

Deployment of Augmented Reality Across Science Topics in Junior High School: A Review

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Abstract: The practical application of science education often encounters various challenges, particularly in conveying abstract scientific concepts in a tangible and meaningful manner for students. Many concepts in junior high school science, such as astronomical phenomena, biological structures, and environmental systems, are inherently abstract and difficult to visualize through conventional instructional approaches. Augmented Reality (AR) offers opportunities to integrate virtual and real environments, enabling abstract scientific concepts to be represented in interactive, visual forms that may support conceptual understanding and student engagement. This study aims to describe and explain patterns of Augmented Reality (AR) utilization across science topics in junior high school education in Indonesia. A Systematic Literature Review (SLR) was conducted following the PRISMA protocol to ensure transparency and rigor in the review process. A comprehensive literature search was conducted across Google Scholar, Scopus, and ERIC databases. Of the 874 articles identified, 17 studies met the predetermined inclusion criteria and were selected for data synthesis. The findings indicate that research on AR-based learning media at the junior high school level in Indonesia remains relatively limited, with much of it focused on specific science topics. The structure and function of living organisms and the solar system were the most covered topics, with 4 articles (31%) and 3 articles (23%), respectively, while other topics each had 1 article (7.7%). In contrast, earth and environmental science topics, including ecology and biodiversity, receive comparatively less attention. This review is limited to open-access studies conducted in Indonesia between 2016 and 2025 and focuses exclusively on junior high school science education. The results of this study provide an overview of current research tendencies and may serve as a reference for future studies seeking to examine AR implementation more comprehensively.

Keywords: Augmented Reality; Learning Media; Science Learning; Systematic Literature Review.

Introduction

Natural science constitutes a discipline that methodically investigates the cosmos, distinguished by a coherent corpus of knowledge that connects inherent phenomena to physical reality, which is fundamentally grounded in empirical observation and inductive reasoning [1]. Science learning in practice still often faces various challenges, one of which is that not all science concepts can be presented in real life to students. The concepts of science that cannot be presented in real terms are caused by some abstract science materials [2]. The abstract scientific concept includes temperature and heat because they can be felt but not directly seen [3]. Other concepts include atomic structure, circulatory system, photosynthesis, and many more. Abstract scientific material will be difficult for students to understand because it cannot be observed directly. This can lead to students lacking an understanding of science concepts. In addition, students' poor understanding of concepts is also caused by their lack of enthusiasm for learning and active involvement during the learning process. This affects students' ability to understand new concepts, especially since they have not fully understood the concepts they have already learned. Technological advancements have addressed this problem with the advent of augmented reality.

Augmented reality (AR) is a technology that merges the virtual and real worlds, creating an immersive, interactive learning experience [4]. The integration of technologies such as AR in education has attracted significant attention for its potential to not only improve the learning experience [5] but also enhance conceptual understanding and engage students' interest, especially in subjects with abstract concepts [6]. Augmented reality combines the virtual and real worlds, enabling teachers to project abstract information into an interactive environment. The application of augmented reality in education aims to enable students to have a meaningful learning experience, so that the concepts they acquire can be stored in long-term memory.

Many studies have explored the potential of AR in education. In a systematic literature review, analyze the implementation of AR in the field of education [7]. The trend of AR implementation in science learning [8-9]. The use of AR in student learning activities and in understanding concepts and learning interests [10-11]. However, there have been few systematic studies examining the use of AR in science learning that focus on how AR affects specific science topics and their respective characteristics, especially at the junior high school level in Indonesia. Therefore, a systematic literature review (SLR) is needed to map the distribution, effectiveness, and open research gaps from the

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literature published in the last decade. Unlike several previously cited reviews that categorize studies based on types of technology or measured learning outcomes, this systematic literature review (SLR) explicitly focuses on the science topics investigated and the content characteristics underlying the use of augmented reality within each topic. By systematically examining science topics and their inherent characteristics, this SLR aims to provide a deeper understanding of the relationship between the abstract nature of science content and pedagogical decisions to integrate augmented reality, thereby yielding more specific implications for the development of instructional media and science teaching practices.

Research Methods

This literature review uses the systematic literature review (SLR) method, which is used to review and analyze pre-existing studies using a series of systematic study systems. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework is used to ensure transparency and accuracy in the review process. The planning stage is the first stage of an SLR. In the planning stage, research questions, databases, keywords, and inclusion and exclusion criteria are determined to facilitate implementation.

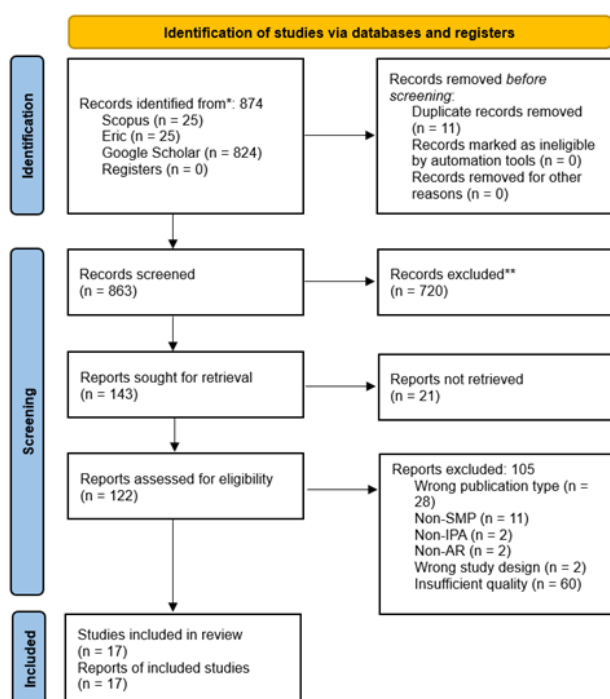


Figure 1. Review Process Using The PRISMA Framework

In this SLR, bias is minimized through the use of the PICO framework in formulating research questions. The initial research question was the extent of augmented reality learning media implementation in junior high school science instruction in Indonesia over the last 10 years. To clarify the scope of the review and to explain how potential bias was minimized, the PICO framework and explicit inclusion–exclusion criteria were employed. In this SLR, the PICO framework comprises: (P) junior high school science students and science teachers in Indonesia; (I) augmented

reality–integrated instructional media implemented in science learning, including classroom implementation, teachers’ perceptions, and AR-specific training programs for junior high school science teachers; (C) science instruction without the use of AR or conditions prior to AR implementation (where available); and (O) science learning outcomes, student engagement and motivation, as well as teachers’ perceptions and readiness, based on primary data. In addition to the application of the PICO framework and stringent inclusion–exclusion criteria, potential bias was further minimized by restricting the review to publications based on primary data and by conducting a systematic article selection process. Furthermore, the conducting stage refers to the PRISMA framework. Figure 1 shows information on the implementation process through the PRISMA framework.

In the early stage (identification), the literature search was conducted by entering several keywords into the Scopus, ERIH PLUS, and Google Scholar databases. The Google Scholar database search was conducted using the Publish or Perish 8 application. At the search stage, 874 articles were found across the three databases. Table 1 presents the detailed results from a September 2025 search.

In the second stage (screening), literature with similar content is excluded to ensure no duplicate literature. A total of 11 studies were excluded due to duplication, leaving 863. Furthermore, a screening of titles and abstracts was carried out, during which 720 publications were eliminated, leaving 143. Then the screening is carried out in full text. Several records could not be retrieved as full manuscripts, either through the available links in the downloaded (RIS) database files or via manual searches using search engines; some were also inaccessible due to paywalls.

Table 1. Search Queries and Search Results

Data base	Search query	Filter setting	Search result
(Search period: 29th September 2025)			
Scopus	Augmented reality AND junior high schools AND science learning	Year: 2016-2025 Excluded: Conference review	25
Eric	"Augmented reality" AND "junior high schools"	Since 2016	25
Google Scholar	Media pembelajaran augmented reality AND IPA SMP NOT SD NOT matematika NOT geometri	2016-2025	824
Total			874

The literature available for full-text screening is 122 articles. Full-text filtering is performed according to pre-planned inclusion and exclusion criteria. Then, up to 105 pieces of literature were eliminated, as detailed in Figure 1. Finally, 17 articles were selected for data extraction. Due to resource constraints, data extraction was conducted by a single reviewer using a structured Microsoft Excel worksheet containing predefined extraction categories. To enhance data validity, a self-checking procedure was

implemented by re-examining the full texts of all included studies and cross-verifying the extracted information against the original source sections. Extraction rules and variable definitions were documented to ensure consistency throughout the process. After data extraction was carried out on the publications that passed, it was then synthesized based on the similarity of the theme. The last stage is reporting.

Table 2. Inclusion-Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Published since 2016	Published before 2016
Limited to the junior high school level in Indonesia	Other levels
AR integrated learning media	Learning media is not integrated with AR
AR integration only in science learning	AR integration is not in science learning
The teacher's perception and AR training programs only applies/attended to junior high school science teachers	The teacher's perception and AR training programs are not only applied to/attended by junior high school science teachers
The form of publication type is an article	The form of publication type is other than an article
Publication types using primary data	Review, meta-analysis, and bibliometrics

Results and Discussion

Seventeen articles were found that examined augmented reality in junior high school science learning in Indonesia from 2016 to September 2025. The last publication was in 2025, and the earliest was in 2019. Most of the publications (15 articles) are from the last five years. The publications found used *R&D*, quasi-experimental, survey, and action research types.

Research on AR in science learning often uses research and development (R&D) models. R&D models can be used to develop and validate educational products [12]. This is because the R&D model has complex stages, namely analyzing research related to the product to be developed, designing, developing, implementing, and evaluating the product [13]. By using the R&D model, AR research can be more structured, innovative, and actively involve researchers in the development process. Eight publications are R&D studies. [14], [15], and [16] focus solely on product validity or feasibility and do not include a product trial stage. Meanwhile, [17], [18], [19], [20], and [21] not only focus on developing but also researching the effectiveness of AR learning media. There were also preliminary studies conducted by [22], which focused on analyzing the need for the development of innovative smartphone-based augmented reality (AR) learning media, and a need analysis conducted by [23], which was the initial stage of analysis before the development of augmented reality integrated e-modules using the ADDIE model.

In addition to R&D, quasi-experimental research is quite widely used in AR technology research. This relates to the characteristics of AR as a technological innovation that requires initial evaluation and proof of effectiveness in the

context of learning. In quasi-experimental research, some use a one-group pretest-posttest design, while others use control classes and experimental classes. In many studies, researchers chose a one-group pretest-posttest design because of its practical nature and suitability for early-stage media trials. This design allows researchers to measure students' improvement in understanding before and after using AR directly, without the need for a comparison group, making it particularly relevant when the media is still in development or when the research is conducted in a class with a limited number of participants. In addition, the design is effective at identifying the initial impact of AR on understanding abstract science concepts, such as organ structures, body system mechanisms, and astronomical phenomena that cannot be observed in real life.

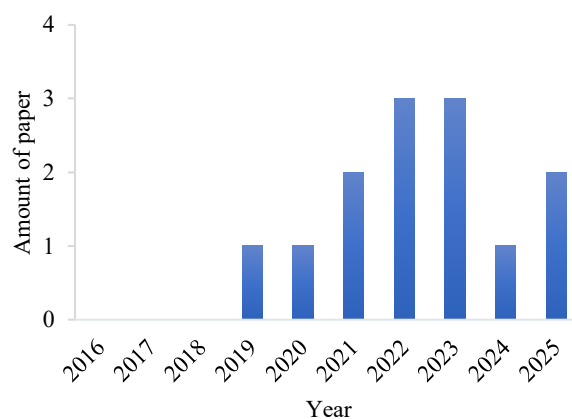


Figure 2. Publication of AR Learning Media from 2016 to 2025

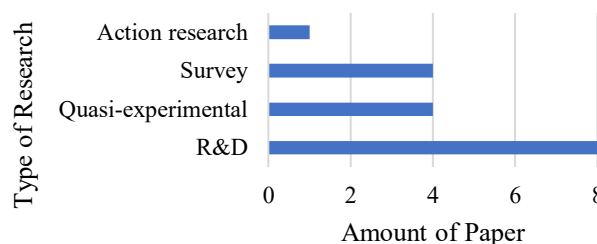


Figure 3. Types of Research in AR Learning Media Publications

Meanwhile, quasi-experimental designs with control classes and experimental classes are also widely used. In AR research, this design allows researchers to compare the effectiveness of AR with conventional learning methods or other media, thereby showing whether the improvement in learning outcomes is indeed due to AR rather than external factors such as classroom conditions. Quasi-experiments are especially important at advanced stages of research, when AR has matured and needs to be tested more rigorously to demonstrate its superiority over traditional methods [24]. Overall, the use of these two designs shows that there is a multi-level approach to AR research in science learning, starting with the initial evaluation of the media's effectiveness through a pretest-posttest design, then continuing with comparative proof using quasi-experiments. This pattern reflects the need to assess AR as a medium that is not only innovative but also viable and proven to significantly increase learning effectiveness. Another type of

research that emerged was the survey method conducted by [25], [26], [23], and [22]. Research using this method primarily aims to understand students' and teachers' perceptions of AR learning media. The last type of research to emerge was action research conducted by [27] to evaluate science teachers' positive response to the use of AR following training and workshops.

Furthermore, judging from the integration of AR in science learning, the results of the synthesis show that the most dominant topic in the research on augmented reality (AR) learning media is the structure and function of living things, including the respiratory system and excretory system [17], circulatory system [16], the movement system of living things [14], and the structure and function of plant tissues [28]. The circulatory system has abstract characteristics and processes that cannot be felt directly [29]. AR media visualizes abstract concepts to understand and structure object models [30], [31], [32], [33].

Research on the topic of the solar system [26], [15], [34]. The solar system is also widely researched because it encompasses large-scale astronomical concepts that students cannot observe directly. When using the AR learning media application, students can view the shapes of the planets in the solar system from various angles in 3D and receive explanations in text and audio to help them understand how the planets model their shapes [35]. It is easier for students to understand material concepts, such as moon phases, because they can observe them in 3D without having to observe them directly in the field [36]. AR provides a real-life, interactive representation of planetary systems, celestial object orbits, and the relative positions of objects. This dynamic visualization helps learners understand concepts that are usually abstract, such as revolution and rotation, distances between celestial objects, and periodic movements in the solar system [37], [38], [39], [40].

Furthermore, several studies have focused on AR in work and simple machine materials [20] and motion concepts [14]. Both of these topics relate to mechanical concepts such as force, motion, levers, muscles, and skeleton that require an understanding of cause-and-effect relationships and process visualization. AR facilitates this understanding through interactive simulations that show how tools or organs work, so students can observe the mechanisms of movement and the application of force more clearly than in conventional experiments.

The use of AR in earth and environmental materials, such as ecosystems and biodiversity, was also found, even though there was only one [18] fewer than for anatomy or the solar system. AR integrates real environments with digital overlays [41]. This is because environmental topics are basically contextual and can be observed directly around students. Nevertheless, AR is still considered useful for visualizing intangible processes, such as energy flows in ecosystems, changes in species populations, or the cumulative impact of global temperature increases.

In addition, several studies have applied AR to molecular physics topics such as particles, atoms, ions, and molecules [23], heat and heat transfer [19], dynamic electricity [21], and sound waves [42]. These concepts are

at a microscopic or theoretical level, so they cannot be directly observed. AR provides visual representations that make it easier for learners to understand the structure of matter, charge interactions, the direction of electrical flow, sound wave propagation patterns, and heat transfer mechanisms. AR allows students to explore concepts invisible to the naked eye and make them visible [43], as well as display real objects that have never been seen before [44]. Although not as popular as anatomy or solar system material, AR is still considered effective to overcome the gap between abstract concepts and students' concrete understanding.

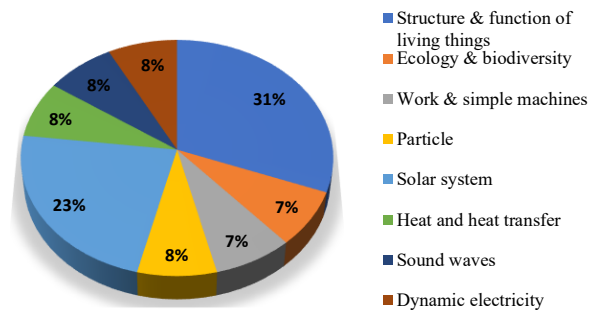


Figure 4. Learning Topics in AR Learning Media Publications

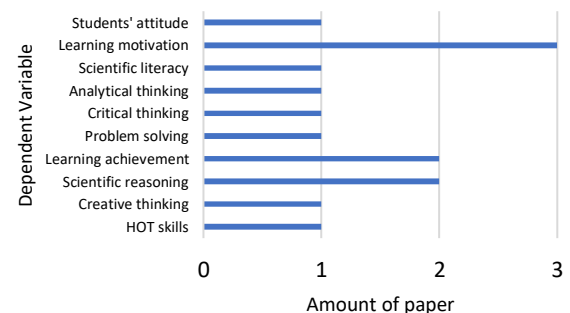


Figure 5. Dependent Variables in The Publications of AR Learning Media for Junior High School Science

AR integration has several influences on science education, as reflected in the distribution of the dependent variables that the research focuses on. These variables are learning motivation [45], [28], and [15]; learning achievement [34] and [28]; scientific reasoning [20] and [18]. Other variables reported in only a single article included high-order thinking skills [17], creative thinking and attitude towards science [42], problem-solving [28], critical thinking [21], analytical thinking [19], and science literacy [16]. Thus, the research's focus on learning motivation, learning achievement, and scientific reasoning skills illustrates the tendency for AR technology to be positioned not only as a visual aid but also as a learning technology with the potential to improve students' affective, cognitive, and scientific thinking processes. These three variables were chosen because they represent the main competency dimension in science education and are the most sensitive indicators for detecting the pedagogical impact of AR-based technology.

Among the publications is research focusing on teachers' perspectives on AR in science learning. An action research article examined the positive responses of 24 science teachers after participating in training and workshops on creating AR learning media for global

warming materials [27]. Marker-based AR was chosen based on an analysis of learning needs arising from problems in Sikka, NTT, related to unequal internet access. After attending the training and workshops, teachers showed high optimism about using AR in science learning.

Table 3. Review and Analysis of the Selected 17 Research Papers

Authors, Year	Title	Methods	Variables	Topics	Research Result
14	Textbook Enriched with Video Augmented Reality: Contextual in Motion Concept Learning in Junior High School	R&D	Textbook feasibility	Motion concept	Based on the results of the materials, media, and learning feasibility test, textbooks enriched with AR videos were found to be very effective for contextual learning of motion concepts.
15	Development of student worksheets based on Augmented Reality Sub Material Phases of the Moon to Increase Student Learning Motivation	R&D	Worksheet feasibility & practicality; Perceived learning motivation measured via questionnaire	Solar system	Based on the findings from the assessment of student learning motivation, AR-based LKPD is valid for increasing learning motivation.
16	Development of AR-based Interactive Teaching Materials Equipped with the IBL-STEM Model to Improve the Scientific Literacy of JHS Students on the Topic of the Human Circulatory System	R&D	Product feasibility	Human Circulatory System	Media validation indicates that AR-based interactive teaching materials using the IBL-STEM model are highly feasible, and readability tests show very good results.
17	Virtual – Augmented Reality (VAR) for Science Learning: Development and Impact on Students' HOTS Skills	R&D	Product feasibility, HOTS Skills	Excretory and respiratory system	The study found that students' HOTS skills increased significantly when VAR-integrated learning tools were used in science subjects.
18	STEM-AR-based ecology and biodiversity e-book development for increasing students' scientific reasoning	R&D	Product feasibility, Students' scientific reasoning	Ecology & biodiversity	The analysis showed that using STEM-AR-based e-books increased scientific reasoning abilities, with an N-Gain of 63% in the moderate category.
19	Integration of Augmented Reality in Physics E-Module: Heat and Heat Transfer Study through Ulos Making for Enhancing Analytical Thinking	R&D	Product feasibility, Analytical Thinking	Heat & heat transfer	The effectiveness test showed a significant increase in students' analytical thinking skills, with an N-Gain of 0.58 (moderate). Observations of student engagement yielded an overall average score of 4.35 (very high).
20	Developing Madura Local Content and Augmented Reality-Based Digital Textbook to Improve Scientific Reasoning Ability	R&D	Product feasibility, Scientific Reasoning Ability	Work & simple machine	Based on the score gain obtained on each indicator, the digital textbook developed is effective in improving students' scientific reasoning skills.
21	Augmented Reality-Based Student Worksheet to Stimulate	R&D	Product feasibility, Critical thinking skills	Dynamic electricity	The AR-based LKPD, developed on the concept of dynamic electricity, is effective in stimulating students' critical

	Students' Critical Thinking Skills					thinking skills, with an N-Gain of 0.67 in the quite effective category.
22	Android-based augmented reality in science learning for junior high schools: Preliminary study	Survey	-	-		A needs analysis shows that the development of smartphone-based augmented reality is well-suited to addressing the lack of innovative learning media.
23	Student needs analysis for the development of augmented reality integrated e-modules about particles in science learning	Survey	-	Particle		Based on student and teacher questionnaires, it is necessary to develop e-modules with AR on particles, atoms, ions, and molecules, which are considered difficult subjects.
25	Investigation on teachers' perception of augmented reality as interactive media for science learning	Survey	Teacher perception	-		Based on the questionnaire, applying AR media to science teaching materials is believed to foster student enthusiasm and motivation, thereby creating an effective learning atmosphere.
26	Students' Perception of Augmented Reality Learning Media on Solar System Topics	Survey	Students perception	Solar system		The research results prove that AR learning media provides a positive perception of learning about solar system material.
27	The Science Teachers' Optimism Response to the Use of Marker-Based Augmented Reality in the Global Warming Issue	Action research	Teachers' perception	-		Based on the post-training questionnaire, the teachers showed high optimism about using AR in science learning.
28	Augmented Reality for Teaching Science: Students' Problem-Solving Skill, Motivation, and Learning Outcomes	Experimental	Problem-solving skill, motivation, and learning outcomes	Structure & function of plant tissue		The use of AR media effectively improves students' problem-solving skills, motivation, and learning outcomes.
34	Implementation of Mobile Augmented Reality on Physics Learning in Junior High School Students	Experimental	Learning achievement	Solar system		Based on pretest-posttest scores, students who use mobile-based AR have higher learning achievements.
42	Integrating Traditional Musical Instruments into Mobile Augmented Reality: The Effect on Creative Thinking and Attitudes in Science Learning	Experimental	Creative thinking, students' attitude toward science	Sound waves		This study concludes that integrating traditional musical instruments into Mobile AR influences creative thinking and fosters positive attitudes toward science learning.
45	The Use of Mobile-Based Augmented Reality in Science Learning to Improve Learning Motivation	Experimental	Learning motivation	-		Mobile-based augmented reality media increases students' learning motivation during the learning process, as shown by pretest-posttest results in the experimental group.

In addition, [25] conducted research to examine science teachers' perspectives on AR as an interactive science learning medium that can stimulate students' curiosity, enthusiasm, and motivation. Based on

questionnaire responses from 10 science teachers in Makassar, the use of AR media in science learning has the potential to foster students' enthusiasm and motivation, thereby creating an effective learning environment. Thus,

this AR media is well-received and trusted, fostering strong enthusiasm and motivation among students and thereby improving student learning outcomes.

After reviewing the findings, several facts about AR research in science education over the past 10 years were identified. Through a review of the literature, it can be concluded that the things that must be underlined are: 1) several development studies have been carried out, but product dissemination is still lacking; 2) the dependent variables studied are still dominated by learning motivation; 3) learning approaches with local content have been widely integrated in AR learning media; 4) the form of use of AR features is still not optimal, 5) training programs have been carried out to make AR, but they still need to be multiplied, and 6) the affordability of internet access has not been resolved until now. This can be a reference for future research and a consideration for policymakers.

Conclusion

Based on a study of publications over the last 10 years, it can be said that the implementation of augmented reality in science education at the junior high school level remains limited. However, evidence suggests that augmented reality has been adopted to support learning on the material structure and function of living things, the solar system, and particle physics. These findings provide a reference for teachers to encourage the adoption of AR in science learning. Furthermore, limited research on the application of AR at the junior high school level, especially in the earth and environment, provides opportunities for further research. Schools, along with higher education institutions, should increase cooperation in procuring AR development training for science teachers. The government, in addition to striving to accelerate the equitable distribution and affordability of internet access, may be able to provide public facilities, such as AR-based science museums, to support non-formal science learning accessible to everyone.

Author's Contribution

A. Noviani: responsible for identifying articles through the databases, then carrying out the screening process, further screening, and analyzing and reviewing the selected articles according to the inclusion and exclusion criteria using Rayyan.com as an assisting tool (web-based application developed by the Qatar Computing Research Institute to support researchers in conducting Systematic Reviews and Meta-Analyses); N. Eralita: responsible for writing the research report and compiling the findings systematically and academically as part of the final documentation of the study.

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