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Augmented Reality in Solar System Learning at Primary School Level in Indonesia: A systematic literature review

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Abstract

A systematic review of the use of AR in learning about the solar system in primary schools in Indonesia was conducted. This review identified 25 articles using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. We examined the tools used to develop AR, the type of AR used, the focus of the research, and the benefits of AR for solar system learning. Our findings show that the most commonly used tool for developing AR is Unity, and the most popular type of AR used is marker-based AR. Most of the research focuses on development and only a few on effectiveness and implementation. The use of AR is known to improve learning outcomes, critical thinking skills, scientific literacy, visual spatial skills and student curiosity. This systematic review provides researchers and educators with avenues for future research.

Keywords: ***Augmented Reality, Solar System, PRISMA***

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A. Introduction

Astronomy is a science that studies the universe and celestial bodies from different angles [1]. Astronomy is considered to be a miniature of the progress of a nation's civilisation [2]. Despite the high interest of students in astronomy in Indonesia, there is no specific astronomy education in the curriculum used in Indonesia [3]. Astronomy is still used as an interface with other subjects such as science, physics and geography [4]. Astronomy is important to be introduced and taught to children because many of the things it involves are very relevant to children's real lives [5]. Primary school students in Indonesia have been slightly introduced to the discussion of astronomy, namely the solar system.

Technological developments have made breakthroughs in various fields, one of which is education [6]. Technological developments provide teachers and students today with unlimited opportunities to learn beyond the confines of the classroom and access the whole world in just a few seconds [7].An example of technological developments in the field of education is the use of Augmented Reality as a learning medium. Augmented Reality (AR) is one of the technologies that can project 2D or 3D objects in the virtual world into the real world in real time [8]. AR can be used with different devices such as smartphones, tablets, laptops or computers [9]. By combining real environments with digital information, augmented reality is able to develop new learning environments and experiences and enhance active and collaborative learning processes [10]. The use of AR in education is increasing because it has opened up new possibilities in the teaching and learning process [11]. AR enables learners to visualise complex spatial relationships and abstract concepts [12].

In the last decade, several articles have been published discussing the use of AR in education. Therefore, it is important to review, analyse and classify the existing research related to solar system learning through AR. This paper presents a systematic review of studies investigating the use of AR in solar system learning. This systematic review examines research trends and identifies similar themes, frameworks and research samples. To guide the research, the following research questions (RQs) were developed:

1. What are the most popular tools for developing AR in dataset learning in primary schools?
2. What are the most popular types of AR developed for solar system learning in primary schools?

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3. What is the focus of research on AR in solar system learning in primary schools (application, development and effectiveness)?
4. What are the benefits of using AR in solar system learning in primary schools?

B. Methods

The method used in this research is a systematic review of the literature. A systematic literature review can help with several aspects of the research process, such as setting the context and delimiting the research problem, finding theoretical support, rationalising problems and exploring new areas, distinguishing what has been done from what needs to be done, identifying key findings (and methods used in previous studies) and avoiding wasted research [13]. The systematic review in this study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The aim was to analyse the content of the selected articles to answer the research questions. The PRISMA flow chart is shown in Figure 1. The database used was Google Scholar. The articles selected for review had the following criteria:

1. Discusses AR in primary school solar system learning published for the last five years, from 2019-2023.
2. In Indonesian and English.
3. Journal article or seminar proceedings
4. Indexed by Sinta or Scopus
5. Having a complete manuscript

To ensure the scientific integrity of our research, we excluded from our analysis sources such as books, book reviews, journals, brief surveys, brief communications, correspondence, newsletters, discussions, product reviews, editorials, publishers' notes, erratums and theses (25 articles in total). We then undertook a thematic analysis of the remaining articles to identify themes related to our research patterns and trends. The results of this analysis were grouped into four main themes necessary to answer our research questions.

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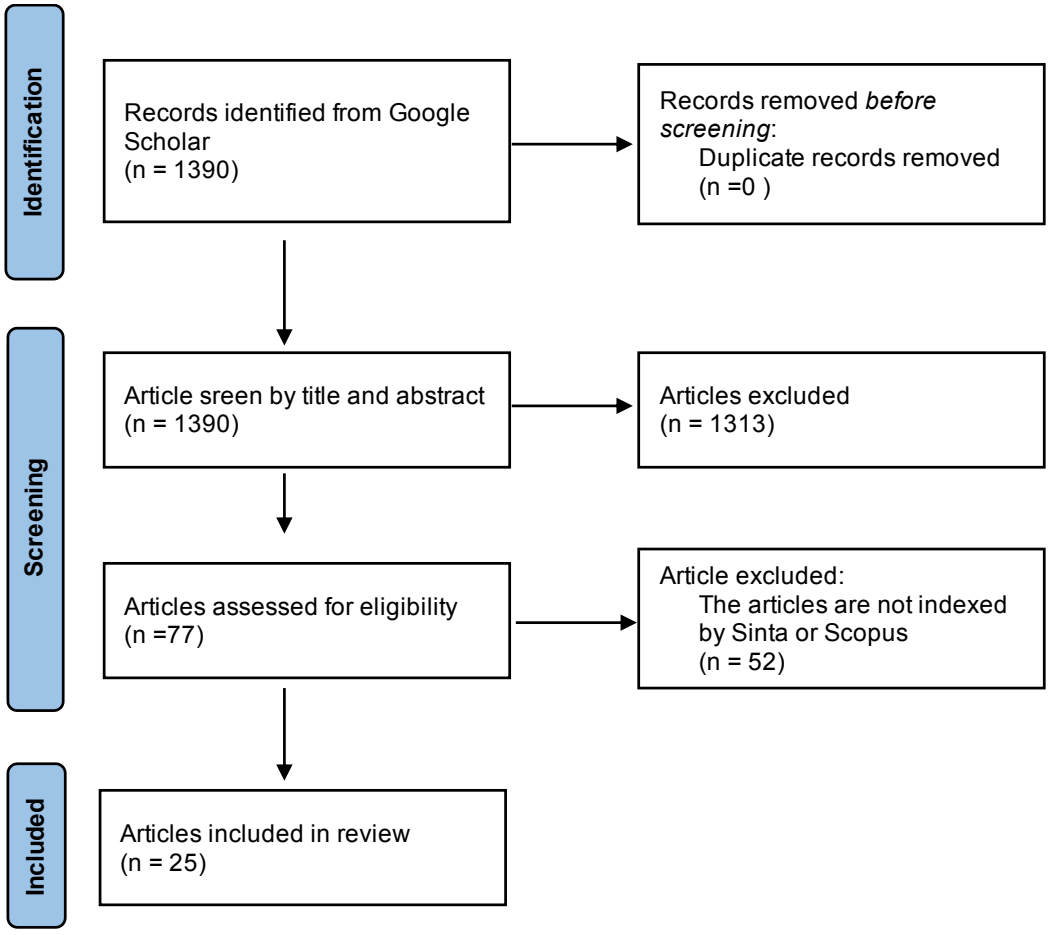

Figure 1. The PRISMA flow chart

C. Resultsand Discussion

Results

Based on the search results from the database, 1390 articles were found using the keywords 'augmented reality' and 'solar system' and 'primary school'. As only one database is used, there is no duplication of data. Filtering was done manually based on the title and abstract that contained all three keywords, leaving 77 articles. Therefore, 77 articles were assessed for eligibility. 52 articles were excluded because they did not have full text and were not indexed in Sinta or Scopus. After assessing the eligibility of the articles, 25 articles were used for this systematic review due to their relevance and usefulness to our topic.

We extracted the selected articles in order to answer the previously mentioned research questions. The purpose of data extraction was to obtain the results of this systematic literature review based on the research questions. We extracted some relevant information as follows:

- Year of publication of the article.

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- Tools used to develop the AR.
- Type of AR used.
- Research focus (development, implementation and effectiveness).
- Benefits of AR for learning about the solar system.

Figure 2 shows the trend of publications included in this review from 2019 to 2023. There was a significant increase in the number of articles from 2022 to 2023. This review was conducted in July 2023. Despite this, the number of articles discussing the use of AR in solar system learning has exceeded previous years.

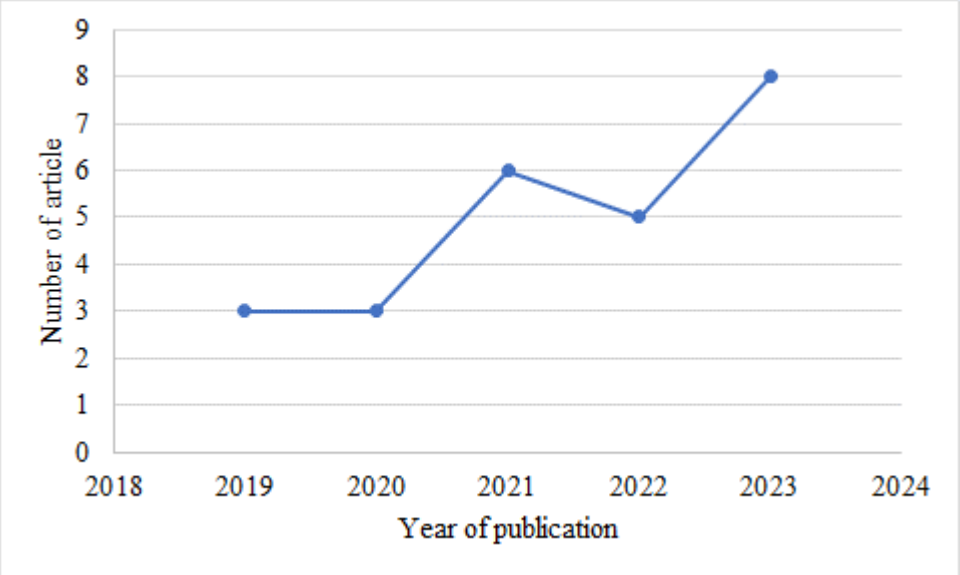

Figure 2. Number of articles per year

RQ1. What are the most popular tools for developing AR for solar system learning in primary school?

Only 19 out of 25 articles describe the tools used to develop AR in primary school solar system education. Most articles use Unity 3D software (90%) to develop AR. Other software used to develop AR are Assmblr apps (5%) and SparkAR (5%). Table 1 shows the articles based on AR development tools.

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Table 1. Articles based on AR Development Tool

Ar Development Tool	Frequency	%	References
Unity 3D	17	90	[14][15][16][17][18][19][20][21][22][23][24] [25][26][27][28][29][30]
Assemblr apps	1	5	[31]
SparkAR	1	5	[32]

The tool used for AR development is Unity 3D. Five articles explain the use of Unity 3D only, while other articles explain the use of Unity 3D with Vuforia SDK. The first research to use Unity 3D is Setyawan [17] who uses AR in science learning. Utomo, et al [22] used AR technology as a thematic visual media. Iskandar and Mayarni [23] found that Unity is easy to use and can be used to create 3D or 2D games or applications. Research by Matin and Utomo [27] found that the use of AR applications can improve students' understanding. Furthermore, research by Prasetio, et al [26] used Unity 3D with Vuforia SDK to create an AR application to introduce the solar system. Vuforia SDK is used as a marker storage medium in the creation of AR [18]. Rakhmat [14] used AR as an interactive learning medium. This is similar to the research by Aini, et al. [15] who made an AR interactive learning application. Research by Pulingkareng, et al [16] aims to help students, teachers and the public understand astronomy using AR. AR can be used as an additional medium to present the solar system in a new and informative way [19]. The presence of AR can make the process more interesting and interactive [20][25]. Research by Adiyati, et al. [21] aims to provide comfort in learning and understanding the material.

Another tool used to develop AR in solar system education is Assemblr apps. This tool was used by Santi, et al. [31] in a study aimed at developing AR-based textbooks. Assemblr Apps is an application that originated in Indonesia and is used to design 3D or AR objects. The last tool used for AR development is SparkAR. Research by Satria, et al. [32] used SparkAR to develop Instagram filter-based AR for learning about the solar system.

RQ2. What types of AR are popular for solar system learning in primary schools?

AR can be divided into two types, marker-based and markerless [9]. These two types of AR serve different specific purposes and use different approaches in their development. Table 2 shows articles based on AR types.

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Table 2. Articles by AR type

Types of AR	Frequency	%	References
Marker-based	22	88	[14][15][16][17][18][19][20][21][22][23][24][25] [26][27][28][29][30][31][32][33][34][35]
No explanation	3	12	[36][37][38]

There are 22 articles that explain the type of AR used, while the other three articles do not explain the type of AR used in the study. The 23 articles that explain the type of AR used are all marker-based. None of them use markerless AR. Markers are used as markers for cameras that display 3D objects from the virtual world to the real world [26], [30]. The markers used to display 3D objects can be books integrated with AR [14], [33]. The marker can also be a map [22], [23]. Markers can be created using many tools, one of which is Canva [24]. Aini, et, al. [15] explained that marker-based AR types can be used as learning media for elementary school students to make learning more fun. Pulingkareng, et al. [16] stated that AR technology can make the material presented more interesting. Setyawan [17] uses marker-based AR to motivate students to learn. Wahyudi and Arwansyah [36] developed an application to facilitate students to learn the solar system visually. Satri, et al. [32] aimed to enable students to directly visualise their imagination about solar system objects. Mattola, et al. [18] used marker-based AR to make learning more interesting. Parno and Agustinus [19] used markers to get students interested in learning about the solar system. This is similar to the research of Tresnawati, et al. [25] who developed a marker-based AR application to increase students' interest in understanding lessons. The use of marker-based AR can be used as a learning medium that is not boring [21], [34]. Research conducted by Santi, et al. [31] states that AR-based textbooks can help students in the learning process. Jannah, et al. [29] used marker-based AR to improve students' science knowledge. Markers that can be detected by the camera can also be set to detect multiple markers at once or multimarkers. This is done by Pradibta [20] who developed an AR application that can detect multimarkers in the solar system simulation.

RQ3. What is the focus of research on AR in learning about the solar system in primary schools (applicability, development and effectiveness)?

The research focus of the selected articles can be divided into three, which are:

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development, implementation and effectiveness. Most of the research on AR for learning about the solar system in primary school is focused on development (88%). The rest are effectiveness (8%) and implementation (4%).Table 3 showsarticles by research focus.

Table 3. Articles by research focus

Research Focus	Frequency	%	References
Development	22	88	[14][15][16][17][18][19][20][21][22][23][24][25][26][27][28][29][30][31][32][33][34][36]
Effectiveness	2	8	[37][38]
Implementation	1	4	[35]

The first research focus is on development. Some research discusses the development of AR applications as interactive learning media in solar system learning [15], [16], [18], [26]. AR applications are developed as effective, efficient and interesting learning media [27]–[29]. AR applications are also being developed as learning media that can make students more interested and easier to understand the material, and not boring [21], [25], [34]. In addition, AR applications are also being developed based on Android [24], [30]. Setyawan [17] developed an AR application as a medium to support the independent learning process. Wahyudi and Arwansyah [36] developed an AR application to facilitate visual learning for students. Parno and Agustinus [19] developed an Android-based e-learning application using AR technology. Satria et al. [32] developed AR based on Instagram filters to learn about the solar system. Pradibta et al. [20] developed an AR application that can detect multi-markers. Ainni and Prasetyo [33] developed AR applications as an alternative learning medium. Santi et al. [31] developed an AR-based textbook. Utomo et al. [22] developed maps using AR technology as thematic visual media for students.

The second focus of research is effectiveness. There are two studies that discuss the effectiveness of AR in solar system learning. The first research was conducted by Andriani and Ramadani [37] who discussed the effect of using AR media on students' critical thinking skills. The next research was conducted by Zuniari et al. [38] who also discussed the effect of AR media on students' critical thinking skills.

The final research focus is implementation. There is only one article that discusses the implementation of AR in solar system learning. Research by Apriliani et al [35] implements

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the use of AR learning media to determine the improvement of student learning outcomes..

RQ 4. What are the benefits of using AR to teach about the solar system in primary schools?

There are several advantages to using AR to teach the solar system in primary schools. Setyawan [17] stated that AR can increase students' curiosity about the material being taught. Wahyudi and Arwansyah [36] explained that the use of AR can improve students' visual spatial skills. Apriliani [35] found that the use of AR as a learning medium can improve student learning outcomes. This is similar to the research conducted by Santi et al. [31] who found that AR-based textbooks can improve student learning outcomes. The use of AR in learning about the solar system in primary school can also improve students' critical thinking skills [37], [38]. The use of AR can also increase students' scientific literacy [29].

Discussion

The results of this review can help to understand the systematic analysis of the last five years of research on the use of AR in solar system learning in primary schools in Indonesia. It also provides an updated analysis of the need for more in-depth research that could be conducted in the future. This review is limited to the tools used to develop AR, the type of AR used, the focus of the research, and the benefits of AR in Solar System learning in primary schools.

AR-based solar system learning can help students to better visualise the material content. This review found that all articles discussing the use of AR in Solar System learning in primary schools are marker-based AR. Most of the research is developmental, and few have investigated the effectiveness and implementation of the use of AR in Solar System learning in primary schools. The use of AR in Solar System learning in primary schools has several benefits, namely it can improve learning outcomes, critical thinking skills, scientific literacy, visual spatial skills and student curiosity.

D. Conclusion

The results of this systematic literature review show that there is a promising trend in the use of AR for solar system learning in primary schools. This review focused on the tools used to develop AR, the types of AR used, the focus of research, and the benefits of AR on Solar System learning. Our findings show that the most commonly used tool for developing

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AR is Unity, and the most popular type of AR used is marker-based AR. Most of the research has focused on development and few have investigated effectiveness and implementation. The use of AR is known to improve learning outcomes, critical thinking skills, scientific knowledge, visual spatial skills and student curiosity. This systematic review provides researchers and educators with more avenues for future research.

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