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FACTORS SHAPE THE SUCCESS OF IMPLEMENTING AR MODELS FOR STEM LEARNING

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ABSTRACT

Research on AR in STEM education requires information about AR models and their impact on student learning. In higher education, many studies have been conducted on the use of AR in STEM education to determine its impact on student learning. However, there is a knowledge gap and little research on the application of AR-STEM education in middle schools. Furthermore, the impact of AR-STEM education on student learning has not been studied. To address the knowledge gap, this article reviewed 42 articles in the Methods and Meta-Analyses Reference Manual – Assessment (PRISMA) using a new systematic literature review (SLR). Research on student learning outcomes in STEM education typically includes six categories of variables that influence learning outcomes (e.g., cognitive knowledge, understanding of STEM material, technology usability, knowledge synthesis ability, visualization of virtual objects). However, this study will only produce three variables including use of technology, synthesis ability and cognitive ability. The contribution of this research helps professionals and teachers to provide student learning experiences through the AR platform environment.

Keywords: *Student Learning Outcomes; AR For STEM Learning; STEM Learning; PRISM; Systematic Review*

1. INTRODUCTION

In the 21st century educational context, STEM education is ubiquitous. After the COVID-19 outbreak in December 2019, distance education in STEM subjects has become an urgent need for all universities when face-to-face meetings are not possible. It can be seen that STEM education has become an important choice for most higher education projects based on the country's educational goals in the field of international education.

Student cognitive knowledge is an important part of STEM education [1]. This knowledge is also represents students' ability to participate in school activities and have the opportunity to develop a good STEM achievement result [2]. Students who participate in STEM education will have better understanding and achieve better learning outcomes [3]. Over the years, scholars have proposed various types and characteristics of students' learning outcomes related to their cognitive knowledge [4,5].

An important study on learning outcomes was conducted by Alexiou and Schippers [6], who proposed the concept of learning outcomes, which includes five elements: (i) position, (ii) intelligence, (iii) coordination, (iv) personality and (v)) emotion. However, the framework for the emergence of this knowledge has not been studied in detail.

In addition, students in STEM distance learning often face STEM education problems such as disobedience and low motivation [7]. This is relevant to the study goal, especially for analyzing the important factors improving student learning results.

In detail, there are several indicators of STEM learning which required to be analyzed in-depth. After Covid-19 outbreak, authorities have mandated changes in the curriculum resulted in a lack of classroom meeting. It has impacted STEM education since it focus is mostly on practice. Furthermore, in STEM programs the practice is expensive. In addition, the limited number of face-to-face classroom also poses high burdens for teachers and students. In fact, most STEM applications are divided into specific disciplines, but the numbers are small and inconsistent. As a result, STEM outcomes and academic achievement will be lower and require more corrections.

AR in STEM has been enabled by technological advances. It allows teachers to connect and interact with students in flexible time. This type of AR is considered a flexible tool for both teachers and students in STEM learning. It also has added benefit to the virtual teaching process.

A deep understanding of STEM materials and designs requires attention to detail and coordination. Teachers should be empowered to identify STEM curricula to support student independent learning for achieving learning outcomes [8].

This research only uses secondary data to analyze what factors shape the success of implementing AR models for STEM learning. This study did not quantitatively analyze these factors.

Other researchers added that the AR-based approach could improve student learning outcomes especially for students to improve their understanding of STEM materials. Therefore, this article aims to conduct a SLR that provides scholars with new information about the impact of the use of AR on students' STEM achievement.

Problem Formulation In Slr Study	Research Purposes
1. (RQ1) From the reviewed papers, what factors shape the success of implementing AR models for STEM learning?	1. To review the factors that shape and influence AR implementation models.
2. (RQ2) From the reviewed papers, which components must be prepared in designing models and prototypes for implementing AR for STEM Learning?	2. To review the design models and prototypes for implementing 3D AR that are suitable for users.
3. (RQ3) From the reviewed papers, how far the performance of the STEM learning AR model can be achieved from the user's perspective?	3. To review which papers represents the testing to of 3D AR models and prototypes to be implemented in STEM learning.

Table 1. The research question formulation of this study.

This research is important to produce AR models that have broad potential to complement STEM learning [9]. However, to produce a viable AR Model, it needs to be designed and tested for effectiveness. This needs to be done to ensure whether the AR model created really has advantages, has benefits, and can be run easily by users.

Apart from that, the AR model that will be developed needs to be adapted to the needs of its users [20]. Thus, the resulting AR model will suit the needs of its users and can support the STEM learning process. Referring to the obstacles and challenges in developing AR models, appropriate efforts or strategies are needed so that the use of AR technology can run effectively [21]. AR technology development must continue to be carried out so that AR technology can continue to be developed so that it is easy for teachers and students to use for chemistry learning.

2. RESEARCH METHOD

This research method uses meta-analysis, which is one way to synthesize results statistically (quantitative techniques) and/or narratively (qualitative techniques). This technique is useful for expressing a general idea about a particular topic and is also useful for understanding new concepts.

This study used PRISMA approach. PRISMA recommends guidelines for conducting a comprehensive literature search by identifying relevant studies through (1) inclusion/exclusion, (2) using a search strategy, (3) reviewing and collecting diverse studies, (4) interpreting and evaluating included studies. The researchers used the PRISMA to review research objectives and (5) identify and assess learning outcomes.

3.1. Criteria of Inclusion and Exclusion

This study uses specific criteria of inclusion and exclusion to identify main topic of the reviewed articles in the sources based on emerging questions. Table 2 describes the inclusion and exclusion criteria for this SLR study.

Table 2: Inclusion and exclusion criteria.

Inclusion	Exclusion
The studies has empirical evidence	The studies has review analysis
The studies is written in English	The studies is non-English publication
The studies discuss mainly the usage of AR for STEM	The studies has publication years in range of 2019 to

learning purposes	2023
The studies focused on the student learning outcomes in STEM education	The studies are not related to the education purposes.

Regarding the exclusion criteria, no controversial studies were included in this review as the studies used must be taken into account. Non-English studies were also excluded because we focus on the student learning outcomes in STEM education from global perspectives. Furthermore, we did not include studies on secondary schools as they were outside the scope of this study, for example secondary schools. The literature search and literature overview are presented in the following table.

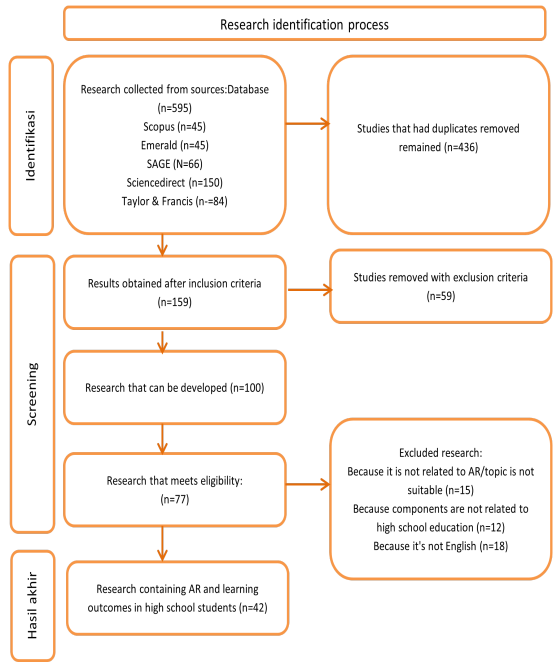
3.2. Literary Search

Many databases are explored in our SLR such as Emerald, SAGE, Scopus, Science Direct Journal, Taylor & Francis. The databases are used since they cover many publication and scopes. Of the total 595 papers which found in the database, we select unique research topic by the definition of a Boolean operators for their keywords.

The use of keywords and search terms ensured that only relevant topics were included in this literature review. In the first phase of this study, the terms "student learning outcomes," "review of STEM education," and "STEM learning" were used as the search keywords. This results in a database search for (TITLE-ABS-KEY ("Student Learning Outcomes") and TITLE-ABS-KEY ("STEM Learning") and TITLE-ABS-KEY ("AR for STEM Learning"). A total of 595 articles about the performance of STEM students in AR for education were found.

Researchers then extract logs from the data for further analysis. After content comparison, 436 similar articles were identified and these overlapping articles were deleted, reducing the number of articles to be reviewed to 159. After reviewing the articles, 59 articles were removed because they were not relevant to the study, further reducing the number of articles to be reviewed. The quantity is collected to 100 papers. A total of 23 papers were not analyzed because incomplete text pages. For further analysis, the remaining 77 articles were downloaded.

A review based on the criteria excluded 15 articles due to limitations, 12 of which were unknown or lack of empirical explanation, and 8 of which were removed due to irrelevant content. It left the 42 articles which included in the final reviewed studies. Figure 1 illustrates the research process based on the PRISMA guidelines



3.2. Quality Rating

In the article selection process, a scoring system is carried out. The assessment of this article was used to determine the inclusion and exclusion criteria. Table 3 is the assessment criteria based on the nine criteria identified to assess the quality of the 42 selected studies.

Table 3. Assessment Criteria

No	Questions
1	Clear research objectives
2	Research design objectives
3	Clear variable discussion
4	Clarity of the research steps
5	Clarity of data collection method
6	Reliability and validity measures are clear
7	Clear statistical discussion
8	Clarity of discussion and results
9	Impact on your research

The journal that has been selected will be assessed based on the 9 items above. Each question on the assessment checklist (as in Table 4) is scored according to a three-point scale (Yes = 1 point, Some = 0.5 points, No = 0 points). The selected study will be given a score from 0 to 9, with the higher the percentage of the journal, the higher the usefulness of the journal to the researcher.

Table 4. Quality Assessment Results

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No	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total	Percentage
1	1	1	1	1	0,5	1	1	0,5	1	8	89%
2	1	1	1	1	1	1	0,5	1	1	8,5	94%
3	1	1	1	1	1	1	1	1	0,5	8,5	94%
4	1	1	1	1	1	1	1	1	1	9	100%
5	1	1	1	1	0,5	1	1	0	1	7,5	83%
6	1	1	1	1	1	0,5	1	1	0,5	8	89%
7	1	1	1	1	1	1	1	1	1	9	100%
8	1	1	1	1	1	1	0,5	0,5	1	8	89%
9	1	1	1	1	1	1	1	1	1	9	100%
10	1	1	1	1	1	1	1	0,5	0,5	8	89%
11	1	1	1	1	1	0,5	1	0,5	1	8	89%
12	1	1	1	1	1	1	1	1	1	9	100%
13	1	1	1	1	1	1	1	0,5	1	8,5	94%
14	1	1	1	1	1	1	1	0,5	1	8,5	94%
15	1	1	1	1	1	1	1	1	1	9	100%
16	1	1	1	1	1	1	1	1	0,5	8,5	94%
17	1	1	1	1	1	1	0,5	1	1	8,5	94%
18	1	1	1	1	1	1	1	0,5	0,5	8	89%
19	1	1	1	1	1	1	1	0	1	8	89%
20	1	1	1	1	1	0,5	1	1	1	8,5	94%
21	1	1	1	1	1	1	1	1	1	9	100%
22	1	1	1	1	0,5	1	1	0,5	1	8	89%
23	1	1	1	1	1	0,5	1	1	1	8,5	94%
24	1	1	1	1	1	1	1	1	1	9	100%
25	1	1	1	0,5	1	1	1	0,5	1	8	89%
26	1	1	1	1	1	1	1	0,5	1	8,5	94%
27	1	1	1	1	1	1	1	1	1	9	100%
28	1	1	1	1	1	1	1	1	1	9	100%
29	1	1	1	1	0,5	1	1	0,5	0,5	7,5	83%
30	1	1	1	1	1	1	1	0,5	1	8,5	94%
31	1	1	1	1	1	1	1	1	0,5	8,5	94%
32	1	1	1	1	1	0,5	0,5	0,5	1	7,5	83%
33	1	1	1	1	1	1	1	0,5	0,5	8	89%
34	1	1	1	1	1	1	1	0,5	1	8,5	94%
35	1	1	1	1	1	1	1	0,5	1	8,5	94%
36	1	1	1	1	1	1	1	1	1	9	100%
37	1	1	1	1	0,5	1	1	0	1	7,5	83%
38	1	1	1	1	1	1	0,5	1	1	8,5	94%
39	1	1	1	1	1	1	1	1	0,5	8,5	94%
40	1	1	1	1	0,5	1	1	0,5	1	8	89%
41	1	1	1	1	1	1	1	0,5	0,5	8	89%
42	1	1	1	1	1	0,5	1	0,5	1	8	89%

From the quality assessment carried out on the 42 selected studies, it was found that all studies were above 60% so they were declared to have passed the quality assessment. 42% of studies scored 100%, 33.3% of studies scored 94%, while 40.47% of studies scored 80-89%. The following section presents an in-depth analysis of the data collected from 42 selected studies.

3. RESULTS AND DISCUSSION

These 42 articles were identified through review and included criteria as recommended by PRISMA approach to answer the research questions (see Supplementary Material). The analysis results shows that the purpose of this article is fulfilled to identify trends in STEM education and student outcomes in using AR for STEM education.

4.1. Year of Publication

Based on the released year of publication, this study examines the adoption of AR in STEM education over the past five years, starting in 2019. After review process, this study found that using AR for STEM education can improve the student learning outcomes. In addition, it also found some empirical studies from the reviewed papers about the impact of using AR in STEM Education and student learning outcomes. However, the empirical studies of AR for game in secondary schools is still rare [7]. Figure 5 shows the publication year and the number of selected articles for this SLR article.

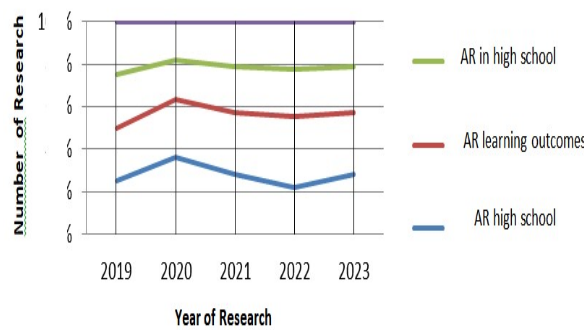

Figure 5. Year of publication.

Figure 5 visualizes the number of articles by publication year taken for this study between 2019 and 2023. Since the publication years in 2019 and 2020, AR is just beginning to take hold in STEM education research mainstream. However, the number of publications increased in 2019 due to changes in STEM education technology, possibly due to the use of AR in higher education. In 2019, research on the use of AR in STEM education and student performance in STEM education reached an all-time high.

This growth comes amid the global impact of COVID-19 and an almost complete shift in teaching and learning around the world to STEM education. As reported by Yegorina et al. (2021) STEM learning using AR have been popular in the next years as they offer many benefits, such as the opportunity for teachers to evaluate and create teaching materials that meet global education standards. From the review results, the researchers also propose the benefits AR as solutions to STEM education problems and evaluate the impact of AR on improving student learning outcomes.

4.2. Geographic Location

The reviewed papers comes from 15 countries representing the main topic of the AR as a tool to support student learning content, STEM education and platform to assess student learning outcomes. However, it raises many questions about student outcomes in STEM education, especially in simplified platform such as mobile android platform. There are lack of research to understand the mechanism of mobile android platform and its role to enable students and teachers in STEM learning. The review result shows that many

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scholars have utilized research methods and teaching tools across a variety of models and populations to improve teaching quality and learning outcomes for STEM students. Figure 3 shows the geographical distribution of the reviewed papers.

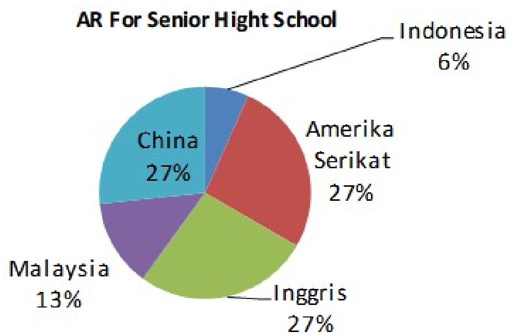

Figure 6. Geographical area distribution.

4.3. Methodology used in the reviewed papers

Depending on the elements included, the two main methods found from the reviewed papers are (i) qualitative and (ii) quantitative methods. Most of them are made using different methods except (Afacan, 2016)which uses a qualitative method. The following pie chart (Figure 7) provides a graphical representation of the types used in the text.

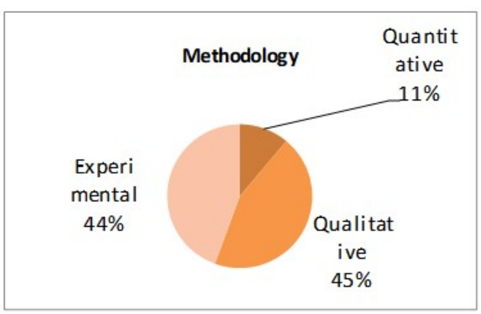

Figure 7. Research methodology methods found from the reviewed papers

The quantitative approach is used because the research in AR STEM education often requires data analysis. However, a qualitative approach is also useful because it can provide a general overview of how students understand AR in STEM education.

5. RESULTS

5.1. RQ1 from the reviewed papers, what factors shape the success of implementing AR models for STEM learning?

In this study, it is important to identify the factors that influence the use of AR for STEM education. According to DeCoito and Briona [10], the concept of educational outcomes should include (i) learning, (ii) cognitive, (iii) behavioral, (iv) collaborative, and (v) emotional learning outcomes. Therefore, the included studies were divided according to the type of learning students received, as shown in Table 3.

Table 3. Factors that influence student learning outcomes in STEM learning

Success factors for implementing AR	Total
Cognitive Ability	3
Collaborative Behavior	2
Emotional Condition	2
Cognitive, emotional and collaborative behavior abilities	3
Cognitive abilities, and behavior	5
Collaborative behavior and emotional states	5
Number of articles	6
Success factors for implementing AR	26

All aspects of student learning process are important in improving learning outcomes. For example, the study by Afacan et al. [9] identified three themes that emerged from academic learning outcomes and interactions with classroom peers. Student learning outcomes is determined by time spent on work, time in lectures, time in short discussions, time critiquing presentations, time in interactive lectures, and many other topics. Intelligence and critical thinking are critical to STEM education. Nortvig et al. [11] stated that learning requires feedback and discussions with peers and teachers to promote knowledge outcomes. STEM learning classroom help students succeed and improve academic performance. DeCoito and Briona's [10] study confirmed that information sharing features on STEM education platforms influence student learning. The students' collaborative activities, such as interactive sessions, often require students to work in groups and build a sense of community. This activity allows students to collaborate and participate in STEM education, for example by sharing information with teachers. On the other hand, they increase the feeling of ownership and participation in STEM education process and thereby improve student learning outcomes [12]. In other words, through effective engagement, teachers gains insight about their student learning progress and how the students get benefits of learning using AR for STEM education.

Most of the reviewed papers with topic of STEM education have data which collected from student activities. The more students access the AR platform, the higher level of participation in learning process. Additionally, it is important for students to ensure that their thinking and behavior are linked. Students who are capable of stabilizing their emotion and behavior will have better imagination and finally successful in STEM education [13]. In addition, students who are able to maintain a positive mindset and attitude throughout their STEM studies will achieve better academic results than those who are unable to maintain the same emotional balance. Previous research on student learning outcomes provides teachers with knowledge to help the students especially for improving their interest in learning. This role become more important when the student learn the STEM remotely.

Scholars reported that the students lack of platform to support the remote learning [8]. However, providing remote platform with adequate features are not easy to be designed. The platform must support the learning outcomes, thinking content, knowledge content and behavioral content [14]. Different learning outcomes have confused teachers to solve students' problems from different perspectives. According to the research, teachers need the platform to take immediate action to help students understand the STEM content and learning outcomes.

As DeCoito and Briona et al. [10] shows, that a good AR platform must encompasses the five learning styles of students. The scholars DeCoito and Briona et al. [10] also proposed that the AR platform must support the student's characteristics, eg, (1) personality and interests and (2) intelligence and personality. According to Osuna et al. [15], the education experts becoming aware of the adequate AR platform to support their student learning outcomes. However, the publication about integrating AR platform with the goal of learning outcomes are still rare. Therefore, it is important to help educators to find better ways to promote students' STEM learning by proposing AR platform for STEM education.

5.2. RQ2 From the reviewed papers, which components must be prepared in designing models and prototypes for implementing AR for STEM Learning?

The reviewed papers proposed some characteristic of good AR platform for STEM education. The AR platform for STEM education must support teaching and learning materials [16]. The concept has been proposed by scholars [17]. They proposed an AR model for STEM education, including the AR platform with the main goal of fulfilling the educational content to support student learning.

There are some indicators representing adequate AR quality for STEM learning especially from the features of text, color, object movement, rendering and pixel.

a. A good AR platform for STEM education must have adequate and strong features, eg, text is the right size, font, style and contrasted colors. The platform must contain features to influence and students' knowledge and learning outcomes. Examples of features include making recommendations to help students who need additional help.
b. The AR platform must have colors with appropriate background tone, softer and various colors pixel suitable for the users. Specific colors track student performance on selected activities. It also help students understand lessons and encourage cognitive development. The AR platform also must have features to evaluate the students' assessment of the STEM learning process and contributes to improving the learning results. It also must have features for analyzing and profiling students' use of AR in order to help the students to learn STEM learning materials.
c. The AR should provide running text and virtual object movement of words to affect student learning motivation. the length of the text must be short and, the AR contain a description of the text. The AR must combine text with relevant images to provide adequate explanation about the virtual object for representing the STEM learning material.
d. the AR platform must provide image dynamics representing the movement of the virtual object from 3d perspective by the user to improve the user learning outcomes. This goal is to provide the necessary conditions to guide students in understanding STEM learning materials in an AR learning-based educational environment. The platform must provide students and teachers with feedback features on the effectiveness of the STEM learning evaluation.
e. Object scaling refers to the change in object size during the rendering process, for

example, the moving the rendering software closer to the AR image.

f. The drawings must use original images with a resolution that is clearly visible support the STEM learning. The images are needed to be framed into two pictures per frame. Charts for STEM learning are used as animation to review student activities. This goes beyond traditional research and data collection methods and provides real-time evidence of real-world observations [18]. For example, it can identify learning outcomes, which helps teachers to evaluate the students learning results [19], and more importantly, it can track the student learning progress to determine whether student behavior is improving. In the AR platform, when students participate in STEM education, student learning outcomes must be tracked [20, 21]. This type of AR for STEM education enables a better understanding of student learning outcomes by creating patterns or models that can improve learning outcomes [19]. According to Table 4, half of the reviewed articles use research topic of AR for STEM education and student learning evaluation [19]. The studies shows that the use of AR platform is important in the STEM learning. The use of AR platform has linked to the student academic performance [19]. A study by Titsworth et al. [22] suggested that the accuracy of STEM teaching materials influences students' attitudes. This is consistent with Gbollie et al. [23] which argued that the use of AR platform helped the teachers to set up classes with clear goals and improve the student's reasons for studying STEM courses.

g. The reviewed papers showed that the Lighting or illumination contains the combined pixel with tone colors representing the various virtual objects to create beautiful animation. An adequate AR platform must combine the decorative visual effect with the pixel and tone color representing the virtual objects movement.

5.3. RQ3 From the reviewed papers, how far the performance of the STEM learning AR model can be achieved from the user's perspective?

The reviewed papers showed that the quality of AR platform is indicated by its effectiveness of the AR model from the user side, comments on AR and the frequency of use. The AR platform must support the teaching goal and tracking student success in STEM education The variables associated with learning outcomes and AR platform are Cognitive Knowledge, understanding of STEM learning material, Technology usability, Knowledge synthesis, Visualization of virtual objects and learning interest. Most of the study have including the creation of 3D AR models for the study of STEM learning. However, there is rare research about the combination of the technology use, and cognitive abilities.

Furthermore, among the seven variables discovered during the SLR process, most of study has focused on the best practices and examples for virtual reality/augmented reality systems (VR/AR). For example, based on the research model of Papanastasiou et al. [24], the use and knowledge of which can improve student learning and extend knowledge to the real world. Huang et al. [25] created an unconstrained agent that learns to transfer consciousness such as the DALLE and GPT4. Most of the AR platform is linked to the AI-based agents to understand and create situations in the virtual world.

The reviewed papers also proposed the model development. Some of the papers contains three different variables including where the AR platform are used and the reason to use it. Papanastasiou et al. [37] stated that the reason for choosing the above three changes was to improve the learning outcomes. The research has helped the teachers and students to resolve the problems in STEM learning particularly due to a lack of technology and students' awareness.

Furthermore, previous studies also contributes to a better understanding of the factors influencing the use of AR platforms and their impact on students' abilities. In addition, factors that influence the effectiveness of AR models also have been studied and investigated. Their AR platforms and performance have been evaluated based on user opinions. In addition, their study also shows the connection between the uses of AR platform for chemistry education. A new direction in their research have focused on the intellectual abilities and interests in STEM courses. According to the teaching effect (ease of use, ease of use, interest in learning, interest in learning), In addition, for collecting the reviewed papers, some keywords are implemented, eg, knowledge synthesis, content display, user interaction, ability, skills and attitudes, and self-expression. The main keywords for searching the related papers are: cognitive ability indicators (color, writing, video, animation, text, images, collaboration, collaboration, games)

Name	Category	Dimension	Indicator	Type
Martono et al. [26]	Technology usability	User needs	usefulnes, ease of use, ease of learning, dan satisfaction	Game
Choi, [27]	Technology usability	User needs	Ease of Learning, and Satisfaction	TAR
Yoon, et al [28]	Technology usability	User needs	Technical and cost perception	Mobile applications
Ariansyah et al.[29]	Technology usability	User needs	Displays, maintenance,	AR mobile
Xiao et al. [30]	Technology usability	User experiment	Interaction	AR mobile
Papakostas[31]	Technology usability	User experiment	Participation	AR mobile
del Amo et al. [32]	Synthesis of New Knowledge	Knowled transfer	Display (material display), content, interaction	AR mobile
Looi[33]	Synthesis of New Knowledge	Knowledge development	Abilities, skills and attitudes	AR mobile
İbili et al. [34]	Synthesis of New Knowledge	Knowledge development	attitude and self-efficacy	Game
Elford et al. [35]	Cognitive knowledge	Recall retrieval	Color, writing, video, animation	Simulation
Bursztyn et al. [36]	Cognitive knowledge	Recall retrieval	Text, images, videos	Game
Wang [37]	Cognitive knowledge	Recall retrieval	animation	Simulation
Wen, Y. [38]	Cognitive knowledge	Kolaborasi dan peer interaction	acquisition, sharing, creating artifacts	Game
Huang et al. [39]	Cognitive knowledge	Kolaborasi dan peer interaction	Collaboration ,	Simulation

5.3.1. Variable of Cognitive Knowledge

Cognitive knowledge has been proposed as important variable in AR studies. It is defined as the effort to understand and remember facts, concepts, and principles after studying STEM subjects [40]. These skills are important factors in improving learning outcomes. For example, when student learns STEM Couse materials, they can understand complex concepts because they engaged in cognitive processes [11]. Cognitive knowledge are the final results after the students engaging in learning resources [12]. When students can combine ideas through social interaction, it positively impacts their knowledge and leads to better learning atmosphere [41]. Therefore, it is necessary to create STEM education programs with better learning atmosphere to encourage students. As proposed by previous studies, AR platform can be a tool to realize the benefits of education as they can promote positive thinking in STEM education.

5.3.2. Variable of Technology Usability

Furthermore, technology literacy in STEM learning environments manifests itself in the use of technology as a bridge for interaction between students and colleagues or experts. This technology is an important tool in STEM education and can make cooperative learning effective [[1]. By using appropriate technology, learning activities can be designed to promote interaction between students and teachers, thereby promoting collaborative learning [16]. Activities such as discussion forums promote collaboration in STEM education because students can participate in small groups [42]. These group activities encourage collaboration. Through these group activities, students can learn to collaborate with peers and teachers to achieve better learning outcomes [16]. In addition, activities such as skating and collaborative writing can also promote students' cooperative learning [42]. Regardless of the collaboration, it must be carefully planned and implemented to achieve STEM education goals [11]. Therefore, it is important to identify appropriate activities to help students achieve cooperative learning and enhance their STEM education.

6. DISCUSSION

The aim of this article is to explore the low level of student learning outcomes in STEM education and how AR platform will improve STEM learning outcomes. From a total 42 included articles, 26 were identified as relevant to AR performance, 15 of which were found to be relevant to users/students learning outcomes. From the reviewed papers, there are some research questions and gaps in the article which become main focus here.

There are three variables that can be used to determine the impact of AR platform on student learning outcomes. Therefore, it was interesting to examine effect of AR platform on student learning outcomes. In total, there are some variables impacting student learning outcomes, eg, cognitive

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knowledge, technology usability, knowledge synthesis, and visualization of virtual objects. It is interesting to highlight the importance of the variables in the STEM learning process especially after the students use the AR platform. This concept is supported by Garzón et al. [43] that argued that AR platform enable teachers to motivate students and achieve better learning outcomes because the AR platform meet the student needs.

There are learning perspectives on a variety of topics, including cognitive skills, understanding of STEM materials, cognitive skills, and the use of virtual reality technology. However, these results can be different across gender. For example, Lee et al. [44] found that age and gender impacted differently toward student learning outcomes (knowledge, thinking and reasoning) in STEM education. This was the case of Huang [45] those investigated how time spent in AR affects students' behavior, knowledge, and learning outcomes and ultimately concluded that every student learns differently. They found that students take responsibility for STEM learning on the AR platform and decide how to engage with the STEM learning content.

Additionally, several reviews mention the general potential of AR to overcome cognitive load. However, according to a review by Ibáñez and Delgado-Kloos [42], there is still a lack of conclusive empirical evidence. However, some studies have examined this aspect in more detail [43], but they have not revealed homogeneous findings. For example, Altmeyer et al. (2020) investigated students' direct experiences of basic electrical circuits in laboratory learning.

However, according to the literature review, there are currently no studies that integrate all types of the variables. by integrating all of these variables into a single model, effective measures can be taken to address the educational challenges faced by STEM students. Therefore, more research is needed to integrate and evaluate the learning outcomes and the different types of student’s characteristics in STEM education. In this way, higher learning outcomes can be achieved through AR platform since it has advantages for students and teachers, especially in STEM education.

7. CONCLUSION

Based on the research results, it was found that the factors that influence the success of implementing the AR model for STEM learning include (i) learning outcomes, (ii) cognitive, (iii) behavioral, (iv) collaborative, and (v) emotional learning outcomes. The components that must be prepared in designing AR implementation models and prototypes for STEM learning are mainly text, color, object movement, rendering and pixel features, while the performance of the AR STEM learning model that can be achieved from the user's perspective shows that the AR Platform supports STEM teaching objectives. Variables related to learning outcomes and the AR platform are Cognitive Knowledge, Understanding of STEM learning materials, Use of Technology, Knowledge Synthesis, Visualization of virtual objects and Interest in learning.

Therefore, more research on new model of AR platform and its impact on student learning outcomes is needed to improve the quality of STEM education. In addition, the quality of STEM education can also be improved by adding AR platform combined with other online learning platforms and courses that support STEM education. By combining the features, the benefits of STEM education can be improved to solve the problem of STEM education. The idea of combining all five variables with the features of AR platform into one model of new AR can be challenging. However, such model provides guidance for future researchers in examining the AR model for both students and teachers. Therefore, this idea is worth taking since it provide accurate insights to the content of students' learning outcomes. The model also helping professional and teachers to provide students' learning experiences through AR platform environments.

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