the applications of AR in educational contexts and its implications for enhancing students' motivation.

4.1. Summary of Findings

The review revealed two primary findings. First, AR has been predominantly applied in fundamental subjects such as mathematics, science, and art, emphasizing its capacity to offer immersive and engaging learning experiences (Chang & Hwang, 2018; Erbas & Demirer, 2019; Estapa & Nadolny, 2015; Sampaio & Almeida, 2016). This highlights the alignment between AR's unique affordances and the pedagogical demands of these disciplines, where visualization and interaction play pivotal roles in fostering students' curiosity and learning motivation (Ibáñez et al., 2020; Kirikkaya & Basgül, 2019; Kul & Berbe, 2022). Second, AR's integration into education remains concentrated in classroom settings, with limited exploration of its potential in extracurricular or blended learning environments.

On the other hand, it is observed that research on the impact of AR on learning motivation seems to be constrained by educational system characteristics, as evidenced by the emphasis on educational technology and student performance in the studies (Chang & Hwang, 2018; Lai et al., 2019). Considering that the use of the Educational Resources Information Center (ERIC) database implies potential biases (e.g., language and sources) in the sample selection process, the geographical distribution of the studies indicates varying levels of interest in AR among different education systems. Apart from the expected prevalence of research conducted in China (including Taiwan), other countries such as Malaysia and Turkey have shown high levels of interest in competitive educational models.

4.2. Implications and Broader Significance

The findings underscore AR's transformative potential in K-12 education, particularly for cultivating scientific thinking and practical skills in foundational disciplines. However, the geographical distribution of studies, with a notable emphasis on China, Malaysia, and Turkey, suggests that interest in AR may be influenced by regional educational priorities and technological adoption trends. Additionally, the reliance on quantitative and quasi-experimental methods, while effective for assessing short-term impacts, underscores the need for longitudinal studies to examine AR's sustained influence on learning motivation.

Regarding the methods used in the studies, it is evident that, similar to the typical approach in research on learning motivation, quantitative methods are the most prevalent, with mixed methods increasingly gaining importance. The primary approaches employed are quasi-experimental or experimental methods, which allow for controlled investigations of AR's impact on learning motivation. However, it is essential to highlight that a considerable proportion of the analyzed studies relied on small sample sizes (Chu et al., 2019). This aspect represents a potential limitation when attempting to generalize the findings to larger populations or diverse contexts.

The analysis of the studies reviewed in this paper suggests that AR's educational applications are primarily concentrated within classroom settings, although there are some instances of blended learning integration (Garzón et al., 2019a). To advance the field, future research could explore the potential of AR in extracurricular and other learning environments. This would provide valuable insights into how AR can enrich teaching scenarios and methods across different educational contexts (Khowaja et al., 2020).

The majority of the studies indicate that the use of AR has a positive impact on students' learning motivation. However, it is worth noting that a minority of research has found negative effects on learning motivation related to AR usage (Garzón et al., 2019a). To gain a comprehensive understanding of these discrepancies, future investigations should delve deeper into the factors that contribute to these varying outcomes and explore how AR's effects might differ among diverse learner groups. Understanding these nuances would enable researchers and educators to make more informed decisions about when and how to implement AR effectively to enhance learning motivation and outcomes (Georgiou & Kyza, 2018).

4.3. Limitations

This review highlights several limitations in existing research, including small sample sizes and short study durations, which constrain the generalizability of findings. Furthermore, while most studies report positive effects of AR on learning motivation, occasional negative outcomes warrant further investigation. While this study provides valuable insights into the relationship between augmented reality (AR) and learning motivation, several limitations should be acknowledged to contextualize the findings. The specific limitations are as follows:

Methodological Constraints: The study primarily relied on a systematic review of existing literature, which is inherently dependent on the quality and comprehensiveness of the selected articles. As such, the findings may reflect biases present in the source studies, including variations in methodological rigor or reporting standards.

Sample Size and Diversity: Many of the studies included in the review utilized small sample sizes, limiting the generalizability of their findings to broader populations. Moreover, the samples often lacked diversity in terms of geographic and cultural representation, which could affect the applicability of the results across different educational contexts.

Short Study Duration: Approximately 60% of the reviewed studies had a duration of less than three months. This limitation restricts the understanding of AR's long-term impact on learning motivation, as most findings capture only short-term effects.

External Validity: The majority of studies were conducted in controlled environments, such as classrooms, which may not fully represent the dynamic and multifaceted nature of real-world learning scenarios, particularly in extracurricular or blended learning settings.

4.4. Strengths

Despite these limitations, this study possesses several notable strengths that contribute to its academic and practical significance:

Comprehensive Scope: By systematically analyzing 44 high-quality studies, this research provides a broad and detailed understanding of how AR influences learning motivation, encompassing various educational levels, domains, and teaching modes.

Novel Insights: The findings highlight ARs unique potential to enhance motivation by creating immersive and interactive learning environments, offering both theoretical and practical contributions to the field of educational technology.

Practical Implications: The study identifies key areas where AR can be effectively integrated into education, particularly in fundamental subjects like mathematics and science, offering actionable insights for educators and policymakers.

By addressing these limitations and emphasizing the study's strengths, this research lays a solid foundation for future investigations into the broader applications and long-term effects of AR in education.

4.5. Comparison with Existing Literature

The findings of this study align with previous research in demonstrating the positive impact of augmented reality (AR) on students' learning motivation. Similar to studies by Garzón et al. (2019b) and (Anuar et al., 2021), this review highlights how AR fosters engagement by creating immersive and interactive learning environments that capture students' attention and curiosity. Consistent with these studies, the findings suggest that AR enhances autonomous learning and reduces cognitive load, which are critical factors in increasing learning motivation.

However, our results diverge from some earlier studies, such as those by Amores-Valencia et al. (2022), which reported mixed or negative effects of AR on learning motivation. These discrepancies could stem from differences in study designs, sample characteristics, or the specific AR applications used. For example, while many studies in our review employed educational AR tools designed for classroom use, Khan et al. (2019) focused on less structured AR environments, which might have caused cognitive overload or frustration for some students.

Additionally, while previous studies primarily explored AR's impact within STEM fields, our review identified its growing use in non-STEM domains such as art and language learning. This trend reflects the expanding scope of AR's application in education and its potential to address diverse learning needs, as highlighted by recent works (Badilla-Quintana et al., 2020; Gómez-Galán et al., 2020; Tzima et al., 2019)

These comparisons underscore the novelty of this study, as it provides a more comprehensive overview of AR's applications across educational settings and subject areas. Furthermore, by identifying gaps in existing research, such as the limited exploration of AR's long-term impact and its use in extracurricular contexts, this study contributes to the academic dialogue by offering directions for future research.

5. RECOMMENDATION FOR FUTHER RESEARCH

- Geographical Scope: Future research on the relationship between learning motivation and augmented reality should broaden its geographical scope to include a more diverse range of countries and regions. This expanded approach would allow researchers to gather data and insights from different cultural, social, and educational contexts. By including a more extensive and diverse sample of participants, the findings would be more representative and generalizable, enabling a better understanding of the impact of augmented reality on learning motivation across various global settings (Estapa & Nadolny, 2015).

- Exploring Additional Variables: In addition to examining learning motivation, future research should also consider exploring other variables that could influence the impact of augmented reality on learning outcomes. Variables such as learning attitudes, aptitude, and psychological states of students might play a crucial role in determining how AR technologies affect their motivation to learn. Investigating these factors would provide a more comprehensive understanding of the complexities involved in integrating AR in educational settings and its effects on learners' engagement and achievement (Lu et al., 2020).
- Applications across Different Subject Domains: Further investigation should focus on the diverse applications of augmented reality across various subject domains. By exploring how AR can be effectively incorporated into different academic disciplines, educators can tailor its use to meet the specific teaching needs of different subjects (Chen, 2020; Chu et al., 2019). Understanding the subject-specific benefits and challenges of using AR can lead to the development of more targeted and effective instructional strategies, maximizing its potential for enhancing learning experiences in different areas of study (Liou et al., 2017).
- Combination with Other Educational Technologies: As technology continues to evolve, it is essential to explore the combination of augmented reality with other educational technologies (Chiang et al., 2014). Integrating AR with virtual reality, gamification, artificial intelligence, or interactive simulations could create more comprehensive and personalized learning experiences (Astuti et al., 2019). This integration could enhance learner engagement, promote active participation, and provide opportunities for learners to apply knowledge in practical and immersive ways, fostering deeper understanding and retention of concepts (Chen et al., 2019).
- Promoting Interdisciplinary Research: Encouraging interdisciplinary collaboration is crucial to driving innovation and development in augmented reality's application within the educational domain (Di Serio et al., 2013). Researchers from different fields, such as education, technology, psychology, and design, should come together to explore the multifaceted aspects of AR integration in education. This collaborative effort would facilitate the development of more sophisticated AR learning tools, instructional approaches, and frameworks that align with diverse learning needs and pedagogical goals (Djamas et al., 2018). Moreover, it could lead to the identification of best practices for incorporating AR into various educational contexts, ensuring its effective use in enhancing learning outcomes for students of all ages and backgrounds (Omurtak & Zeybek, 2022).

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