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# Augmented Reality in Science Education: A Systematic Literature Review of Research Trends in Indonesia (2020–2025)

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**abstract**

The rapid evolution of digital technology necessitates fundamental transformations in educational practice, most notably through the systematic integration of Augmented Reality (AR) as an innovative pedagogical tool. This study analyzes AR research trends in science education within the Indonesian context over the period 2020–2025. Employing a bibliometric approach guided by the PRISMA protocol, a final corpus of 471 relevant articles was systematically synthesized from an initial pool of 985 records retrieved from Publish or Perish and Mendeley databases. Bibliometric data were visualized using VOSviewer through network, overlay, and density analyses to map the intellectual structure and thematic evolution of the field. The findings reveal a consistent upward trajectory in annual AR publication output, peaking in 2024. AR implementation is most prevalent at the senior high school level, theoretically consistent with Piaget's formal operational stage, wherein learners require visual scaffolding to engage with abstract scientific concepts. A significant methodological gap is identified: existing research is predominantly characterized by quantitative efficacy testing, with a conspicuous scarcity of qualitative investigations into pedagogical barriers and shifts in student learning behavior. This study contributes a distinctive perspective through thematic mapping within the Indonesian educational context, identifying underexplored opportunities in collaborative AR-based learning and long-term cognitive retention. Two principal recommendations are proposed: teachers are encouraged to integrate AR into inquiry-based learning worksheets as dynamic pedagogical scaffolds rather than static visual aids, and policymakers are urged to standardize digital infrastructure and develop validated AR content repositories to ensure equitable technology adoption across all educational levels in Indonesia.



## 1. Introduction

The rapid development of the technological world consciously or unconsciously forces various fields of human life to change and be in line with it. One of the areas of life that has experienced this impact is education. The progress of education cannot be separated from the influence of technological development (Seogoto, 2014). Education based on Undang-Undang No. 20 of 2003

can be summarised as an effort to create a learning atmosphere that actively develops the potential of students to have religious spirituality, character, intelligence, and skills needed for themselves (Megahantara, 2017). To create a learning atmosphere that is comfortable and can support the development of students' potential, innovations in education are needed that are adapted to the advances in information technology that are developing in that era. One of the innovations in education is the development of learning media that is attractive to students. Quality education requires innovative and creative teaching materials or learning media (Putriyana, 2020). Many learning media can be applied. Apart from teaching aids, educators can use technology-based applications (Rahmatullah, 2020). One of the emerging technologies in the world of education is Augmented Reality (AR).

Augmented reality is a technology that aims to integrate and expand the physical environment or user world digitally and directly by adding layers of digital information (Arena, 2022). In education, augmented reality can provide a more vivid and interesting learning experience for learners (Tika, 2024). The use of augmented reality during learning can enable increased learner understanding by visualising abstract concepts, simulation and direct interaction with virtual objects (Dewi, 2024). By using augmented reality, users can view the surrounding environment enriched with additional information such as images, sounds, animations, or 3D objects through devices such as smartphones, tablets, or AR glasses. Indonesia is the focus of this study due to its unique geographical characteristics and disparities in access to education. As the country with the fastest-growing adoption of educational technology in Southeast Asia, an evaluation of how AR is integrated into the Merdeka curriculum is crucial for assessing teachers' digital readiness and the relevance of learning materials to local wisdom.

Science comes from the Latin "scientia" which means knowledge. In Webster's New Collegiate Dictionary, science is knowledge gained from learning and proof, or knowledge that covers a general truth of the laws of nature that occur, obtained and proven through scientific methods (Putra, 2013). Based on this explanation, it can be explained that science is a system used to obtain knowledge through certain methods to explain phenomena that occur in nature.

Explaining natural phenomena requires equipment that supports and is easily available because direct observation requires knowledge, skills, and even large costs. So that the use of teaching aids is very helpful in the process of understanding and scientific research, one of which is the use of augmented reality technology. Therefore, research on the development of augmented reality in the field of science is very important.

Augmented reality development research has received attention in science education, especially in terms of understanding and developing students' reasoning skills. One of the augmented reality development studies conducted by Dendodi shows that the use of augmented reality in science learning has a significant impact in the aspect of understanding the material, increasing activeness and memory, and the effectiveness of learning in the digital era (Dendodi, 2024). Research conducted by Sutrisno and friends shows that the use of augmented reality-based interactive media has a significant effect on improving students' science literacy (Sutrisno, 2024). Another study conducted by Nina Merliana showed that the STEM approach assisted by augmented reality had a positive effect of 49.7% on the creative ability of students on the material of human organs (Merliana, 2023). Based on research conducted by Rohmani, it shows that the application of augmented reality in science learning effectively improves students' understanding, motivation, and learning outcomes (Rohmani., 2024). Meanwhile, research conducted by Elisa Nur Azizah shows that the Concrete-Pictorial-Abstract (CPA) approach assisted by augmented reality (AR) can help improve students' mathematical critical thinking skills by 81.3% (Azizah, 2024).

The trend of a research is needed to see how the development of the research occurs at a certain time interval and the direction of further research in the future. Augmented reality research trends will provide an overview for academics to determine the direction of further research based on the main concerns of researchers in a field of science and gaps in some areas of research that are still not widely researched (Mulyani, 2024). Although the studies mentioned above demonstrate the partial effectiveness of AR in certain subjects, most of them still focus on small-scale product development (R&D). There remains a gap in the literature that provides a systematic, macro-level overview of the development of AR in Indonesia over the past five years. A weakness in previous bibliometric studies of AR in education is that they often overlook the classification of specific science content characteristics and their relationship to students' cognitive levels. This study aims to fill that gap by evaluating publication trends not only in terms of quantity but also in terms of the prevalence of research designs and the appropriateness of science content. Based on this description, the researcher wants to study and explore how the development of augmented reality research in the field of science for 2020-2025 in Indonesia. The study aims to describe the extent to which augmented reality research is developed in Indonesia from 2020 to 2025 by analysing research articles collected through the help of Publish or Perish (PoP) Software and visualising augmented reality research trends based on analysis using VOSviewer.

## 2. Method

This study employs a Systematic Literature Review (SLR) as its primary research methodology. In accordance with established SLR protocols, the literature review process encompasses the systematic identification, screening, interpretation, and evaluation of research articles pertinent to the designated research topic (Nurhaliza, 2023). Three computational tools were utilized in the execution of this study: Publish or Perish for the systematic retrieval of articles from scholarly databases, Mendeley Desktop for the sorting, management, and elimination of irrelevant articles based on predefined criteria, and VOSviewer for bibliometric data analysis and the visualization of keyword relationships, research trends, and thematic clusters.

The procedural framework adopted in this study follows the PRISMA protocol (Rodrigues, 2023), which comprises four sequential stages: Identification, Screening, Eligibility, and Inclusion, as comprehensively illustrated in Figure 1. The PRISMA protocol was selected as the methodological framework for this study owing to its rigorous and transparent structure, which effectively minimizes the risk of selection bias and provides a standardized and replicable approach to the reporting of systematic reviews. This methodological rigor ensures that the findings of the present study are reproducible and methodologically comparable to those of other systematic reviews in the field, thereby enhancing the overall credibility and scholarly contribution of the research.

**Table 1**. Inclusion and exclusion criteria

| Type | Inclusion | Exclusion |
|---|---|---|
| Publications | Journals, proceedings | Book, Dissertation, and others |
| Year | 2020-2025 | Less than 2020 |
| Source | Google Scholar | Besides Google Scholar |
| Field | Science, Maths, Chemistry, Physics and Biology | Other |
| Subject | Elementary school, Junior high school, Senior high school, University students, and Teachers | Other |
| Data Type | Quantitative, Qualitative | Other |

At the identification stage, an initial article search was conducted using the Publish or Perish application with the search keywords "Augmented Reality", "Science", and "Indonesia", yielding a total of 985 articles indexed in Google Scholar. At the screening stage, articles were evaluated for duplication and accessibility, resulting in the removal of 12 duplicate records and 105 inaccessible articles, thereby reducing the corpus to 868 articles. At the eligibility stage, the remaining articles were further filtered using Mendeley Desktop based on the predefined inclusion and exclusion criteria outlined in Table 1. A total of 397 articles were identified as irrelevant and subsequently excluded, yielding a final corpus of 471 articles eligible for inclusion in the subsequent analytical stage. At the inclusion stage, the 471 selected articles were subjected to comprehensive bibliometric data analysis using VOSviewer, through which all relevant scholarly information was systematically visualized across three analytical dimensions: network visualization, overlay visualization, and density visualization.

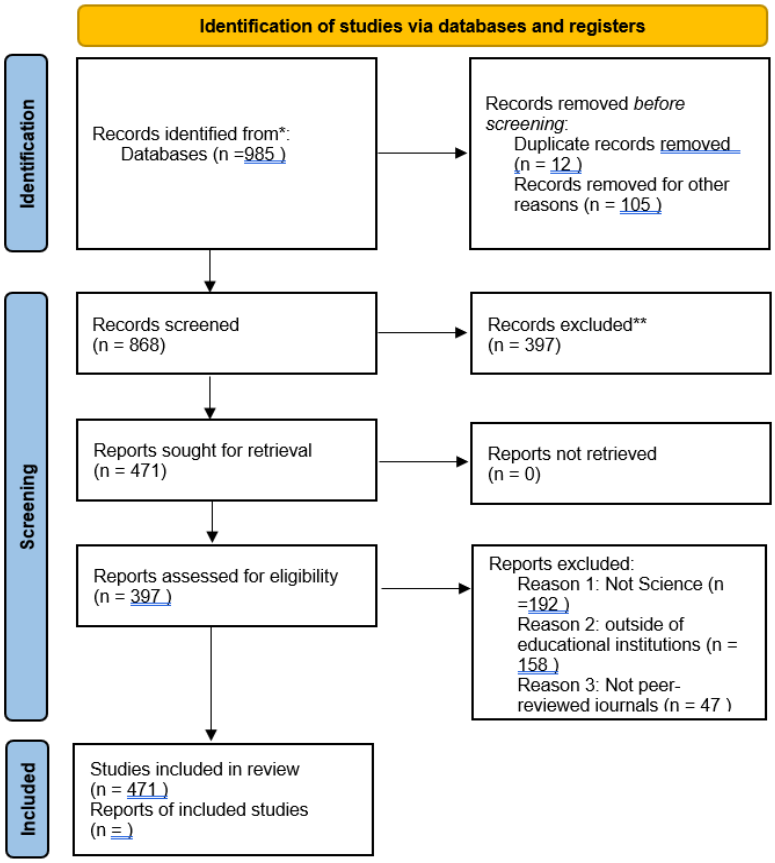


**Figure 1**. PRISMA flow diagram of the study selection process

## 3. Result and Discussion

The articles incorporated at the inclusion stage were systematically analyzed to map scholarly publication trends pertaining to Augmented Reality (AR) research in the field of science education. The analysis was conducted across five principal dimensions: number of publications, publication type, field of science, research subject, and data type. Bibliometric analysis using VOSviewer was subsequently performed across three analytical dimensions: network visualization, overlay visualization, and density visualization, collectively enabling a comprehensive mapping of the intellectual structure and thematic evolution of AR research in science education in Indonesia. The

annual publication trends of AR research in the field of science education from 2020 to 2024 are presented in Figure 2.

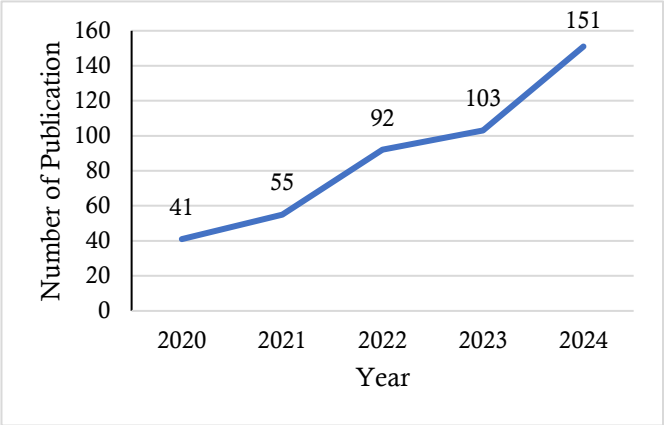


**Figure 2**. Annual publication output of augmented reality research in science education in Indonesia (2020–2025)

Based on Figure 2, the number of augmented reality research publications published in 2020-2025 experienced fluctuating developments, with publications in 2020 totalling 41 publications, in 2021 totalling 55 publications, in 2022 totalling 92 publications, in 2023 totalling 103 publications, in 2024 totalling 151 publications, and in 2025 totalling 29 publications. Augmented reality research trends in the field of science based on the type of scientific publication can be seen in Figure 3.

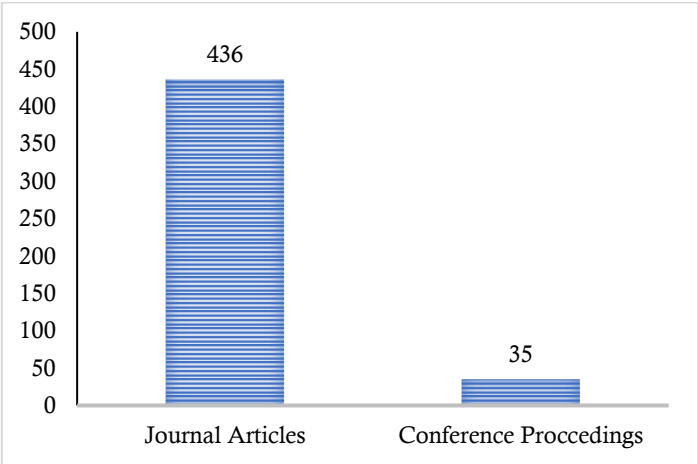


**Figure 3**. Distribution of Publications by Publication Type

As presented in Figure 3, the distribution of AR research publications by publication type reveals a pronounced disparity between the two categories identified in the corpus. Journal articles constitute the dominant publication format, comprising 436 publications, while conference proceedings account for a considerably smaller proportion, with only 35 publications recorded. This substantial difference underscores the prevailing tendency among AR researchers in Indonesia to disseminate their scholarly findings through peer-reviewed journal platforms, reflecting the growing academic maturity and credibility of AR research within the Indonesian science education landscape. The distribution of AR research trends by field of science is presented in Figure 4.

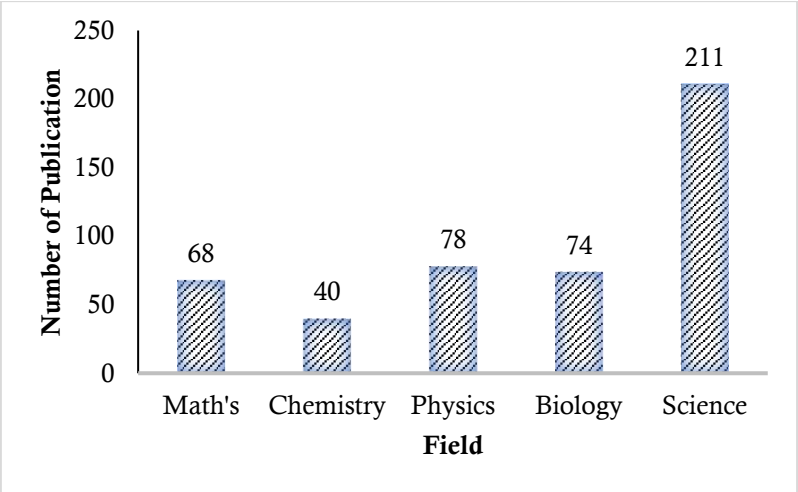


**Figure 4**. Distribution of publications by science subject area

As illustrated in Figure 4, the distribution of AR research publications across science subject areas reveals considerable variation in scholarly output among the identified disciplines. The highest volume of publications was recorded in the integrated science category, comprising 211 publications, followed by biology with 78 publications, mathematics with 74 publications, physics with 68 publications, and chemistry with the lowest output of 40 publications. The pronounced dominance of integrated science publications suggests that AR technology is most extensively applied within broad, interdisciplinary science learning contexts, wherein its capacity to visualize complex and abstract phenomena across multiple scientific domains is most effectively leveraged. Conversely, the comparatively limited publication output in chemistry may indicate an underexplored research frontier, warranting greater scholarly attention regarding the application of AR in chemistry education specifically. Representative examples of research conducted within each science subject area are systematically documented in Table 2.

**Table 2**. Augmented reality research in various fields of science

| Autor | Material | Field |
|---|---|---|
| Nabil (2023) | Electricity | Physics |
| Wadiasih (2023) | Optic | |
| Khunaeni (2020) | Sounds Physics | |
| Harahap (2023) | Nature of Chemistry | Chemsitry |
| Aris (2020) | Atoms | |
| Prasetiyo, (2020) | Chemical Compounds | |
| Badia (2024) | Excretory system | Biology |
| Sholikha (2024) | Virus | |
| Sulisetijono (2023) | Flower structure | |
| Hasni (2022) | Geometry | Math's |
| Saumi (2024) | Vector | |
| Nasution (2023) | Geometry | |
| Fakhrudin (2020) | Science elementary | Science |
| Rahma (2024) | Science Junior High | |
| Chairunnisa (2023) | Science elementar | |

The distribution of AR research publications in science education based on research subject categories is presented in Figure 5.

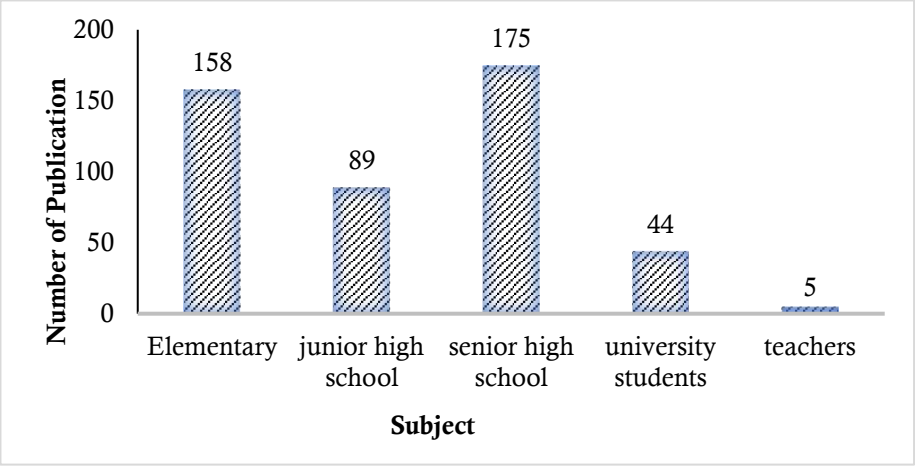


**Figure 5**. Distribution of publications by research subject category

As illustrated in Figure 5, the distribution of AR research publications in science education varies considerably across research subject categories. The highest volume of publications was recorded for senior high school students, comprising 175 publications, followed closely by elementary school students with 158 publications, and junior high school students with 89 publications. University students accounted for 44 publications, while teachers represented the least frequently investigated subject category, with only 5 publications. The predominance of research targeting senior high school students is particularly noteworthy, as this pattern is theoretically consistent with Piaget's formal operational stage of cognitive development, wherein learners at this level require structured visual scaffolding to effectively engage with abstract scientific concepts, a need that AR technology is uniquely positioned to address. Conversely, the markedly limited number of studies focusing on teachers as research subjects reveals a significant gap in the literature, underscoring the need for future investigations into AR adoption from the perspective of pedagogical practice, teacher digital competency, and professional development. The distribution of AR research in science education based on the research methods employed is presented in Figure 6.

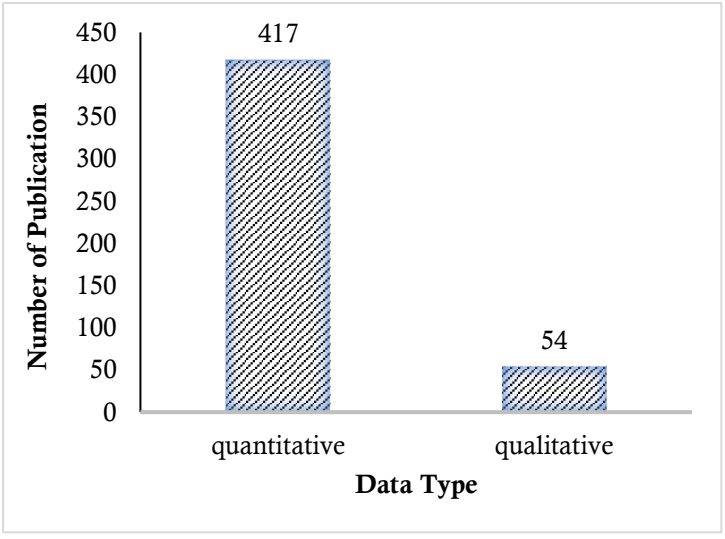

**Figure 6**. Distribution of publications by research data type

Based on Figure 6, the number of augmented reality research publications based on the type of research data is seen to have a very large difference with quantitative data types with 417 publications while qualitative data types only number 54 publications. In addition to being analysed using the criteria table, data included in the included stage is analysed using bibliometric data using the help of VOSviewer. Network visualisation results can be seen in Figure 7.

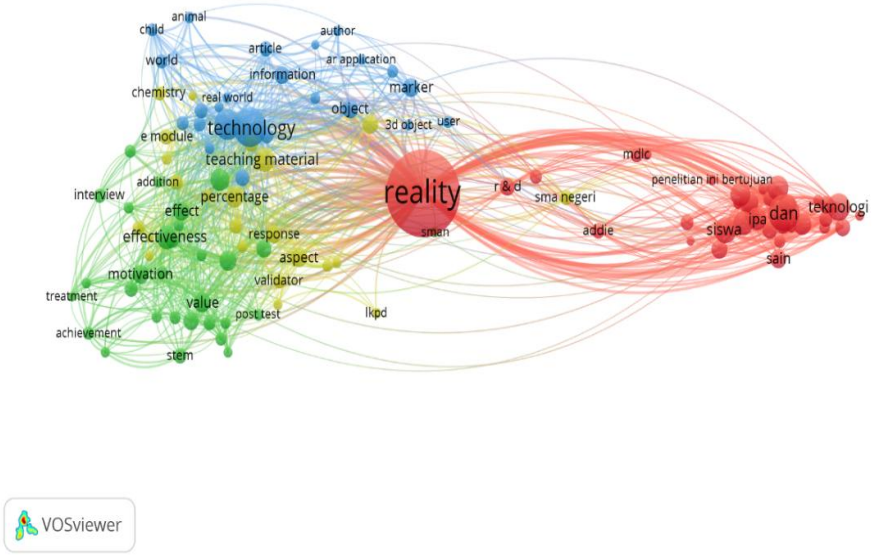


**Figure 7**. Network visualization of augmented reality research in science education in Indonesia (2020–2025)

Based on Figure 7, the results of the network visualisation-based analysis provide an overview of some topics that are widely cited and have a close relationship with other topics. The word 'Reality' has the largest node and is at the centre of the network. This shows that augmented reality is the main and most frequently occurring topic in the literature. This word connects the various clusters, signalling its central role in linking the various aspects of AR research in science.

In general, there are four major clusters distinguished by colour: red, yellow, green, blue. The red cluster addresses education and implementation in schools. This section is filled with words such as, students, public high school, ipa, technology, addie, r&d. In addition, the results also show that a lot of research is directed towards the design and development of augmented reality for high school students. The blue cluster discusses technology and virtual objects. The analysis results show that this section is filled with words such as, technology, 3d object, ar application, object, information. This section focuses on the technical aspects of developing augmented reality devices such as 3d objects and augmented reality applications. This section also deals with the development of augmented reality and its integration in learning materials. The green cluster discusses evaluation and effectiveness. This section contains topics such as effectiveness, motivation, achievement, interview, treatment, value, e-module. This section shows that augmented reality research focuses on the impact of augmented reality on learning, student motivation, and learning achievement. It also indicates that augmented reality is not only developed, but also evaluated for its effectiveness. The yellow cluster contains words such as percentage, aspect, response, validator, post-test, worksheet. This section shows that augmented reality research focuses on instruments

and methods of evaluation and validation of augmented reality learning media. The analysis results based on overlay visualisation can be seen in Figure 8.

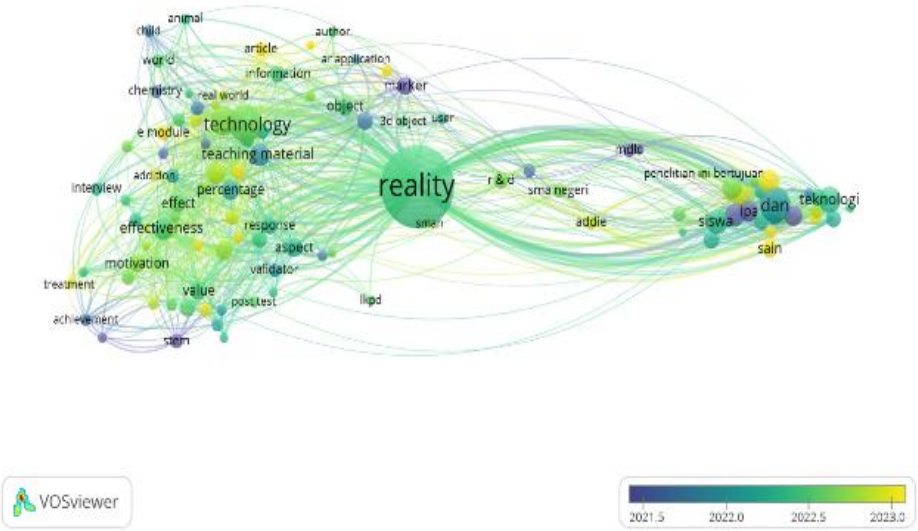


**Figure 8**. Overlay visualization of augmented reality research in science education in Indonesia (2020–2025)

Based on Figure 8, it shows two contrasting areas of yellow and dark blue. The dark purple to blue section contains longer topics in 2020-2022 such as, stem, achievements, 3d object, addie, effectiveness, treatment. The initial focus is on developing methods and evaluating augmented reality-based learning media. The green section is a topic that appears in 2022 and contains topics that continue to develop and become a bridge between trends and contains words such as, reality, technology, teaching, materail, user, high school, object, effect. This indicates that augmented reality is increasingly integrated with teaching materials and learning systems, and is used in real life in schools. In the yellow section are topics that appear in 2023 to 2025 and are the latest trends and topics that are currently developing. This section contains topics such as, students, science, information, response, percentage. This highlights the focus of research on improving student learning outcomes, and scientific publications. In addition, there is a trend towards analysing the direct effectiveness of science students, as well as the use of quantitative data.The results of the analysis based on density visualisation can be seen in Figure 9.

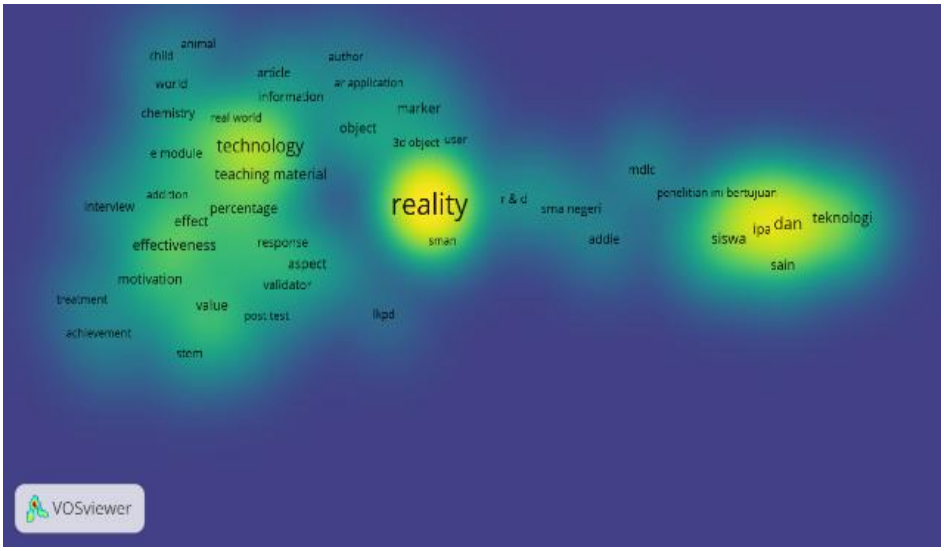


**Figure 9**. Density visualization of augmented reality research in science education in Indonesia (2020–2025)

Based on Figure 9, the density visualisation results show the frequency of occurrence and connectedness of keywords divided into three colour zones. The bright yellow zone contains topics such as, reality, science, students, technology. This shows that the term 'reality' in augmented reality is the most dominant keyword and the terms science, students, and technology are a big focus in the context of augmented reality implementation in science education. The yellow green zone contains topics such as, teaching materials, effectiveness, motivation, 3d objects. This area reflects the development and evaluation elements of augmented reality. The blue-purple zone contains topics such as, stem, achievement, interview, e-module, post-test, validator, treatment. These topics rarely appear in research or only in certain studies.

The results showed that the trend of augmented reality research in the field of science based on the number of publications each year experienced fluctuating developments. As shown in Figure 2, there is a decline in the number of publications in 2025. However, it is important to note that this decline does not indicate a decrease in researchers' interest in AR technology in absolute terms. This is a limitation of the data, as 2025 was still ongoing at the time this study was conducted. There is a time lag in the article indexing process in the Google Scholar database, so the 2025 data in this study does not yet fully reflect the total annual publications. One of the publications published in 2020 is research conducted by Ni Putu Dinayusadewi which discusses the development of augmented reality applications as a medium for learning mathematics in elementary schools on geometry material (Dinayusadewi, 2020). In 2021, one of the publications published is research conducted by Lainufar which discusses the exploration of the potential use of GeoGebra augmented reality in a project-based learning environment in geometry (Lainufar, 2021). In 2022, one of the publications published is research conducted by Yonatan Vari which discusses the use of augmented reality to train 21st century thinking skills in science learning (Vari, 2022). In 2023, one of the publications published is research conducted by Agung Laksono which discusses improving cognitive learning outcomes on the theme of the solar system through digital modules for junior high school students (Laksono, 2023). In 2024, one of the published articles is research conducted by Aulia Rahma which discusses the use of augmented reality-based worksheet

in science learning for junior high school / MTs students (Rahma, 2024). In 2025, one of the publications published is research conducted by Venny Haris which discusses the development of magnetic field learning modules integrated with augmented reality for high school (Haris, 2025).

Augmented reality research trends in the field of science based on the type of publication provide very contrasting results where scientific publications in the type of journal articles have a very large number of publications when compared to publications in the type of proceedings articles. Scientific journal type publications have higher scientific standards, stricter publishing processes, and focus on more in-depth research publications. In addition, in the Director General of Higher Education Circular Letter Number 152/E/T2012 dated 27 January 2012 concerning Publication of Scientific Work states that the requirements for graduating Bachelor, Master, and Doctoral students must publish papers published in scientific journals (Hasbi, 2017), so this is what makes publications in the form of journal articles more than in the form of proceedings articles.

Augmented reality research trends in the field of science based on the field of science studies have many imbalances where of the five fields of science studies only the field of science studies has the highest number of publications. This happens because many studies are conducted on elementary and junior high school research subjects where physics, chemistry and biology studies are included in one subject, namely science. The presence of mathematics topics (such as geometry or solid geometry) alongside science topics (such as the solar system or cell biology) indicates that AR in Indonesia is most commonly applied to subject matter with abstract and spatial characteristics. These two fields require a high level of visualization that is difficult to achieve through conventional two-dimensional media. Therefore, researchers in Indonesia tend to use AR to bridge the understanding of concepts that require mental rotation and depth perception, both in the context of mathematical calculations and scientific phenomena.

Augmented reality research trends in the field of science based on research subjects can be seen that most research subjects are school students (elementary, junior high, high school) with the largest number of high school student subjects. The predominance of high school students as subjects of AR research in Indonesia can be explained through Piaget's Theory of Cognitive Development. According to Jean Piaget, human cognitive development is divided into several main stages, with the stage most relevant to secondary education being the formal operational stage (beginning at age 12 and older). At this stage, individuals begin to develop the ability to think abstractly, logically, and idealistically without the need for the direct presence of physical objects. Students in upper secondary school are in the formal operational stage, during which they begin to grapple with scientific concepts that are abstract, theoretical, and microscopic (such as molecular genetics or chemical kinetics). The abstract nature of this material demands a high level of spatial visualization. AR serves as a cognitive bridge that transforms these abstract entities into concrete 3D visual representations. This aligns with Cognitive Load Theory, where the use of AR helps reduce students' intrinsic cognitive load by providing direct visual assistance, thereby facilitating the assimilation of complex information. Conversely, at the elementary school level, science material tends to be more phenomenological and observable directly in the surrounding environment, so the urgency of using immersive technologies like AR is not as high as at the high school level. It is these differences in material characteristics and stages of mental development that have led researchers in Indonesia to focus more on implementing AR at the upper secondary level.

Augmented reality research trends in the field of science based on the type of research data looks very lame between quantitative data types and qualitative data sources where the number of publications with quantitative data types has a very large number compared to qualitative data types. The results of the analysis show that quantitative research designs dominate over qualitative

ones in the AR literature in Indonesia. This indicates that current research trends remain at the efficacy testing stage, where researchers tend to focus on statistically measuring learning outcomes, science literacy, or motivation through experimental methods. The low percentage of qualitative research is a critical finding in this study. Qualitative research in the context of AR typically takes the form of case studies or ethnographies that explore in depth the process of student interaction with technology, teachers' pedagogical barriers, or changes in collaborative behavior in the classroom. The lack of qualitative data creates an "information gap" regarding the psychological mechanisms and actual field constraints that occur during AR implementation; therefore, future research should be more directed toward qualitative or mixed-methods approaches to obtain a more comprehensive picture.. This research is in accordance with an article published on the UNESA web page of the faculty of education on 9 December 2024 which explains that quantitative research types have advantages, namely, high objectivity which reduces researcher bias, generalisation to a wider group, efficient with easy to obtain data in a short time, easy replication, and suitable for testing cause-and-effect hypotheses (Methodology, 2024). This is what encourages many researchers to conduct quantitative type research.

The results of the network visualisation analysis show that there are strong interconnections between the clusters, especially through the word 'reality' in augmented reality, indicating that all aspects (technology, education, evaluation) are highly integrated in the research. These connections indicate a multidisciplinary approach, integrating technology, pedagogy and evaluation. The implication for research trends is that AR research in science is highly developed, especially in secondary education. The main focus is not only on technology development, but also on its application in learning and its effect on student learning outcomes. One of the studies related to the application of augmented reality to student learning outcomes is research conducted by Helen showing that student learning outcomes increase with an N-gain value of 0.82 which means that augmented reality-based Flashcard learning media made can improve student learning outcomes (Helen, 2023).

The results of the overlay visualisation analysis show implications for augmented reality research trends in the field of science. This overlay visualisation shows that AR research in science has transformed from the development aspect to the implementation and evaluation aspect and has experienced a shift in topics that shows the maturity of this field. This is evidenced by the fact that in 2021 and back, most research was only based on the development of learning media. One example of augmented reality development research is research conducted by Adrian in 2020 which discusses the design of AR-based electronic books on learning to build spaces in elementary schools (Adrian, 2020). This research only discusses media development without implementing it to students. Meanwhile, from 2023 until now the latest trend emphasises the direct impact on students and science learning in the form of augmented reality implementation on students. Meanwhile, since 2023 until now the latest trend emphasises the direct impact on students and science learning in the form of augmented reality implementation on students. One example of research on the implementation of augmented reality is research conducted by Agustin which discusses the effect of AR media assisted by assemblr on the learning outcomes of junior high school students (Agustin, 2023).

Based on the results of the density visualisation analysis, it can be seen that the dominant focus in current research is on the application of AR in the context of science for students, with an emphasis on technology and its learning effects. Technological aspects such as 3D objects remain important, but are beginning to shift towards student learning outcomes and learning effectiveness.

Low density areas could be less explored research opportunities such as, AR integration in STEM learning and more in-depth evaluation using qualitative methods or learning outcome tests.

## 4. Conclusion

The conclusion of this study shows that augmented reality research in the field of science between 2020 and 2025 can provide information on how augmented reality is applied and the topics of augmented reality applications that need to be researched in the future. Augmented reality research in the field of science has increased significantly every year. Most augmented reality research publications are journal articles. Augmented reality research is widely applied to various fields of science, especially natural science. The subjects of augmented reality research range from elementary education students to higher education and teachers with the highest number of high school student subjects. Most augmented reality research methods are quantitative research. Based on the results of the VOSviewer analysis, it can provide information that augmented reality research is a topic that has many relationships with other variables in the field of science and has received a lot of researcher attention in recent years. This study indicates that although the AR trend in Indonesia continues to grow, there remains a significant gap in the exploration of qualitative methods, such as barriers to AR learning and changes in students' learning behaviors. Based on the results of this bibliometric study, the following recommendations can be made: for teachers, AR should be used to integrate inquiry-based worksheets rather than merely as static visual aids. For the government, there is a need for policies that support the standardization of digital infrastructure and the provision of validated AR repositories, as well as equitable continuing education for teachers at all levels of education.

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