JSER

Journal of Science Education Research

Journal homepage: www.journal.uny.ac.id/jser

Augmented Reality Research Trends in Indonesia: A Systematic Literature Review

Muhammad Reza Firmantara[1*], Imam Mudakir[2], Nuriman[3]
[1,2,3] Study Program of Master Science Education, Faculty of Teacher Training and Education, Universitas Jember, Indonesia
** Corresponding Author. Email: rezacchary@gmail.com*

Keywords
Augmented Reality, research trends, systematic literature review

Abstract
Augmented Reality (AR) may be defined as a technology capable of incorporating two-dimensional or three-dimensional virtual objects into a real environment. This content analysis study aimed to systematically analyze AR research trends in Indonesia based on articles published in national and international journals. It compared the two methods in applying AR, namely Marker Based 77% and Markerless Based 23%. No output appeared in 2013, 2014, and 2016, while 2022 had the highest productivity with 12 papers. A significant increase in the number of articles was seen from 2018 to 2022, where 2021 and 2022 were the most productive year with 40 publications, and 639 was the highest number of citations in 2022. The AR research method dominated by research and development (40%), followed by a literature review (23%), experiment (13%), mixed method (8%), survey (4%), classroom action research (4%), and correlational (3%). Furthermore, the number of articles with 2 authors experienced a rapid increase between 2020 and 2022 and more than half of publications (66%) were written by the collaborations of 2 authors and 3 authors.

INTRODUCTION

Augmented Reality (AR) media is a technology that consists of a combination of objects in the form of two or three dimensions in real-time and is a unique application because it can add to the user's reality. Through the use of AR in learning, it is expected to be able to attract students in the learning process. Another benefit of using AR media is that the learning media is more advanced because it utilizes current technology. At a minimum, AR supporting equipment consists of a camera and display device, and in certain cases requires a special device to interact with virtual objects. The main devices needed to run AR-based applications are displays, input tracking devices, and computers. Display devices are used to display images or computer output. There are three types of displays in AR. The first is a head-mounted device (HMD), which is a display that is used to display images resulting from a combination of the virtual environment and the real environment (Carmigniani et al., 2010).

AR media can provide space for students to imagine so cognitive results will increase. The measured aspects include aspects of remembering, understanding, applying, and analyzing. According to Mustaqim (2016), AR is an interaction directly or indirectly from the world of the physical environment into the real world which has been added by adding a virtual computer that produces information. Using AR technology is expected to attract students' learning interest. AR is a technology developed in a virtual world environment into the real world through intermediaries (Sugianto, 2014). In the field of education, augmented reality technology has been widely applied, such as applications that use augmented reality books, games, object modeling, and observation-based learning. The convenience offered by technology cannot be denied by shifting the way children who were born and raised in the digital era (Ramadhan et al., 2022).

AR media has been researched in Research and Development (RnD), qualitative, and quantitative ways. Research and Development (RnD) research was conducted by Tasrif et al., (2020). In his research, AR media was developed using AR applications in computer network installation courses. Qualitative research was also carried out by Ramadhan et al., (2021) which explained an Android-based computer hardware recognition

application using AR. In addition, it was also examined quantitatively by Jannah (2020) who explained the effect of using AR media on students' interests. AR media combines images, video, audio, and text into a real environment. The point is that AR media makes students feel what they see from the media. Dewi & Sahrina (2021) explain that AR media can potentially attract and motivate students. In addition, it was also studied by Masri & Lasmi (2018), who explained that by using AR technology, objects that were previously two-dimensional will appear to be real and blend with their surroundings. From this, it concluded that AR media has been used by several researchers, but this study will use AR media to determine its effectiveness in learning on students' cognitive learning outcomes. The results of the study (Arifitama et al., 2022) which was carried out by comparing marker-based tracking and markerless tracking stated that the markerless tracking method was 93% superior to marker-based tracking, which was 80% on identical AR objects, the farthest distance, and produces an accuracy of 86% for markerless tracking compared to 50% for marker-based tracking for short distances.

The Merdeka curriculum supports relatively high involvement in the implementation of AR as indicated by the emergence of various empirical studies on AR over the last decade. Kaleka et al., (2023) explained that one of the most important and basic characteristics for achieving educational goals is independence. In the world of education, the ability of each student is assessed not only from the cognitive aspect but the character or attitude of a student is also equally important. The selection of learning media is not only determined by the teacher's taste and willingness (Seknun, 2013). But, the selection also depends on the nature of the media, goals to be achieved, talents, knowledge, and technology to overcome teaching problems, and to develop principles used to support learning (Alfirani, 2017). Character education is the thing that must be possessed by every individual, which serves to distinguish the nature of each person.

Independence is an attitude that arises for someone to start or do something and discipline, including working according to time and maintaining comfort during learning activities (Kaleka et al., 2023). A student has independence in learning. The student can face learning difficulties and reduce the habit of depending on other students. Therefore the role of AR is to make it easier for students to reach the goal of learning. More importantly, based on how important independent learning is in the latest Merdeka curriculum today, it is not surprising that more and more researchers are interested in developing AR to be applied in learning. This fact can be proven through a Google Scholar search with the keywords "AR", "Augmented Reality", and "Indonesia" which yielded more than 200,000 findings. AR research that is flexible, innovative, and can be carried out more practically, can close theoretical gaps because research trends in AR have been revealed. Then, the identification with systematic studies are needed to examine these research trends within the scope of Indonesia.

Systematic reviews exploring the status and trends in certain themes have become commonplace in educational research, such as a systematic literature review on research trends within the European continent entitled “Augmented Reality in Heritage Apps: Current Trends in Europe” by Luna et al., (2019) whose result is the educational opportunities for legacy learning and teaching provided by mobile device-based AR is a strong recommendation for further research and gaining scientific attention. Projections on the proposed future research domain include defining the key features that will enable AR applications to be created, continuing the analysis of these applications to evaluate useful applications, and identifying successes suitable for legacy learning and teaching.

Research on AR globally in the logistics sector conducted by Glockner et al., (2014) results in AR having promising future recommendations in the logistics industry because it can make it easier for people to provide an overview of the projected problems. From capturing based on 3D visualization in warehouses to helping customers more easily understand situations with after-sales activities, there is no doubt that AR can play a role in almost every step of the logistics value chain. AR research on a global scope generally refers to various sub-topics and methods that have been carried out by Irwanto et al., (2022) with the title "Trends of Augmented Reality Applications in Science Education: A Systematic Review from 2007 to 2022" which discusses various AR research with the result that more than a total of 300 manuscripts were researched, evaluated, including annual scientific results, number of authors, countries the most productive, the most productive journal, the most cited articles, and the most preferred research method. It was found that the number of articles on the application of AR in science education is increasing rapidly, and the field is gaining momentum. The peak will be in 2020 and 2021.

Research that organizes AR publication research in Indonesia holistically and comprehensively has not yet been carried out. This basis strengthens this research which aims to systematically analyze AR research trends in Indonesia based on published international and

national journal articles. The details of the research questions that initiate the analysis process are as follows: (1) What topics are most explored in AR research?; (2) What research methods are most widely used in AR research?; (3) What is the frequency of AR research publications in Indonesia?; (4) how to compare AR research citations and publications in Indonesia; (5) how is the comparison of AR research in Indonesia categorized according to the number or number of authors in one article?; and (6) how is the comparison of AR studies using/researching markerless AR marked based AR?

RESEARCH METHOD

This qualitative study used a content analysis approach with a systematic literature review technique to analyze AR research trends in Indonesia. Data comes from published study reports that systematically synthesize existing information and knowledge on a particular issue, find gaps, and draw conclusions on a matter (Møller and Myles, 2016). This study adopted the review process with education in Indonesia as the research object (Ardwiyanti et al., 2021), which is explained as follows: (1) formulating research questions; (2) Determining inclusion criteria (Table 1); (3) searching for articles in various databases (Google Scholar, ERIC, DOAJ, journal websites); (4) typing in the keywords "Augmented Reality" and "Indonesia"; (5) coding article using Paper Classification Form (PCF); identify patterns across articles; and (6) synthesizing these patterns to answer research questions. The filter stage produced 62 articles that met the inclusion criteria (Table 2).

Content analysis is defined as a systematic review/view, modified and expanded to transform many words of text into fewer content categories based on coding rules that are arranged holistically (Stemler, 2001). This content analysis is generally used for generalizing qualitative data purposes in the sense that the same can be done for purposes of summarizing, assisting, classifying, and quantitative analysis of knowledge based on the scientific method and knowledge boundaries will be split depending on the objectives of the researchers. The overall analysis was carried out based on the "Paper Classification Form (PCF)" developed by Sozbilir et al., (2012) according to the main discipline that paper belonged such as biology, physics, chemistry, etc. The instrument has met the validity and reliability requirements. The collected data were analyzed using percentage calculation (Ardwiyanti et al., 2021).

Table 1. The Inclusion Criteria

Category	Inclusion Criteria
Journal specifications	National peer-reviewed journal accredited minimum grade 5 (Sinta 5); international peer reviewed journal indexed minimum SCOPUS
Publication year	2012-2022
Research setting	Indonesia
Researcher's nationality	Indonesian; the combination of Indonesian and foreigners
Independent variable	Augmented Reality and all kinds of application patterns
Field	Science, social, physics, chemistry, biology
Type of study	Empirical and theoretical
Research subject	Students and teachers at all level (elementary, junior high school, senior high school,college)

Table 2. The Distribution of Articles Based on the Journals' Identity

Journal Type	Status		Journal Name	Quantity
International	Scopus Indexed	Q2	Research Journal of Turkish Science education	1
	Scopus Indexed	Q2	International Journal of Instruction	1
	Scopus Indexed	Q3	International Journal of Learning Teaching and Educational Research	1
National	SINTA 1		Jurnal Pendidikan Indonesia	2
	SINTA 2		Jurnal Pekommas	2
			Jurnal Pendidikan Sains Indonesia	18
			JPPIPA JURNAL PENELITIAN PENDIDIKAN IPA	5

Journal Type	Status	Journal Name	Quantity
		Jurnal Al-Ibtida: Jurnal Pendidikan Guru MI	1
		Journal of Educational Science and Technology	1
		Premiere Educandum: Jurnal Pendidikan Dasar dan Pembelajaran	1
		UNNES Science Education Journal	2
		Jurnal Edukasi & Penelitian Informatika	4
		Journal of Educational Science and Technology	1
		Kwangsan: Jurnal Teknologi Pendidikan	1
	SINTA 3	UNNES Science Education Journal	2
		Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan	6
	SINTA 4	Jurnal Pendidikan Teknologi dan Kejuruan	5
	SINTA 5	Jurnal Basicedu	8
		Total	62

RESULT AND DISCUSSION

The results of the research described include 5 discussions. First, starting from trending AR topics which are classified into teaching materials, learning media, learning evaluation & assessment, student perceptions, and teacher perceptions (see Table 3). Second, the annual scientific growth is based on the frequency of AR research publications from 2012 to 2022 (see Figure 1). Third, the most AR tracker used based on a comparison of the total use of marker-based tracking and markerless AR (see Figure 2). Fourth, a comparison of the development of publications and citation trends in AR from 2012 to 2022 so that publication growth will be known, which year has citations followed by the highest number of publications and which year has the lowest number (see Table 4). Fifth, discussing the AR research methods trends. Trends in this method are divided into 3 major groups, namely: (1) quantitative, consisting of experiment, survey, and correlational; (2) qualitative, divided into literature review, phenomenology, and narrative inquiry); and (3) the others, divided into research and development, mixed method, and classroom action research. Sixth, classification based on author numbers in AR research from year to year (2012-2022), the distribution of the number of authors in AR research starts from 1 author, 2 authors, 3 authors, 4 authors, 5 authors, and ≥6 authors. Based on that method, it is known every year how many article authors publish their articles and it is also known which number of articles has the highest and lowest frequency (see Figure 4).

AR Research Topics

There are various kinds of AR research in Indonesia, so a classification is carried out based on the types of topics that are commonly used, especially their application in the field of education. AR research topics are classified into teaching materials, learning media, learning evaluation & assessment, student perceptions, and teacher perceptions. Based on this classification, it can be seen which field topics are dominant (much studied) and which topics are in the minority (less studied).

Table 3. The AR Research Topics Trends

Research topics	Percentage (%)
Teaching materials	34
Learning media	56
Learning evaluation & assessment	4
Students perceptions	2
Teacher perceptions	4

AR research in Indonesia (see Table 3) was conducted on a wide variety of topics. It shows that the learning media (56%) dominated AR research, followed by teaching materials (34%). Learning evaluation & assessment (4%), teacher perceptions (4%), and student perceptions (2%) are the minor topics. This indicates that the research and use of AR are still dominant in the field of learning media and the need for AR in the field of teaching equipment for a teacher in carrying out the learning process in the classroom. There needs to be special attention to AR topics that are still lacking in exposure, namely in terms of evacuation and assessment, even though AR can also play a role in facilitating the implementation of learning, such as ARBOOK which has been studied by Ferrer-

Torregrosa et al., (2014) who succeeded in developing an assessment tool for anatomy based on AR constructed from TC and MRN images, dissections and drawings. This research gave good results in the sense that the scoring process became easier with the ARBOOK and provided motivation for all educational components, both teachers and students.

Avila-Garzon, et al., (2021) conducted a review of AR literature in the world within 5 years saying that since most of the existing literature reviews have focused exclusively on journal articles, this study broadens the scope by including and comparing other types of documents. The obtained data were then divided into two groups, which resulted in two separate BibTeX files. It was stated that most of the studies on AR in education have been published as conference papers, books, and book chapters. Journal articles contain a more elaborate analysis, discussion, and a stronger background compared to conference papers, but their publication process is slow. Conference papers contain more recent research and novel methods because their publication is faster.

Annual Scientific Growth

From various AR studies in Indonesia, a classification was carried out based on annual scientific growth from 2012 to 2022. The aim is to find out the growth of AR studies as indicated by the frequency of publications at that year's interval. Based on the classification and presenting it as a graph, it can be seen, from year to year, there is an increase in the frequency of publications, a decrease in the frequency of publications, fluctuations in the frequency of publications or static (no increase or decrease) in the frequency of publications.

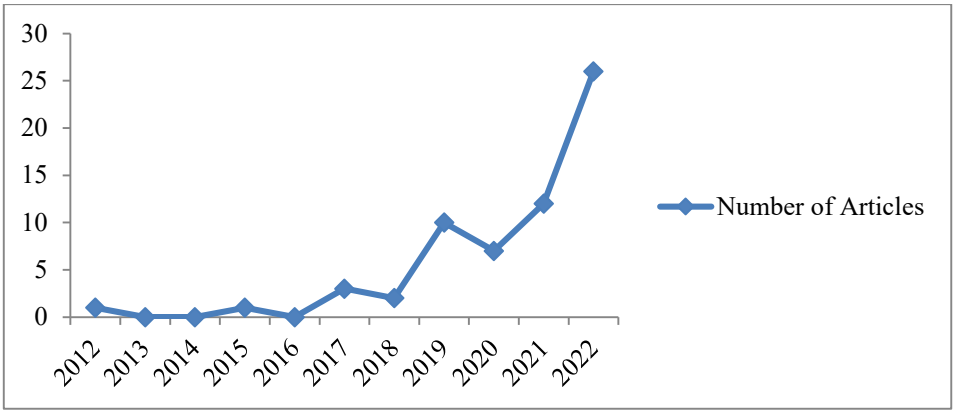

Figure 1. Frequency of Publications in AR from 2012 to 2022

The number of articles by year is presented in Figure 1 and also illustrates the trend of publications of AR since 2012. A single paper was recorded in 2012, indicating the beginning of the growth of publications in the field. No output appeared in 2013,2014, and 2016, while 2022 had the highest productivity with 26 papers. The dataset was taken at the end of January 2023. A significant increase in the number of articles was seen from 2018 to 2022, where 2021 and 2022 were the most productive years. According to Figure 1, 2021 (n = 12) and 2022 (n = 26) saw a sharp increase in publications. In total, 61% of the articles found were from these two years. Compared to 2020 with seven articles. The publications only decreased in 2012-2013 with 1 article, 2015-2016 with 1 article, 2017-2018 with 1 article, and 2019-2020 with 3 articles. The highest increase in article publication occurred in 2021-2022 with 14 articles. Overall, it was observed that there were both increase and decrease in the number of AR studies by publication year.

These results have developments that are quite equivalent to Avila-Garzon's research (2021) which conducted a literature review of AR in the world over 5 years. It conveys that it depicts the number of papers published per year in each group. The period 2013-2019 had the highest productivity in Group A, with more than 50 papers published per year. However, the highest productivity period in Group B was 2010-2019, with more than 50 papers published per year. The most productive year was 2019 for both groups (A = 304 and B = 402), which demonstrates how research interest in this field has grown in recent years. However, because the dataset information was retrieved at the end of January 2020, the number of papers for 2020 is fewer in comparison to the last 10 years.

The Most AR Tracker Used

AR research in Indonesia, which is many and varied, is classified based on the most AR tracker used. The goal is to find out the percentage of AR trackers used using markers and markerless. After classifying and presenting it as a diagram, it can be seen which type of AR tracker is most used and which is least used.

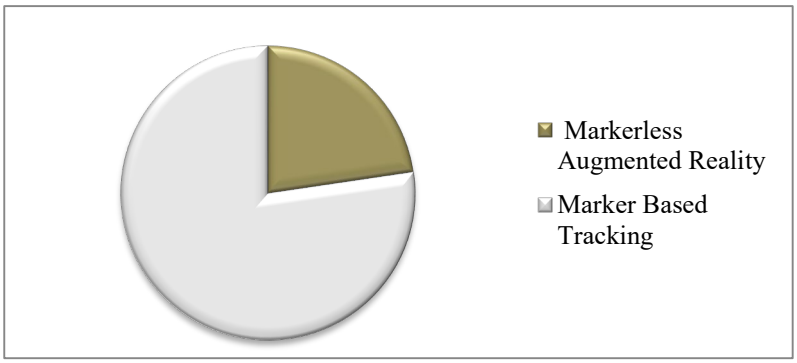

Figure 2. Total research Differences Between Marker Based Tracking and Markerless AR

The marker-based method uses special markers that have a certain pattern so that they will be recognized by the camera. When the camera detects this pattern, a three-dimensional object will be displayed, while the markerless-based method does not use a special marker, but uses the surface of the surrounding environment as a marker to display three-dimensional objects (Mustaqim, 2016). Comparison (see Figure 2) of the two methods of applying AR, namely Marker Based 77% and Markerless Based 23%. Markerless AR is superior to marker-based AR both in terms of accuracy and distance so based on data, researchers in Indonesia still mostly use the marker-based method with a very large difference, namely the difference of 48 articles, although there are many advantages to markerless products. In fact, there are still few researchers in Indonesia who use the markerless method to be used as a medium for visualizing research objects, especially in the field of education. This is compared to research from Arifitama et al., (2022) which was carried out by comparing marker-based tracking and markerless tracking stated that the markerless tracking method was 93% superior to marker-based tracking, which was 80% on identical AR objects, the farthest distance, and produces an accuracy of 86% for markerless tracking compared to 50% for marker-based tracking for short distances.

AR Research Citation Numbers

AR research in Indonesia which has reviewed 62 articles was classified based on citation numbers from 2012-2022. The goal is to find out how many citations have been done on this AR topic, compared to the number of publications each year. Based on this finding, a graph is made showing the development of citations to know the data from year to year. It found that there has been an increase in publication citations, a decrease in publication citations, fluctuations in publication citations, or static (no increase or decrease) publication citations.

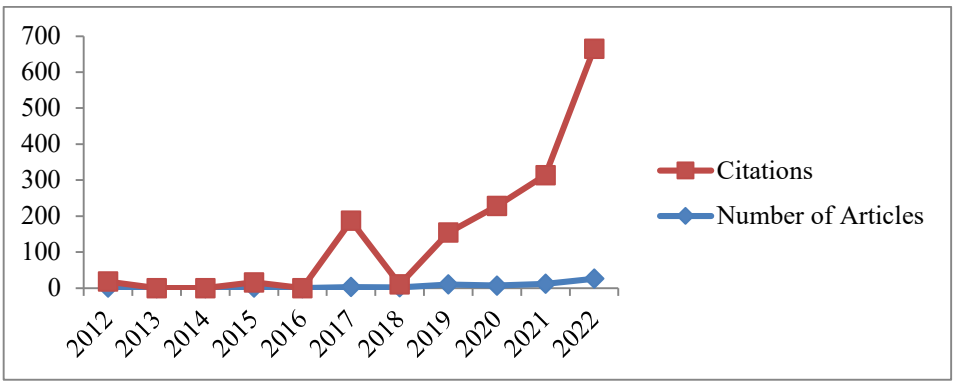

Figure 3. Publications and Citation Trends in AR from 2012–2022

Tarute et al., (2017) explained the technological features of AR remain directly or indirectly the dominant concern of the investigations between 1997 and 2016. The interests of researchers have switched from computers to handheld displays in tune with the growing availability of those products in the professional and entertainment markets. The tendency to focus on MAR solutions and wearables is a consequence of their increasing importance. According to Figure 2 on analyzed by citation, no citations were reported in 2013, 2014 and 2016 because there were no publications related to AR applications in education that year.

Based on the graph in Figure 3, there has been a decrease in citations from year to year starting from 2012 to 2013 of 17 citations because in 2013 there were no published articles at that time. Then, there were 15 citations in 2015-2016 because there were

no published articles in 2016, and in 2019-2020 there were 77 citations. A drastic increase in the publication of AR-related articles was found in 2021-2022 with 337 citations, followed by 2018-2019 with 136 citations, 2020-2021 with 81 citations, 2019-2020 with 77 citations, and 2014-2015 with 15 citations due to in 2014 there were no published articles related to AR. Additionally, we found that the highest number of citations occurred in 2022, where 639 citations were recorded. This is closely followed by 2021 with 302 citations and 2020 with 221 citations. Overall, 62 works have been cited 1530 times over time. This explains why there have been many studies on AR applications in the last decade.

AR Research Methods

AR research in Indonesia that has been studied uses a variety of methods from 2012-2022. All articles are grouped according to the type of research method, including 3 major groups, quantitative, qualitative, and others. The goal is to find out how many methods are on this AR topic. Based on this finding, a graph is made showing which method is most often used with a percentage so that the trend pattern in the AR research method is known.

Table 4. The AR Research Methods Trends

Approach	Research Methods	Percentage (%)
Quantitative	Experiment	13
	Survey	4
	Correlational	3
Qualitative	Literature review	23
	Phenomology	2
	Narrative Inquiry	3
The others	Research and Development	40
	Mix method	8
	Classroom action research	4

The AR research approach is centered on Mustaqim (2016) which states that whatever AR approach is used in class, attention must still be paid and fulfilling the function of the media as a learning stimulus. Among them include (1) presenting the actual object and steps, (2) duplicating the actual object, (3) making abstract concepts into concrete concepts, (4), providing common perceptions, (5) overcoming time barriers, (6) presenting repeat information consistently, and (7) provide a learning atmosphere that is fun, not pressured, relaxed, even interesting so that it can achieve learning goals.

Attention to AR research has increased since 2018 because it is indeed a new research theme in Indonesia compared to other research themes. So, it is not surprising that AR research began with basic topics in curriculum reform that focused on learning strategies. The current systematic literature review (see Table 4) reveals AR research methods were dominated by research and development (40%), followed by a literature review (23%), experiment (13%), mixed method (8%), survey (4%), classroom action research (4%), and correlational (3%) as a trend in AR media education research in Indonesia. The effectiveness of AR media with research and development (R&D) as a method is the most explored topic. It is followed by experimental research as the second most used method, which breaks down into experimental (unequal control group design, factorial design). And, the least is a literature review, which examines qualitatively how the application of AR in Indonesia affects certain subjects such as natural sciences, social sciences, mathematics, and so on.

Author Numbers in AR Research

The last discussion is AR research in Indonesia based on author numbers. The number of authors in each AR article in Indonesia is grouped in this discussion. The goal is to find out which articles with the most number of authors and in what year are the most dominant. Grouping starts from 1 author, 2 authors, 3 authors, 4 authors, 5 authors, and ≥6 authors. Based on the findings, it is known every year how many article authors publish their articles and it is also known which articles with the number of authors have the highest and lowest frequency (see Figure 4).

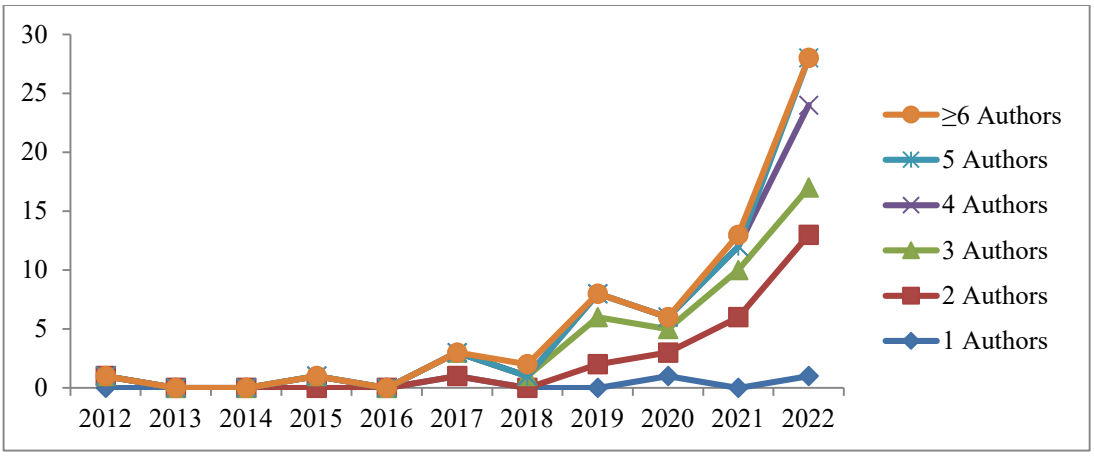

Figure 4. Number of Authors by Year

In Figure 4, there is also an increase in the number of collaborations over time. This reflects that there has been an increase in the number of publications on AR applications. Alzahrani (2020) conducted a systematic review on the topic of AR with 4 main publishers, namely Springer, Science Direct, EBSCO, and Google Sholar. It was conveyed that augmented reality enhances interactivity, facilitates students' engagement and participation, improves satisfaction with learning and outcomes, and encourages collaborative learning, among other benefits. The biggest challenge, as reported in these studies, starts from the pedagogical, learning, and technological issues. Pedagogical issues encompassed resistance from teachers and their lack of skills, training, and experience in the use of AR technologies. Learning issues, based on the findings, include cognitive overload and health issues. Technical issues include connectivity issues and cumbersome devices.

Concerning the number of authors, it is important that only 23-author articles were published during this period. In addition, 23 articles have 2 authors with a proportion of 35 which is the highest number. This finding indicates that two-author articles were commonly published in this field throughout the year. A total of 18 articles were written by 3 authors. Furthermore, the number of articles with 2 authors experienced a rapid increase between 2020 to 2022. This increase is marked by the addition of articles with 2 authors since 2020-2021 of 4 articles (2 articles to 6 articles) and in 2021-2022 of 6 articles (6 articles to 12 articles). It is important that more than half of publications (66%) were written by collaborations of 2 authors and 3 authors. Finally, the least total number of articles from year to year is occupied by articles with ≥6 authors with a total of 2 articles published only in 2018 and 2021.

This growth scheme also follows the research of Avila-Garzon, et al., (2021) number of authors that published AR studies over the examined years in the form of journal articles, conference papers, and other documents, respectively. The results show that the number of researchers working on the topic of AR in education increases every year. This result demonstrates the interest that this topic has created in the research community due to AR technology's impact on education and the technological advances that make AR more affordable for schools. Given this landscape, it is possible that this trend will continue in the coming years and that this topic will be more consolidated in the future as the number of researchers increases.

Overall, the use of AR research in Indonesia has benefits for developing interactive and real learning media. In addition, learning media using AR can increase students' interest in learning because of the nature of AR which combines virtual worlds which can increase students' imaginations with the real world directly. Augmented Reality is interactive which allows students to see real and direct situations and imagine the results of the learning process given by teachers to students. Utilization of educational media using AR can stimulate the mindset of students to think critically about problems and events that exist in everyday life because the nature of educational media is to help students in the learning process with the presence or absence of educators in the educational process. Then, the use of educational media with augmented reality can directly provide learning wherever and whenever students want to carry out the learning process. AR learning media can visualize abstract concepts for understanding the structure of an object model enabling AR as a more effective medium by the objectives of learning media. Also, it is realized in published studies which is increasing from every year. The hope is that in 2023 and the upcoming years, there will be more learning media research in various fields of study that use AR features, be it development, experiments, surveys, literature reviews, and so on.

Future AR Research Recommendations

Referring to the AR research trends identified in Indonesia, several topics have not been fully explored. Based on these findings, the following recommendations are proposed:

1. It needs to carry out quantitative and qualitative research to formulate teacher professional development programs under the Merdeka curriculum, which will effectively increase teachers' readiness to implement AR media in the classroom;
2. The development of technology in teaching materials and learning media needs to begin immediately to align Indonesian AR research trends with international trends;
3. Based on the data, the use of the markerless AR method is still low at 23%, and marker-based AR % is 77% indicating that it needs to use new methods, to increase literacy, and students' curiosity in trying new things. So, it is hoped that there will be a greater transition towards using the markerless because it is believed that this method does not use special marks so the ability to render objects will be better and the AR results will be sharper than Marker Based. According to research from Arifitama et al., (2022), Markerless AR is superior to Marker Based AR both in terms of accuracy and distance. In short, it is hoped that more writers and researchers will discuss and use AR with the markerless method.

CONCLUSION

AR research trends in Indonesia are studied from various perspectives starting from the frequency of publication, citations, research methods, AR methods, and the number of authors in one article. Comparison of the two methods in applying AR, namely Marker Based (77%) and Markerless Based (23%). A paper was recorded in 2012, indicating the beginning of the growth of publications in the field. No output appeared in 2013, 2014, and 2016, while 2022 had the highest productivity with 23 papers. The dataset was taken at the end of April 2023. A significant increase in the number of articles was seen from 2017 to 2022, where 2021 and 2022 were the most productive years with 23 publications in total. The highest number of citations occurred in 2022, where 318 citations were recorded. This is closely followed by 2021 with 210 citations and 2017 with 184 citations. Overall, 62 works have been cited 1530 times. AR research methods were dominated by research and development (40%), followed by a literature review (23%), experiment (13%), mixed method (8%), survey (4%), classroom action research (4%), and correlational (3%) as a trend in AR media education research in Indonesia. This explains why there have been many studies on AR applications in the last decade. It is important that more than half of publications (66%) were written by collaborations of 2 authors and 3 authors. Also, the number of articles with 2 authors experienced a rapid increase between 2020 and 2022.

REFERENCES

Alfiriani, A., Hutabri, E., & Pratama, A. (2017). Analisis Kebutuhan Belajar Mahasiswa Pada Mata Kuliah Strategi Pembelajaran TI. *Prosiding Seminar Pendidikan IPA Pascasarjana UM, 2*, 1–12. Retrieved from https://core.ac.uk/download/pdf/267023929.pdf.

Alzahrani, N. M. (2020). Augmented Reality: A Systematic Review of Its Benefits and Challenges in E-Learning Contexts. *Applied Sciences*, 10, (5660), 1-22. Retrieved from https://doi.org/10.3390/app10165660.

Ardwiyanti, D., Prasetyo, Z. K., Wilujeng, I. (2021). STEM Research Trends in Indonesia: A Systematic Literature Review. *Journal of Science Education Research, 5*(1), 38-45. Retrieved from https://journal.uny.ac.id/index.php/jser/article/view/41752.

Arifitama, B., Syahputra, A., & Bintoro, K.B.Y. (2022). Analisis Perbandingan Efektifitas Metode Marker dan Markerless Tracking pada Objek Augmented Reality. *Jurnal Integrasi, 14*(1), 1-7. Retrieved from https://jurnal.polibatam.ac.id/index.php/JI/article/view/3985.

Avila-Garzon, C., Bacca-Acosta, J., Kinshuk, Duarte, J., & Betancourt, J. (2021). Augmented Reality in Education: An Overview of Twenty-Five Years of Research. *Comtemporary Educational Technology,* 13(3), 1-29. Retrived from https://www.cedtech.net/download/augmented-reality-in-education-an-overview-of-twenty-five-years-of-research-10865.pdf.

Carmigniani, J., Furht B., Anisetti, M., Ceravolo, P., Damiani, E., & Ivkovic, M. (2011). Augmented reality technologies, systems and applications. *Multimed Tools,* 51,341–377. Retrieved from https://doi.org/10.1007/s11042-010-0660-6.

Dewi, K., & Sahrina, A. (2021). Urgensi Augmented Reality Sebagai Media Inovasi Pembelajaran Dalam Melestarikan Kebudayaan. *Jurnal Integrasi Dan Harmoni Inovatif Ilmu- Ilmu Sosial, 1*(10), 1077–1089. Retrieved from

https://doi.org/10.17977/um063v1i102021p1077-1089.

Ferrer-Torregrosa, J., Torralba, J. Jimenez, M. A., Garcia, S., & Barcia, J.M (2014). ARBOOK: Development and Assesment of a Tool Based on Augmented Reality for Anatomy. *Journal of Science Education and Technology, 24*,119-124. Retrieved from https://doi.org/10.1007/s10956-014-9526-4.

Glockner, H., Jannek, K., Mahn, J., & Theis, B. (2014). *Augmented Reality In Logistics*. Germany: DHL Customer Solutions & Innovation.

Irwanto, Dianawati, R., & Lukman, I., R. (2022). Trends of Augmented Reality Applications in Science Education: A Systematic Review from 2007 to 2022. *International Journal of Emerging Technologies in Learning, 17* (13): 157-175. Retrieved from https://doi.org/10.3991/ijet.v17i13.30587.

Jannah, R. (2020). Pengaruh Pemanfaatan Media Augmented Reality Terhadap Minat Belajar Siswa Pada Mata Pelajaran Tematik Siswa Kelas IV Tema Peduli Terhadap Makhluk Hidup di SDN 07 Kota Bengkulu. *Unpublished Thesis*. IAIN Bengkulu. Retrieved from http://repository.iainbengkulu.ac.id/5188/.

Kaleka, M. B. U., Baluk A. B., & Doa, H. (2023). Case Study of Students' Independent Learning in Online Science Learning at Nur Ikhsan Ndori Private MTs. *Journal of Science Education Research, 7*(1), 67-71. Retrieved from https://journal.uny.ac.id/index.php/jser/article/download/50223/pdf.

Luna, U., Rivero, P., and Vicent, N. (2019). Augmented Reality in Heritage Apps: Current Trends in Europe. *Applied Sciences,* 9(13), 2756. Retrieved from https://doi.org/10.3390/app9132756.

Mahananingtyas, E. (2017). Hasil Belajar Kognitif, Afektif dan Psikomotor Melalui Penggunaan Jurnal Belajar Bagi Mahasiswa PGSD. *Prosiding Seminar Nasional HDPGSDI Wilayah IV*, 192–200. Retrieved from https://ejournal.unpatti.ac.id/ppr_iteminfo_lnk.php?id=1723.

Masri, M., & Lasmi, E. (2018). Perancangan Media Pembelajaran Tata Surya Menggunakan Teknologi Augmented Reality Dengan Metode Markerless. *Journal of Electrical Technology, 3*(3), 40–47. Retrieved from https://jurnal.uisu.ac.id/index.php/jet/article/view/1118.

Møller, A. M. and Myles, P. S. (2016). What Makes a Good Systematic Review and Meta-Analysis? *British Journal of Anaesthesia, 117* (4), 428–30. Retrieved from https://doi:10.1093/bja/aew264.

Mustaqim, I. (2016). Pemanfaatan Augmented Reality Sebagai Media Pembelajaran. *Jurnal Pendidikan Teknologi dan Kejuruan, 13*(2), 174 - 183. Retrieved from https://ejournal.undiksha.ac.id/index.php/JPTK/article/viewFile/8525/5566.

Pertiwi, D. E., Samsuri, T., & Muliadi, A. (2019). Peningkatan Hasil Belajar Kognitif Siswa Menggunakan Model Pembelajaran Kooperatif Tipe Group Investigation. *Jurnal Penelitian dan Pengkajian Ilmu Pendidikan: E-Saintika, 2*(2), 136–141. Retrieved from https://doi.org/10.36312/e-saintika.v2i2.114.

Ramadhan, A. F., Putra, A. D., and Surahman, A. (2021). Aplikasi Pengenalan Perangkat Keras Komputer Berbasis Android Menggunakan Augmented Reality (Ar). Jurnal Teknologi Dan Sistem Informasi. *Jurnal Teknologi dan Sistem Informasi, 2*(2), 24-31. Retrieved from http://jim.teknokrat.ac.id/index.php/sisteminformasi/article/view/840.

Ramadhan, Z., S. Andrea, R., Suswanto. (2022). Development of Augmented Reality Traditional Musical Education Applications. TEPIAN Agricultural Polytechnic of Samarinda. Retrieved from https://doi.org/10.51967/tepian.v3i1.690.

Seknun, M. F. (2013). Strategi Pembelajaran. *Jurnal Biosel: Biology Science and Education, 2*(2), 120. Retrieved from https://iainambon.ac.id/ojs/ojs-2/index.php/BS/article/view/376/309.

Sozbilir, M., Kutu, H., & Yasar, M.D. (2012). Science Education Research in Turkey: A Content Analysis of Selected Features of Papers Published. Doris Jorde & Justin Dillon (Eds). Science Education Research and Practice in Europe: Retrospective and Prospective (pp.341-374), Rotterdam: Sense Publishers.

Stemler, S. (2001). An Overview of Content Analysis. *Practical Assessment, Research & Evaluation. 7*(17), 1-8. Retrieved from https://scholarworks.umass.edu/pare/vol7/iss1/17/.

Sugianto. (2014). *Implementasi Augmented Reality pada Brosur RentalMobil CV Asmoro Jati Menggunakan Metode Marker.* Semarang: Universitas Dian Nuswantoro.

Nurbudiyani, I. (2013). Pelaksanaan Pengukuran Ranah Kognitif, Afektif, Dan Psikomotor Pada Mata Pelajaran IPS Kelas III SD Muhammadiyah Palangkaraya. *Anterior Jurnal, 13*(1), 88–93. Retrieved from https://journal.umpr.ac.id/index.php/anterior/article/view/295.

Tasrif, E., Mubai, A., Huda, A., & Rukun, K. (2020). Pemanfaatan Media Pembelajaran Berbasis Augmented Reality Menggunakan Aplikasi Ar_Jarkom Pada Mata Kuliah Instalasi Jaringan Komputer. *Jurnal Konseling Dan Pendidikan, 8*(3), 217-223. Retrieved from https://doi.org/10.29210/153400.

Tarute, A., Nikou, S., and Gatautis, R. (2017). Mobile Application Driven Consumer Engagement. *Telematics and Informatics, 34*(4), 145–156. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0736585316307006?via%3Dihub.