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Innovative Augmented Reality Integration for Enhanced Geometry Education: A Review of the Impact on Student Interest, Self-Efficacy, and Academic Achievement

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Abstract
This study systematically explores the integration of augmented reality (AR) to enhance geometry teaching, recognising the pivotal roles of students' interests and self-efficacy in shaping effective instruction. Augmented reality has emerged as a potent tool, influencing students' interest, self-efficacy, and achievement in geometry. The review, encompassing studies from 2018 to 2022 in SCOPUS and Dimensions, involved a meticulous analysis of 215 articles, culminating in the selection of 11 for detailed examination. This research significantly contributes to geometry education by leveraging AR technology innovatively and devising strategies that capture students' interest and enhance self-efficacy, thereby positively influencing academic achievement. The methodologies in the selected studies involve interventions, educational experiments, or tools. The integration of AR consistently yielded positive responses, fostering heightened satisfaction, motivation, and improved learning experiences, outcomes, and performance. These findings have the potential to expedite the adoption of technology-driven practices in the education system of the Malaysian Federation and globally as they explore how AR affects students' interest and confidence, and they are a helpful plan for making AR learning more accepted in schools. As technology gets better, these findings give a chance to make education in Malaysia and other places better by using AR in smart and effective ways.
Keywords: Augmented Reality, Geometry, Interest, Self-Efficacy

Introduction

Geometry is one of the most important topics in mathematics and deals with the properties and relationships between points, lines, shapes, and space. Its mastery poses a significant challenge for students globally (Tan, 2016). The student's interest and self-efficacy in the learning process must be considered to ensure outstanding success in geometry. In this context, interest is a complex psychological process essential to learning and is commonly defined in studies as the desire to engage with something (Fryer et al., 2021). Self-efficacy, on the other hand, self-efficacy refers to a learner's belief in their capacity to attain a specific level of performance, influencing their subsequent actions (Bandura, 1989).

The use of technology is one of the tools that can increase students' interest, self-efficacy, and performance in learning geometry (İbili et al., 2020). Among the variety of these technologies, augmented reality (AR) is increasingly used to enhance student's learning experiences and encourage them to explore learning from the perspective of new teaching materials (Mamiala et al., 2021; Arvanitaki & Zaranis (2020). This 3D technology creates an additional layer of information within the user's sensory view of the natural world (Rauschnabel, 2021). AR can change the way students learn, play, and relate mathematics to their environment (Nguyen et al., 2020).

In recent years, AR has become a popular technology for learning geometry and has received much attention in educational research. For example, a study conducted by Arvanitaki & Zaranis (2020) has demonstrated that students show interest and positive improvements in learning geometric network topics using AR. In addition, AR was found to increase students' creative thinking, interest, and self-efficacy in learning geometry based on a questionnaire conducted by Yousef (2021) based on the ARCS model. The above findings and studies provide a critical summary to understand the implementation, effectiveness, and prospects of AR in learning geometry in terms of interest and self-efficacy.

However, studies linking the factors of interest and self-efficacy simultaneously to students' learning performance have not been adequately conducted (Nuutila et al., 2020), although interest and self-efficacy influence students' learning performance (Riconscente, 2014). It has also been difficult to find a systematic review that includes detailed, relevant literature on the effectiveness and implementation of AR in geometry teaching. For example, Ahmad & Junaini (2020) conducted a literature review on the types of AR applications and mechanisms of AR development tools and their implementation in mathematics education for 19 sets of degree articles. However, their review is general to mathematics education and not focused on any particular topic, especially geometry.

Another review by Godoy Jr. (2020) examined the applications of AR in different educational settings, including mathematics education. However, the findings only generally highlight the use of AR technology in learning geometry and its value in learning mathematics. This study systematically synthesizes the relevant literature to fill this gap. It analyses the leading trends and applications of AR in learning geometry and their impact on students' interest and self-efficacy in learning geometry.

Specifically, this study asks the following three research questions

- What are the typical characteristics and specific design features of AR-based learning applications for learning geometry?
- What research design is most used by researchers to determine the impact of augmented reality technology on students' interest and self-efficacy in learning geometry?
- Does augmented reality technology affect students' interest and self-efficacy in learning geometry?

Related-Work

Interest and self-efficacy are significant because many studies have shown that students' interest and self-efficacy in learning geometry contribute to their achievement in this topic (Chien et al., 2019; Nzaramyimana, 2021). Students with a positive attitude towards learning geometry are more interested in studying geometry and participating in their learning activities, which leads to achieving high scores in geometry (Bindak, 2004). In addition to interest, the level of students' self-efficacy in Mathematics also becomes a factor in determining students' achievement level in Mathematics (Yeh et al., 2019).

Nzaramyimana (2021) studied the relationship between active learning, student interest and achievement using GeoGebra software. This study has proven that students' interest in learning geometry has increased and influenced student achievement in the learning topic. Meanwhile, the level of student self-efficacy has increased in learning geometry using the Rasch model, along with the post-test score, which is also higher than before (Sudihartinih & Wahyudin, 2019). Thus, students with a high level of interest and self-efficacy in learning geometry will actively involve themselves and try to do the given tasks, which will further improve their achievements in learning geometry.

The significant functions of AR led to the implementation of that technology in education. Lainufar et al (2020) emphasized that learning geometry with GeoGebra made geometry more visual. According to Abdul Hanid et al (2022), studies showed that teaching geometry using AR results in more high-achieving students than using textbooks. This is in line with Nazar et al (2020)'s finding that abstract concepts can be depicted more realistically by using AR. Therefore, AR technology has become important and beneficial for students to understand abstract concepts, especially in geometry.

Methodology

Systematic Searching Strategies

There are three main processes in the systematic search strategies: identification, screening, and eligibility (see Figure 1).

Identification

Identification is a process of gathering the main keywords of a study that are synonymous and related: augmented reality, geometry, interest, and self-efficacy. It aims to enable the database to produce all relevant articles for review. Keywords based on research questions suggested by Jabar et al. (2022) and Ibáñez & Delgado-Kloos (2018). The author has added existing keywords and developed full search strings (based on Boolean operators and phrase searching) to two main databases, namely Scopus and Dimensions (see Table 1).

The advanced search option was used with the keywords "augmented reality AND geometry AND interest AND self-efficacy" (Table 1). 16,024 articles were found with the keyword.

Table 1
The search strings

Database	Search string
Scopus	TITLE-ABS-KEY ("augmented reality") AND geometry AND interest AND self-efficacy
Dimensions	"augmented reality" AND geometry AND interest AND self-efficacy

Screening
This study automatically filters all articles released by the database based on the keywords entered. Articles are then limited to some inclusion and exclusion criteria (see Table 2). This criterion is according to previous AR survey studies in mathematics (Ahmad & Junaini, 2020; Palancı & Turan, 2021).

Table 2
Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Published between 2018-2022	Published before 2018
Education, mathematics, and science social journal	Not related to mathematics education journaleducation journal
Article journal with empirical data	Article review, conference papers, book chapters, conference proceeding
Written in English	Non- English

Because the researcher cannot review all the articles listed, Okoli (2015) suggested that the researcher limit the search year to a specific period. Therefore, the search is limited to the most recent five years, from 2018 to 2022. The year 2023 is excluded because the pursuit started in September 2023, and this year has just ended. Furthermore, today's learning style has also changed, causing the year of publication to be too old and no longer relevant to be used as a reference (Nugraha, 2020). Thus, the period between 2018 and 2022 was selected as the inclusion criteria.

The search is also limited to articles published in English to ensure the article is clear. As a result, 15,989 articles were removed for failing to meet the inclusion criteria. The remaining 215 articles will go through the third process of eligibility.

Eligibility
Eligibility is the third process, where researchers manually screen articles to ensure that this group of articles meets the desired criteria. This process is done by reading the title and abstract of the article transferred to Microsoft Excel. Through this process, 203 articles were released because they focused on STEM or other subjects compared to geometry, focused on virtual reality compared to augmented reality, focused on reviews instead of providing empirical data, and had unclear methodological parts. At last, only 11 articles were selected.

Quality appraisal
The remaining articles were given to an expert for quality appraisal to ensure the quality of the content. According to Theorell et al (2015), experts need to classify the quality of articles into three categories: high, medium, and low. Only articles in high and medium places will be reviewed. As a result, experts have determined that six articles are in the

prominent position and five articles are in the medium position. Therefore, all articles are accepted for review.

Formulation of Research Question

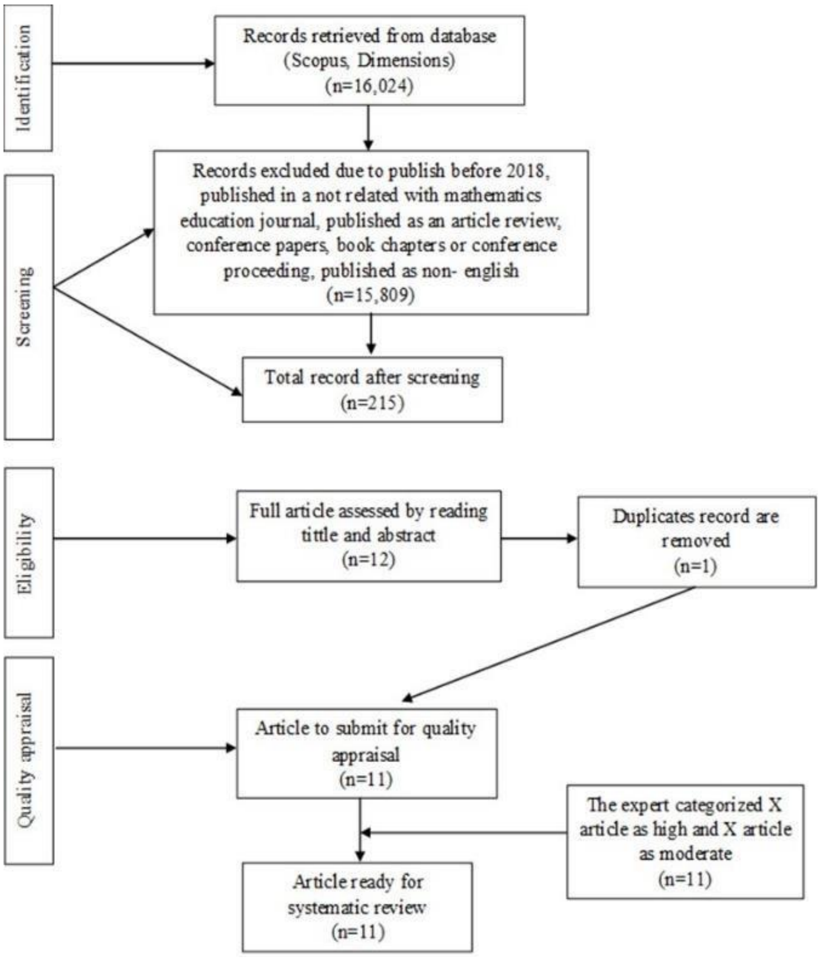

Figure 1. The flow diagram (adapted from (Mohamed Shaffril et al., 2020)*).*

Results
General Characteristics of AR Application
The first research question is addressed in this section. Researchers tested nine different augmented reality applications.

Building tools

Most of the building tools used in the 11 studies reviewed used the existing application. Only two studies were self-developed native applications which used self-programmed device sensors. Seven studies used mobile applications such as SnapShot Bingo, ScholAR, ETNICAR TG 4.0 and Hp Reveal-Zappar. The rest three studies did not specify the mobile application used. Another three studies used GeoGebra. Lastly, one study applied Geometer's Sketchpad.

Application type

The review of the literature highlights three categories of educational applications: (a) exploration applications (four applications), which in turn were divided into the augmented book (one application) and visualization (three studies); (b) simulation tools (six studies); and (c) games (one application).

Research Design Employed

This section addresses the second research question. It presents the research settings and methods used in the studies reviewed (see Table 3).

Out of the 11 articles reviewed from 2018 to 2022, most studies (8 articles) were published in 2021 and 2022. Most of the study participants were middle school students (7 articles). Three articles involved primary school students; only one included upper school students. Six articles were conducted using a quantitative approach. The remaining articles consisted of one article using a qualitative approach, and four were conducted in both qualitative and quantitative approaches.articles in-volved primary school students; only one included upper school students. Six articles were con-ducted using a quantitative approach. The remaining articles consisted of one article using a qualitative approach, and four were conducted in both qualitative and quantitative approaches.

In terms of the augmented reality used in the study, most of the studies (7 articles) used mobile applications, three used GeoGebra, and one used Geometer's Sketchpad.

Table 3
Research design

Author (s) (Year)	School	Research Approach
(Fabian et al., 2018)	Primary	Mixed method
(Fabian & Topping, 2019)	Primary	Mixed method
(Sarkar et al., 2020)	Secondary	Quantitative
(Elsayed & Al-Najrani, 2021)	Secondary	Quantitative
(Wong & Wong, 2021)	Secondary	Quantitative
(Bhagat et al., 2021)	Secondary	Quantitative
(Cuevas & Paymalan, 2021)	Secondary	Quantitative
(Kamid et al., 2022)	Primary	Mixed method
(Ertem Akbas & Alan, 2022)	Secondary	Qualitative
(Uwurukundo et al., 2022)	Secondary	Qualitative
(Yaniawati, 2022)	Secondary	Mixed method

Learning Outcomes

This section addresses the third research question. It presents the results measured in the study (see Table 4).

In addition to the extrapolated results of this study, a configuration analysis of the 11 articles was conducted. Demonstrating the success of AR learning and providing further insight into student motivation and self-efficacy in geometry instruction will provide a deeper understanding than the data reported in the systematic review. Table 4 lists the selected studies organized by factors of interest and self-efficacy.

Table 4
Classification of interest and self-efficacy

Author (s) (Year)	Interest	Self-efficacy
(Fabian et al., 2018)	/	
(Fabian & Topping, 2019)	/	
(Sarkar et al., 2020)	/	/
(Elsayed & Al-Najrani, 2021)	/	
(Wong & Wong, 2021)	/	/
(Bhagat et al., 2021)	/	
(Cuevas & Paymalan, 2021)	/	
(Kamid et al., 2022)	/	
(Ertem Akbas & Alan, 2022)		/
(Uwurukundo et al., 2022)		/
(Yaniawati, 2022)	/	

Discussions
Design of Augmented Reality Applications

The results show that the reviewed AR-based learning applications concern most geometry topics, namely 2D, 3D, symmetry, lines and angles, circles and volumes. Most of the interventions were implemented during in-class geometry instruction, and one intervention was successfully implemented outside of class. It would be interesting to see more studies incorporating AR technology inside and outside the classroom to make learning more active with AR learning tools (Saundarajan et al., 2020). Here is a proposal that illustrates how AR applications can be designed for geometry education.

Firstly, AR applications for education should be designed to deliver a multimodal learning experience. This entails the integration of various sensory inputs, including visual, auditory, and tactile elements, to fully engage students (Liarokapis et al., 2017). In terms of geometry, this integration can include the use of haptic technology to provide interactive audio explanations and tactile feedback in addition to the 3D visualisation of geometric shapes. Previous studies showed that integrating AR into geometry teaching may contribute to increased student engagement and a more positive and engaging learning environment (Hwa, 2018). This approach is in line with the changing nature of education, as increasingly modern learning environments demand the use of traditional instructional methods such as multimedia presentations, video, and 3D models (Fadil & Wahid, 2021).

Here's an example of how an augmented reality application designed for geometry teaching may provide a multimodal learning environment: Through the help of the AR application's visual element, students can view 3D depictions of geometrical shapes on their mobile screens such as enabling the examination of transformations like translations, rotations, and reflections for greater conceptual understanding. To accommodate a variety of learning methods, students can turn on an audio option that provides voiceover explanations of mathematical concepts linked to specific transformations for further depth. Furthermore, the application promotes interaction by helping students create 3D models of themselves using touch gestures and providing instant feedback on the final shape and angle measurements. In the end, teachers can monitor students' performance through an integrated dashboard, helping to spot students who might require extra support or advanced challenges based on their application performance.

In line with the ideas discussed in the paragraph, the AR application provides this multimodal learning experience to enhance students' understanding of geometric learning through auditory, visual, and personalised learning (Vandewaetere et al., 2011). This method makes geometry instruction more interactive and effective in the contemporary classroom by going beyond traditional teaching strategies and multimedia presentations.

Second, adaptive learning algorithms—a concept that has gained popularity in modern educational technology—can significantly enhance the design of AR apps. According to Yang et al (2013), these algorithms can track and assess each student's development individually in real-time, allowing for a personalised learning experience suited to their particular needs. When it comes to teaching geometry, this flexible method can be very helpful. An augmented reality (AR)-based geometry learning tool, for instance, can track each student's progress as they solve a set of geometry problems.

There are multiple methods to employ the adaptive learning algorithms; (i) Adjusting Problem Complexity: The AR application can evaluate a student's performance on basic geometry problems. Once a learner develops a solid understanding of basic concepts, the algorithm can pass them on to more challenging geometry problems. On the contrary, if a student finds it tough to understand an issue, the algorithm can offer more resources or easier challenges. (ii) Individualized Learning Paths: By employing adaptive learning algorithms, each student can have a personalised learning path. For example, a student who excels in 2D geometry but weakens with 3D geometry may get a curriculum that lays a higher emphasis on 3D concepts while reviewing the basics, as necessary. (iii) Personalized Feedback: A student's responses and actions in the AR environment can be used by the application to generate individualised feedback. For example, the algorithm can provide specific suggestions or mini lessons to enhance knowledge if a student repeatedly has problems with calculating angles in triangles.

In summary, the integration of adaptive learning algorithms into AR applications for geometry education can lead to a more individualized and effective learning experience (Vandewaetere et al., 2011). These programmes can improve understanding and involvement while improving the learning process by customising information, feedback, and learning routes to each student's specific needs and progress.

Finally, AR apps in the classroom need to be able to provide a dynamic and attractive learning environment. Accordingly, AR apps should motivate students to actively engage in geometry lessons (Wojciechowski & Cellary, 2013). For example, students may work together with peers in collaborative AR environments to solve geometry problems, or they could manipulate virtual geometric objects or solve problems in AR.

Students' engagement with geometric concepts is transformed by active learning with augmented reality (Kidd & Crompton, 2016). The capability to manipulate geometric things remotely is one of its greatest abilities. Through AR, students may engage with three-dimensional geometric shapes, providing them with a visual knowledge of topics like rotation, scaling, and manipulation. They can examine the different faces, edges, and vertices of a virtual cube, for example, to gain a better understanding of geometry. Furthermore, by providing geometry puzzles and problems in an interactive style, AR includes a gamification component. Equipped with AR gadgets, such as tablets or smartphones, students embarked on missions to find hidden geometric shapes in their environment or solve geometry-related puzzles, adding a playful and engaging element to the learning process. Beyond this, AR takes students to fully immersive virtual worlds that are closely related to geometry. Students can take virtual tours of historical structures like the Parthenon and the Pyramids to learn firsthand about the geometric ideas that underpin these famous buildings. Thus, AR contributes new dimensions to geometry instruction, making it dynamic, engaging, and memorable.

Geometry education has exciting new opportunities through collaborative learning in augmented reality (Gargrish, 2021). The development of shared AR environments, which enable student participation regardless of geographical location, is one noteworthy advantage. With the help of these shared spaces, students can digitally connect, overcome geographical barriers, and work together on group projects including geometry. For example, students can collaborate across classes to create a virtual metropolis using geometric principles applied to urban planning. Moreover, AR enables students to communicate with one another in real-time in these virtual worlds (Yang et al., 2013). They may compare solutions, talk about challenging geometric concepts, and discover information from each other's perspectives because of their direct interaction. Peer-to-peer learning likewise helps students discover geometry more effectively, but it also develops critical communication and teamwork skills, giving them crucial life skills outside of the classroom. When combined, these cooperative AR elements enhance the educational process and equip students for a world where digital cooperation and teamwork are becoming more important. with one another in real time in these virtual worlds (Yang et al., 2013). They may compare solutions, talk about challenge geometric concepts, and discover information from each other's perspectives because of their direct interaction. Peer-to-peer learning likewise helps students discovered geometry more effectively, but it also develops critical communication and teamwork skills, giving them crucial life skills outside of the classroom. When combined, these cooperative AR elements enhance the educational process and equip students for a world in which digital cooperation and teamwork are becoming more and more important abilities.

In conclusion, encouraging interaction and participation, including augmented reality (AR) in geometry education has many benefits. It transforms learning from being passive to becoming dynamic and active, allowing students to solve problems, interact with classmates, and manipulate virtual things. This improves their comprehension of geometry and increases learning motivation, and inclusivity for a wide range of students. The promise of AR in education to transform our understanding of geometric concepts is still going strong as technology develops.

In summary, engagement, interactivity, adaptability, and real-world relevance should be given top priority in the creation of augmented reality applications for geometry learning. AR applications can enhance the geometry learning experience by considering these aspects and making them accessible and enjoyable for students at all education levels. Furthermore, further advancement of AR technology could transform geometry education in the 21st century.

Measures of Student Outcomes

In conclusion, most of the research that has been done on augmented reality (AR) in education has employed a quantitative approach. Five studies, Sarkar et al (2020); Elsayed & Al-Najrani (2021); Bhagat et al (2021); Sides & Cuevas (2020); Uwurukundo et al (2022) have shown positive results in terms of encouraging students' motivation and positive attitude towards learning geometry. These results point to a positive trend regarding the incorporation of AR technologies into educational environments.

A study Wong & Wong (2021) showed that motivationally adaptable learning did not significantly increase students' motivation towards mathematics, which is an important minority finding in literature. The contradiction highlights the need for nuanced considerations in applying motivational approaches within educational contexts, suggesting that a more comprehensive approach is required, considering many factors affecting student motivation.

The qualitative research included in this study, in addition to most quantitative studies, offered insightful information about respondents' views and a comprehensive grasp of learning processes. The mixed-method research highlighted the complementary significance of qualitative data in enhancing the overall analysis and interpretation of findings, even though it frequently focused on the quantitative side (Östlund et al., 2011).

Most of the reviewed studies' emphasis on secondary education highlights gaps in the literature on the use of AR technology to teach geometry in primary schools (Galton & Morrison, 2000; Jindal-Snape & Miller, 2008). Exploring the incorporation of AR in elementary geometry education becomes an exciting topic for future research, given the significant transition from primary to secondary school and the fears connected with it for students. Using AR technology with characteristics that promote knowledge-sharing and differentiated roles to enhance cooperative teaching processes in elementary schools may be advantageous.

It is crucial to comprehend and improve the motivation of elementary school pupils to learn geometry for several significant reasons. Primarily, studies in this field focus on a crucial developmental phase identified by the change from primary to secondary education (Galton & Morrison, 2000). Students' readiness and confidence as they go to higher school levels are influenced by the basic knowledge and attitudes about geometry they gain throughout these formative years (Jindal-Snape & Miller, 2008). Examining the incorporation of AR technology in primary education is crucial as it can develop positive beliefs and incentives that may have enduring consequences on a student's academic progression.

In addition, primary school students often feel more anxiety caused by the change in schoolwork (Jindal-Snape & Foggie, 2008). Geometry can be difficult due to its abstract ideas and need for spatial reasoning. Since AR technology creates an immersive and dynamic learning environment, it may help decrease these anxieties. Teachers can create a more enjoyable and interactive classroom and help students develop a positive attitude towards mathematical concepts from the start by implementing AR into geometry instruction at the primary school level (Jesionkowska & Wild, 2020).

When combined with AR technology, cooperative learning provides opportunities for geometry teaching that should be explored further (Lima et al., 2022). The precise application of cooperative learning in the context of geometry is still largely unexplored in the body of research that is now available, despite its demonstrated effectiveness in a variety of areas. According to Kidd & Crompton (2016), incorporating AR into cooperative learning environments for geometry has the potential to completely transform how students interact with and understand geometric concepts.

The benefits for student learning are clear when one considers research like Mariyana's (2020) investigation of think-pair-share in the context of growing vegetables with AR technology. A way to apply this result to teaching geometry would be to have students solve problems collaboratively while sharing an AR area to comprehend geometric concepts. This method improves spatial comprehension and geometric visualization, by employing AR's immersive and visual characteristics along with the advantages of cooperative learning.

Moreover, the study conducted by Lin & Chen (2020) employs a questionnaire to emphasise the positive effects of cooperative learning experiences on students' confidence and satisfaction. This study offers a strong justification for implementing comparable geometry instruction approaches. With the use of AR technology, students may collaborate to solve geometric problems and better understand geometry's intrinsically abstract and visual character. This cooperative approach might improve critical thinking abilities, provide a more positive learning atmosphere, and advance a deeper comprehension of geometric concepts.

Fundamentally, studies exploring the combination of AR technology with cooperative learning in geometry education have the potential to not only tackle the difficulties related to abstract spatial thinking but also to foster critical cooperation and problem-solving abilities. Understanding how cooperative learning approaches, enhanced by AR, can be successfully used in geometry classrooms becomes a vital avenue for improving the quality and efficacy of mathematics education as we work to reinvent teaching methodologies.

The present status of research on AR in geometry teaching indicates both opportunities and difficulties. Although research using quantitative methods points to positive results, conflicting results highlight the need for an advanced approach to motivational strategies. Furthermore, studies that are primarily concerned with secondary education hint at an area that needs more research in basic education. The emphasis on design concerns points to a direction for future research and development, and the potential of AR technology in cooperative learning for geometry instruction demands more study.

Evaluation of Interventions

An important and fascinating area of study in education is how students' motivation and self-efficacy affect their performance in geometry. Understanding the complex relationships between motivation, student interest, and self-efficacy and how they affect task engagement and performance is crucial for anyone involved in educational psychology. According to Kinnari-korpela (2019), motivation is best described as a dynamic pair consisting of the "want" and "can" aspects. These factors have a substantial impact on a student's likelihood of engaging with a task, completing it successfully, and achieving performance results later on.

A common thread that runs throughout the entire body of research is how important student motivation and self-efficacy are in determining how well they learn geometry. Most of the research explored has produced solid proof indicating that these two elements significantly impact students' performance in geometry. The use of AR technology in textbooks suggests that interest is a powerful motivator for improving students' comprehension of geometry (Yaniawati, 2022). It has been demonstrated that the use of AR enhances the learning process by giving students a more practical and interesting way to approach abstract geometric topics.

Additionally, as studied by Kamid et al (2022), the gamification of learning through augmented reality has increased students' interest in geometry and established a strong correlation between this increased interest and the development of critical process skills required for mastering geometry. These results highlight the potential of creative teaching strategies that use technology to encourage student's interest in and participation in geometry.

It is important to remember that different studies produce different outcomes. A more detailed perspective was presented by Wong & Wong (2021), who proposed that although curiosity and self-efficacy are positively connected with geometry performance, this relationship may not be as strong as previously believed. This disparity casts doubt on the idea of a one-size-fits-all method for figuring out how curiosity and self-efficacy affect geometry learning by pointing to other moderating variables that need more investigation.

As mentioned by Patrick et al (2011), interest and self-efficacy are widely recognised as critical variables in determining student learning performance. However, there is still a lack of study on these dynamics, with most studies concentrating on performance as a function of interest and self-efficacy. Such a one-sided viewpoint ignores the complex, two-way connection among these variables. According to Hidi & Renninger's (2006) theory, self-efficacy and interest may have a mutually reinforcing relationship, with performance acting as a partly mediating factor. This suggests that future research efforts should take a more comprehensive approach, considering not just how curiosity and self-efficacy affect performance but also how performance affects these motivating components.as a partly mediating factor. This suggests that future research efforts should take a more comprehensive approach, taking into account not just how curiosity and self-efficacy affect performance but also how performance affects these motivating components in turn.

It is clear from examining the bigger picture that curiosity and self-efficacy have effects that go beyond how well a task is completed immediately. Interest and self-efficacy results can influence students' future goals and choices on how much more to interact with the material in the future, as well as how well they perform overall. This idea is in line with research by Raedts et al (2007) which emphasises how students' motivation to return to task materials and eventually affect their performance trajectory can be influenced by curiosity and self-efficacy.

However, it is important to highlight that, in this area of research, curiosity has received a lot of attention, whereas self-efficacy has received less attention overall, with a few notable exceptions like the work of (Kosovich et al., 2017). To achieve a more thorough comprehension of the dynamics involved, future studies must find a balance by investigating the impact of interest and self-efficacy at the same time, identifying any interactions between them, and examining how they interact with geometry performance. To put it simply, understanding the complex relationships between student interest and self-efficacy and how they affect geometry learning and performance requires a comprehensive and integrative approach.

Conclusions

Although this study does not claim to be exhaustive, it provides an overview of the current state of the art in augmented reality as a promising technology to support geometry learning. It contains crucial discoveries that may be useful for instructional design and research.

The first research question aimed to identify the typical characteristics and specific design features of AR-based learning applications for geometry-AR studies. In this regard, three categories of AR-based learning applications for geometry learning emerged from the literature: exploration, which in turn was divided into augmented book and visualization, simulation, and game-based applications.

The second research question was formulated to examine the research design employed in geometry-AR studies. In this regard, it was found that some studies employed simple strategies based on information consumption, others were committed to the constructivist instructional strategy based mostly on simulations, and a limited number included learner cooperation. Therefore, researchers might have cooperative instructional strategies that support group interaction, interdependence among group members, and individual accountability.

Finally, the third research question examined the primary learning outcomes measured by geometry-AR studies. In this regard, it was found that the studies measured affective and cognitive outcomes. Some reviewed studies give novel insights into how learning experiences occur in geometry learning environments using AR technology. However, they provide an essential synthesis necessary to understand AR technology's affordances and barriers to geometry learning. Hence, researchers need to measure deeper comprehension beyond retaining information and substance.

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Conflicts of Interest

The authors declare no conflict of interest.

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