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Article Review

Augmented reality in biology education: A systematic literature review

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Abstract: Augmented Reality (AR) has seen extensive utilization in the modern era, driven by rapid technological advancements. The aim of the Systematic Literature Review (SLR) method is to meticulously analyze and assess previous research on a specific phenomenon in a systematic and explicit manner. The search was conducted on the Scopus database using the keyword "Augmented Reality," resulting in 209 relevant articles. Out of this total, 35 articles passed the journal selection criteria and were deemed ready for analysis. The article selection process was carried out using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) model for inclusion and exclusion purposes. Since 2019, there has been a rising trend in research on augmented reality. The issue of AR can be approached through quantitative, qualitative, mixed-methods, and even development research (R&D). The most prominent author in AR research is NF Saidin. The data shows that the keyword "augmented reality" is strongly associated with "education" and "biology." These keywords are linked to concepts such as teacher training, augmented reality tools, teaching, biology learning, learning performance, e-learning, and virtual reality. Themes related to AR in education focus on teacher training in biology, which applies e-learning or mobile learning based on AR and virtual reality (VR). Articles were published by authors from 28 different countries, with authors predominantly from Asia. There are 15 institutions worldwide that fund AR research and publications. It can be concluded that the focus on AR in biology education will continue to grow, supported by the ongoing emphasis on technology in the modern era. This trend is reflected in the distribution year, research types/methods, instruments, areas of study, authors, keywords, authors' nationalities, and collaboration patterns.

Keywords: Augmented Reality; biology education; systematic literature review

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1. Introduction

Technological advancements in the current era have supported all human activities. Its rapid development has brought about changes in various areas of life, including education (Fortuna et al., 2023; Syamsinar, 2022). Many activities are now integrated with technology to support their effectiveness. The implementation of technology has started to proliferate in the field of education. Technological developments are closely related to the use of augmented reality (AR) as a learning media. AR combines the real world with virtual elements, creating an immersive and interactive learning experience. AR technology has been used in a variety of educational settings, such as business schools (Hadi et al., 2021), engineering education (Tuli et al., 2022), addiction treatment (Yang et al., 2022), and experimental education (Zhang et al., 2021).

The AR aims to integrate the real world with advanced virtual technologies, supplemented by contextual data such as audio commentary, location data, historical context, and other forms to enhance students' understanding (Safadel & White, 2019; Tuli et al., 2022; Weng et al., 2020). While educators play an irreplaceable role in the learning process, AR can enhance the delivery of learning materials through visuals, audio, and video, thus improving the effectiveness of education. This enhancement in learning effectiveness can address several student issues, such as boosting their motivation to learn. AR has been

shown to improve learning outcomes, improve students' attitudes towards the subject, and increase engagement and satisfaction (Ciloglu & Ustun, 2023; Santos et al., 2016). The use of AR in education enables effective visualization of abstract concepts, provides hands-on learning experiences, and enables learning in authentic environments. It also offers opportunities for personalized and adaptive learning. Technological developments have paved the way for the integration of AR into educational practices, improving learning processes and outcomes (Huang et al., 2016; Santos et al., 2016; Weng et al., 2020).

The AR significantly influences biology education by improving different elements of the learning process. AR applications in biology education significantly improve students' self-efficacy and motivation by making abstract and complex concepts more tangible and engaging (Ciloglu & Ustun, 2023; Wang et al., 2022). For instance, AR's ability to superimpose 3D dynamic virtual information onto the real world helps students visualize microscopic and abstract biological processes, thereby deepening their understanding and reducing cognitive load (Sung et al., 2020; Wang et al., 2022). Additionally, AR facilitates autonomous and cooperative learning, as seen in a study where students using an AR-based biology lab app developed a more positive attitude towards self-learning and better-grasped lab knowledge through interactive operations (Agrawal, 2022). The technology also enhances spatial understanding and retention of anatomical details. It is particularly beneficial in fields requiring direct skill acquisition, such as medical education (Chang & Yu, 2018; Chien et al., 2010; Kurniawan et al., 2018; Zammit et al., 2022).

Moreover, AR has been found to increase students' flow experiences and motivation, although it does not always translate into higher academic performance (Erbaş & Demirer, 2019; Wen et al., 2023). In remote education settings, AR applications like smartphone-based molecular visualization tools have proven to be powerful educational aids, offering flexibility and ease of use without extensive IT support (Weng et al., 2020). Furthermore, AR's integration with pedagogical approaches, such as inquiry-based learning frameworks, has been shown to enhance student's critical thinking, creative thinking, and knowledge creation efficacy skills significantly, particularly benefiting low-progress students (Safadel & White, 2019). AR's interactive and immersive capabilities make it a valuable tool in modernizing biology education, promoting better understanding, engagement, and retention of complex biological concepts (Agrawal, 2022; Safadel & White, 2019; Wang et al., 2022; Zammit et al., 2022).

Studying AR is crucial for understanding its application in biology education and its relationship to the tools used. This research can lay the groundwork for improving the quality of teaching and learning activities with AR technology integration (Anggrawan & Satria, 2023; Lindner et al., 2019; Wen et al., 2023; Zammit et al., 2022). Following a search in the Scopus database, we identified 35 relevant articles from 209 (total initial). These articles, published between 2015 and 2023, will be thoroughly analyzed to explore the application of AR in education, its connection to the tools used in the digital era, as well as its contribution to teacher performance and teaching and learning activities. Additionally, the study should examine publication trends during this period (based on distribution year, research types/methods, author and keywords, nationality, international collaboration, and funding sponsors). One of the most recommended techniques for such a study and analysis is the Systematic Literature Review (SLR).

Currently, there are 833 articles discussing the application of augmented reality in education. However, these articles do not specifically address the use of AR in biology education. Therefore, this SLR aims to examine and assess previous research on this explicit, systematic, and reproducible phenomenon. Additionally, the SLR aims to review and compare multiple articles published on AR themes. The purpose of using the SLR method is to provide support and references for other researchers and readers interested in the theme of AR, to develop and apply AR in biology education, and to explore its relation to the tools used in teaching and learning activities in the digital era. We initially screened all the articles obtained from the Scopus database. We focused on original article publications related to AR in education and its application with various tools in teaching and learning activities in the digital era. A review of the theme of AR in teaching and

learning activities can serve as a reference for educators and the general public to start adopting various technologies in the digital age. As state by (Garzón & Acevedo, 2019), this consideration of the collaboration between technology and education is expected to enhance the quality of education

The SLR on AR in education have garnered significant attention from researchers. One notable example is the utilization of Geogebra software as a tool to implement augmented reality in mathematics education (Hamzah & Hidayat, 2022). Their research identified 23 articles from the Scopus database using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) model. SLR related to the use of AR by showing a positive impact on learning outcomes compared to conventional teaching methods. The SLR approach allows researchers to analyze and evaluate previous studies on an explicit, systematic, and reproducible phenomenon. The goal of the SLR is to review and compare several published articles on AR themes, then serve as a foundational reference for further development and support for other researchers and readers.

2. Materials and Methods

This study is a Systematic Literature Review (SLR). This SLR systematically analyzes and evaluates previous research on a reproducible phenomenon. Defining the research question helps to establish the scope and develop a clear focus for the study. This question is formulated based on the chosen topic: "*What are the publication trends related to the theme 'Augmented Reality' in Scopus-indexed journals?*"

We used the term "Augmented Reality" in the search menu of the Scopus database. The obtained data were saved in *CSV and *RIS formats and then synchronized into Reference Manager (Mendeley). VOS-viewer software was used to visualize the data, making the information more communicative, engaging, and clear. The search history in Scopus was as follows: "(TITLE-ABS-KEY ("augmented reality" +biology) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "SOCI")))". Using these keywords and search patterns, we found 209 articles. We applied the PRISMA model for inclusion and exclusion criteria, following the model used by Gallagher et al. (2016) in their article. The PRISMA diagram was used for a systematic review detailing the database search, the number of abstracts screened, and the retrieval of full-text articles. The key inclusion criteria for this SLR are: (1) articles published from June 2015 to August 2023; (2) only open-access articles; (3) publications classified as research/original articles; (4) subject areas in social sciences and computer science; and (5) articles published in English related to "Augmented Reality" research. The sequence of inclusion and exclusion processes is presented in Figure 1.

Based on Figure 1, we initially found 209 articles in our search. We then filtered for research/original articles, which resulted in 87 articles (excluding 122). Next, we applied the criterion of articles being in English, resulting in 86 articles, thereby excluding 1 article. We then selected only open-access articles, reducing the number to 55, thus excluding 31 articles. Subsequently, we used the inclusion criteria of subject areas "Social Science and Computer Science," which led to 35 articles completing the criterion (excluding 20 articles). We declined subject areas that did not fit, such as Sciences, Earth and Planetary Sciences, Biochemistry, Genetics and Molecular Biology, Pharmacology, Toxicology and Pharmaceutics, Multidisciplinary, and Medicine. In the final phase, we reviewed the remaining articles to ensure they matched the discussed theme, had accessible full texts, and were published in English. Consequently, we obtained 35 articles that met all criteria and no excluded articles at this stage.

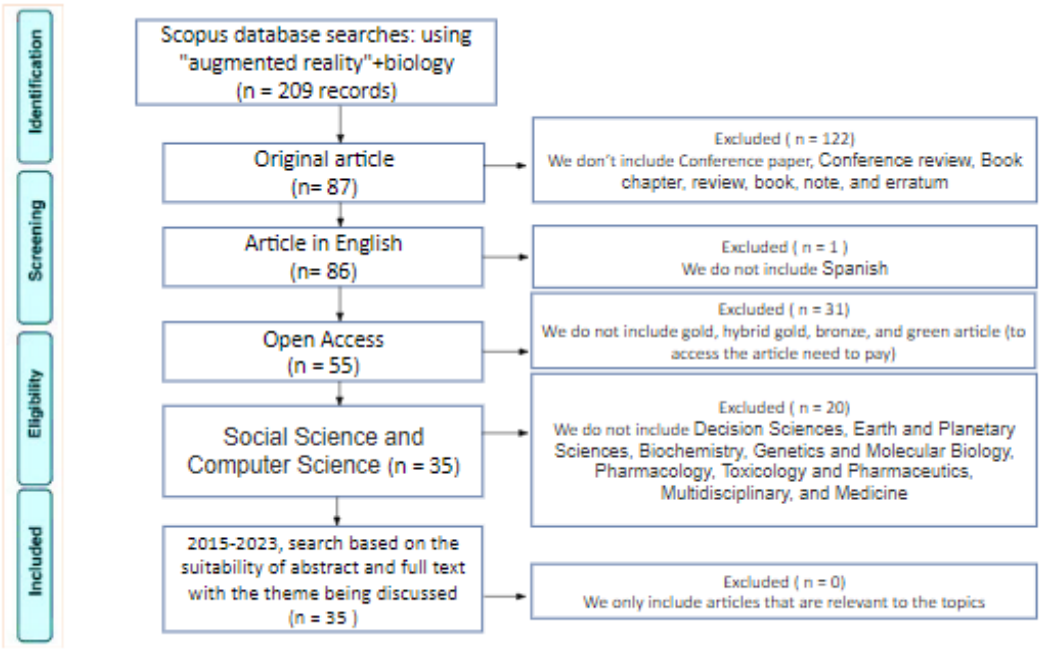

Figure 1. Systematic review flow diagram. Caption: the PRISMA flow diagram for the systematic literature review detailing the database searches, the number of abstracts screened and the full texts retrieved.

Based on Figure 1, it can be seen that in the initial search we found 209 articles. Then we only took articles that were research articles/original articles. There were 87 articles that met the criteria, which means 122 articles were excluded. Next, we use the Articles in English criteria. There were 86 articles that met the criteria, which means 1 article was excluded. We only used Open Access articles and with that criteria there were 55 articles that met the criteria. There are 31 articles excluded. Then we used the inclusion criteria for the field of science or subject area "Social Science and Computer Science". Those that met the criteria were 35 articles, which means 20 articles were excluded. We declutter subject areas that are not appropriate, such as Sciences, Earth and Planetary Sciences, Biochemistry, Genetics and Molecular Biology, Pharmacology, Toxicology and Pharmaceutics, Multidisciplinary, and Medicine. In the final phase, we re-examine existing articles, ensure the articles are in accordance with the themes discussed, ensure the full text is accessible, and the articles are published in English. Based on this, we found 35 articles that were appropriate or met the criteria, which means 0 articles were excluded.

3. Results

3.1. Distribution year

Figure 2 shows the number of articles published per year from 2015 to 2023. Based on Figure 2, it can be seen that the highest number of publications on the science learning theme was in 2022 and 2023, namely 8 articles, which was the year after the COVID-19 pandemic occurred. In 2023 only 8 articles were found. Thus, it can be said that there is an increasing trend in research regarding AR in the last year. However, it is very possible that the AR theme will increase considering that this data search was carried out at the beginning of October 2023. It is very possible that the number of articles on the Augmented Reality theme published and recorded in the Scopus database in November-December 2023 will increase.

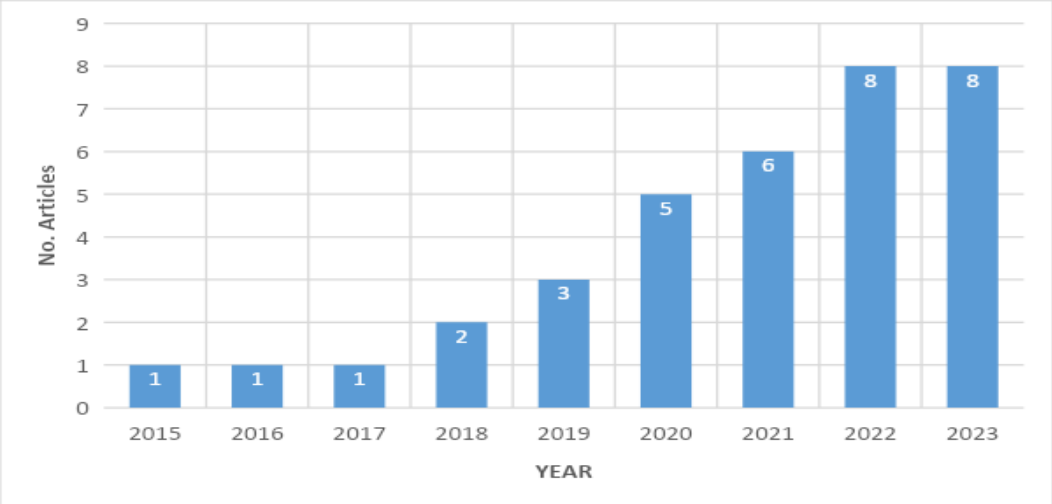

Figure 2. Distribution year of article

3.2 Research types/methods

The trend of types of research related to "Augmented Reality" themes is presented in Table 1. The AR research is predominantly carried out with a qualitative approach (21 articles). Quantitative research is also relatively large, with the number reaching (8 articles). This shows that the issue of augmented reality can be approached quantitatively or qualitatively. Therefore, several researchers are also interested in using mix-methods (4 articles). Another interesting thing is the augmented reality trend which is approached by R&D.

Table 1. Types of research on science learning themes

No	Type of Research	Amount	References
1	Quantitative	8	(Al-Muqbil, 2022; Cahyana et al., 2023; Cejka et al., 2021; Chuang et al., 2023; Kumar et al., 2023; López-Cortés et al., 2021; Petrov & Atanasova, 2020; Wang et al., 2022)
2	Qualitative	21	(Abriata, 2020; Aivelo & Uitto, 2016; Annisa & Subiantoro, 2022; Borrel & Fourches, 2017; Bouksim et al., 2018; Bursjöö, 2022; Celik et al., 2020; Cortés Rodríguez et al., 2022; Fuchsova & Korenova, 2019; Gregorcic & Torkar, 2022; Lam et al., 2023; Loucif et al., 2019; Maraza-Quispe et al., 2023; Nasharuddin et al., 2021; Nuanmeesri, 2018; Pence, 2020; Reeves et al., 2021; Rodríguez et al., 2021; Saidin et al., 2015; Stojšić et al., 2022).
3	Mix-method	4	(Ciloglu & Ustun, 2023; Delgado-Rodríguez et al., 2023; Erbaş & Demirer, 2019; Schmidthaler et al., 2023)
4	Research and Development	2	(Damopolii et al., 2022; Nurhayati et al., 2022)

3.3 Author and keywords

Based on Figure 3, it can be seen that there is no connection between authors. These names can be said to be unrelated, because one author and another author do not collaborate with each other or do not cite each other.

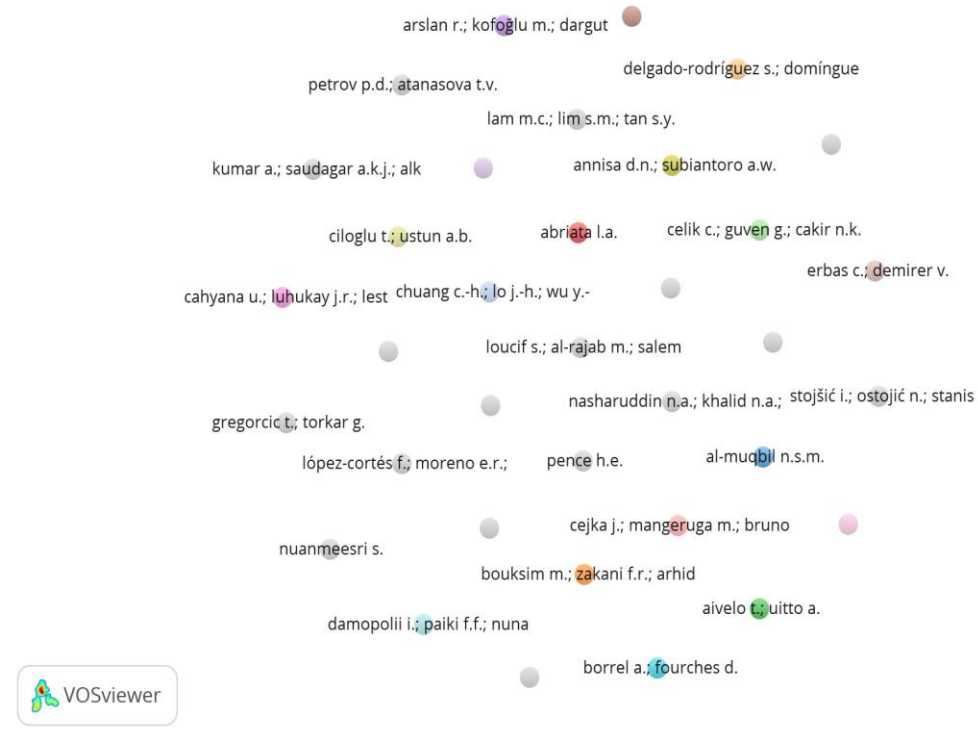

Figure 3. Dominant author and the relationship between authors in the theme of action competence

Figure 4 shows trends in keywords that are widely used by authors in writing science learning themes. Based on Figure 4, it can be seen that augmented reality really dominates its attachment to the keywords education and biology. The two keywords that are closely related to biology and education are also related to the keywords teacher training, augmented reality tools, teaching, biology learning, learning performance, e-learning, virtual reality and learning performance. This relationship is generally described by the keywords biology and education which are dominant with the attachment of augmented reality in biology learning, that is because these keywords are related to the use of augmented reality with the keywords biology and education for biology teacher training who implement AR-based e-learning or mobile learning and virtual reality (VR), then the use of "augmented reality tools" as support in "biology learning" biology learning, so that the teaching process "teaching" will produce "learning performance" or performance in teaching and learning activities after applying virtual AR or learning electronic.

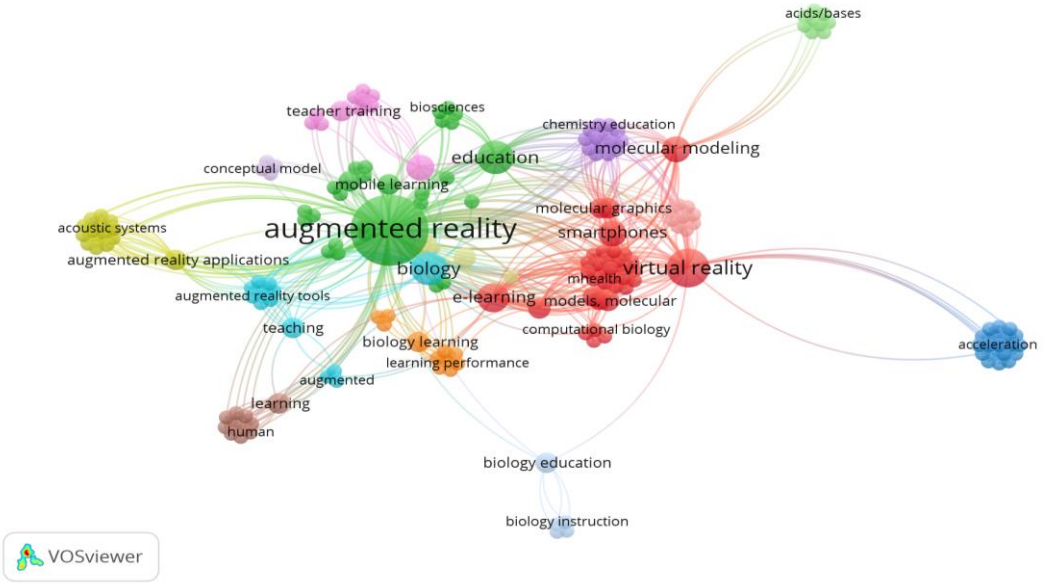

Figure 4. VOS-viewer display for type of analysis "Co-occurrence → keywords"

3.4 Author's nationality and international collaboration

Based on Table 2, it is known that there are 28 countries where the author comes from. The five countries with the most AR theme publications are Indonesia (13 articles), Malaysia (9 articles), Turkey (9 articles), United Kingdom (8 articles), and Saudi Arabia (8 articles). Based on continents, Asia contributed the most authors who published about Augmented Reality (AR) with 49 authors, followed by Europe with 47 authors, and America with 19 authors. Meanwhile, Africa has 5 authors.

Table 2. Author's nationality and continental on science learning themes

Country	Continent	Amount
Indonesia	Asia	13
Malaysia	Asia	9
Turkey	Erope	9
Saudi Arabia	Asia	8
UK	Erope	8
China	Asia	7
Peru	America	6
UAE	Asia	6
Morocco	Africa	5
Austria	Europe	5
US	America	5
Switzerland	Europe	5
Chile	America	4
Argentina	America (south)	3
Serbia	Europe	3
Spain	Europe	3
Taiwan	Asia	3
Cyprus	Europe	2
Slovakia	Europe	2

Country	Continent	Amount
Slovenia	Europe	2
Italy	Europe	2
India	Asia	2
Bulgaria	Europe	2
Finland	Europe	2
Cuba	America (North)	1
Czech Republik	Europe	1
Sweden	Europe	1
Thailand	Asia	1

Figure 5 shows collaboration in article publication carried out by authors, both cross-country collaboration, collaboration between universities in one country, and non-collaboration. Meanwhile, Figure 6 is a depiction of the distribution of scientist collaboration.

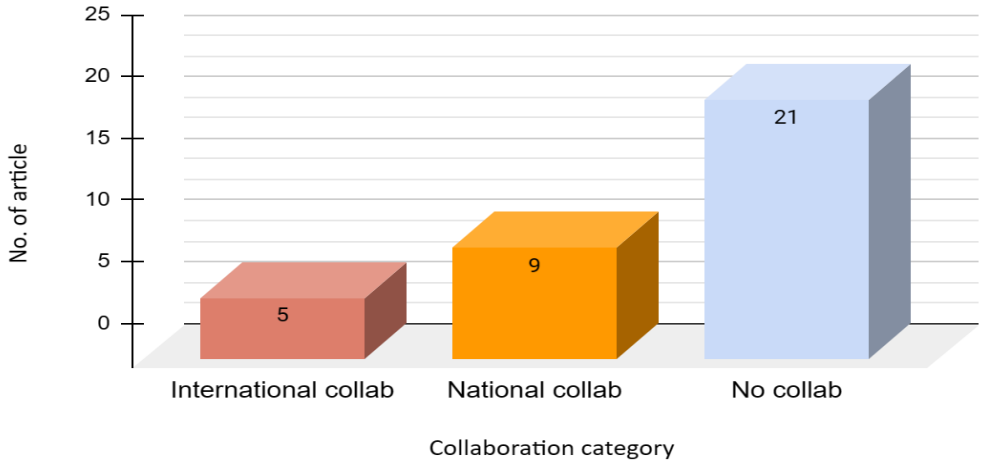

Figure 5. Author collaboration in writing articles

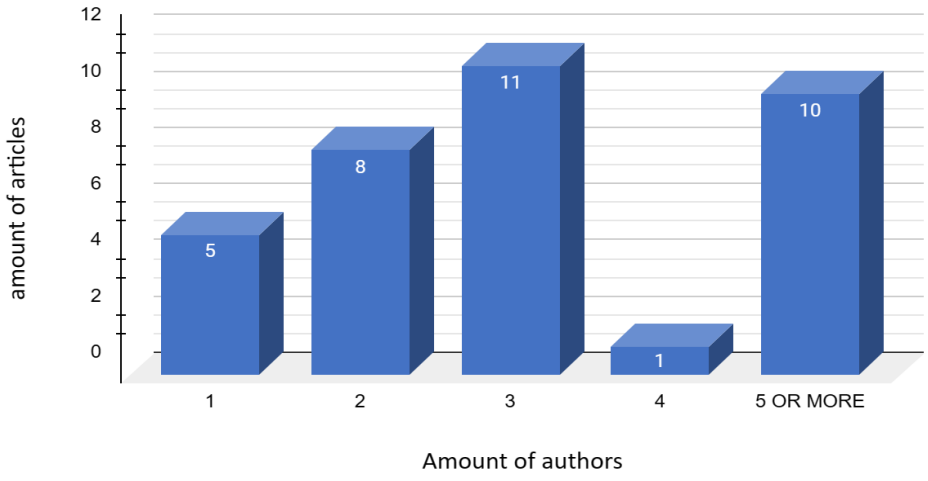

Figure 6. Distribution of scientist collaboration

Based on Figure 5, it can be stated that more articles were published with non-collaboration status (21 articles). Meanwhile, there are 5 articles with national collaborations, and 9 articles with international collaborations. If we analyze the 35 articles found (as

presented in Figure 6) we will conclude that many articles were written by more than one author. There were 5 articles written by 1 author, 8 articles written by 2 authors, 11 articles written by 3 authors, 1 article written by 4 authors, and 10 articles written by more than 5 authors.

3.5 Funding sponsor

Trends in funding sponsorship for research related to "Augmented Reality" can be seen in Table 3.

Table 3. Funding Sponsor science learning themes

No article	Funding sponsor	Amount
AR-1	The Cultural and Education Grant Agency (KEGA)	1
AR-2	Republic of Slovenia and the European Union from the European Social Fund	1
AR-3	Universiti Kebangsaan Malaysia Research Grant	1
AR-4	Solent Learning and Teaching Institute (SLTI) at Solent University Southampton	1
AR-8	Bulgarian Ministry of Education and Science under the NSP ICTinSES	1
AR-9	Kemendikbudristek	1
AR-14	Fondecyt 1180619 Project (ANID, Chilean Government). MINEDUC ESR ULS 1795 LIITEC (MINEDUC, Chilean Government)	1
AR-15	NC State Chancellor's Faculty Excellence Program	1
AR-16	Agora grant CRARP2_202370 from the Swiss National Science Foundation and grant number 21033 from the Hasler Foundation to LAA	1
AR-19	EPFL and by Spark grant CRSK-1_190376 to LAA in a project hosted by EPFL's Laboratory for Biomolecular Modeling led by MDP	1
AR-24	National Science and Technology Council of Taiwan	1
AR-26	The Directorate General of Higher Education, Research and Technology of the Republic of Indonesia through the Kedaireka Matching Fund Program	1
AR-29	The Deanship of Scientific Research at Imam Mohammad Ibn Saud Islamic University	1
AR-33	The Spanish Agencia Estatal de Investigación (AEI) and the European Regional Development Fund	1
AR-35	The Universiti Teknologi Malaysia and Ministry of Higher Education Malaysia	1

Based on Table 3, it can be seen that of the 35 articles, 15 articles were funded and the other 25 articles were not funded. 15 institutions or institutions in the world that fund research and publications on Augmented Reality. In table 3 there are funding sponsors who each fund 1 research/article about Augmented reality, namely The Cultural and Education Grant Agency (KEGA), Republic of Slovenia and the European Union from the European Social Fund, Universiti Kebangsaan Malaysia Research Grant, Solent Learning

and Teaching Institute (SLTI) at Solent University Southampton, Bulgarian Ministry of Education and Science under the NSP ICTinSES, Fondecyt 1180619 Project (ANID, Chilean Government), MINEDUC ESR ULS 1795 LIITEC (MINEDUC, Chilean Government, NC State Chancellor's Faculty Excellence program, Agora grant CRARP2_202370 from the Swiss National Science Foundation and grant number 21033 from the Hasler Foundation to LAA, EPFL and by Spark grant CRSK-1_190376 to LAA in a project hosted by EPFL's Laboratory for Biomolecular Modeling led by MDP, National Science and Technology Council of Taiwan, The Directorate General of Higher Education, Research and Technology of the Republic of Indonesia through the Kedaireka Matching fund program and The Deanship of Scientific Research at Imam Mohammad Ibn Saud Islamic University. Then there are also articles supported by educational institutions, namely, the Ministry of Education and Culture. Apart from that, table 3 also shows that there are 25 articles that were not funded by any agency/institution. So, we can say that the majority of publications have fulfilled one of the ethics in publication, namely clearly stating the name of the institution/institution that funds their research and publications. From table 3, there are several articles that do not disclose the source of funding or financial support. Ideally, scientific publications should disclose the source of funding or financial support received. This helps ensure transparency and integrity. However, the presence or absence of funding does not directly determine the ethics of a publication. Ethics also involves aspects such as honesty in reporting data, proper acknowledgment of contributions, and avoiding plagiarism. However, some journals or conferences may have specific policies regarding funding disclosure. It is recommended to always check the ethical guidelines and policies of the publisher or event organizer before submitting or publishing an article.

3.6 Forms of using Augmented Reality in learning

We reviewed 35 articles and tried to formulate a form of using Augmented Reality in learning. From the results obtained, the contribution in using Augmented Reality in learning uses AR by combining 3D model printing with AR to layer additional information on physical models showing interactions mediated by proteins and small molecules; the physical model of an animal or plant cell and its explanation. From several journals it has been found that AR is used for various things in the learning process. According to research from (Annisa & Subiantoro, 2022), the AR system used is called the Mobile Augmented Reality of Respiratory System (MARRS) to support SSI-based biology learning in smoking problems. The results showed that this system was used to visualize the lung organs against smoking activity; The use of AR in the Agile method e-learning learning process uses the InCell VR application for complex and abstract concepts regarding the process of human cell division (Nasharuddin et al., 2021); Then AR can be used as a digital-based learning resource equipped with illustrations in pictures to improve students' Critical Thinking (Damopolii et al., 2022). From this, the use of Augmented Reality in developing sessions in the teaching and learning process can arouse emotions in students which allows them to improve their learning (Maraza-Quispe et al, 2023; Lam et al, 2023; Fuchsova & Korenova, 2019).

The scope of the problem that causes research on AR media in biology learning in Indonesia is the lack of interactive, attractive, and innovative learning media. The learning media used in Indonesia still uses two-dimensional (2D) media (Bahari et al., 2017; Chaniago et al., 2020; Putu et al., 2018). So, innovation in technology-based learning media is needed (Hidayat et al., 2018; Sugiana & Muhtadi, 2019). The rapid development of technology and information must be used effectively and prioritize its usefulness. The use of Augmented Reality as a biology learning medium has the potential to solve problems in understanding biological concepts. Students' difficulties in understanding abstract or microscopic biological concepts (Fajriani et al., 2022), and can provide solutions to the 21st century challenges.

4. Discussion

4.1 Distribution year

There has been an increasing trend in research regarding augmented reality in the last six years. However, the number of publications from 2015 to 2017 was stable, namely 3 articles. 2018 marked the beginning of an increase in research publications. In 2019 and 2020 there was no drastic increase in research publications. However, in the last two years, this research trend has skyrocketed to 8 articles per year and remains stable at 8 articles per year until 2023.

The large number of publications on the theme of augmented reality in 2022 and 2023 is very reasonable considering that 2022 and 2023 are years that will intensively use technology because at the beginning of 2020, we were experiencing a pandemic situation which required implementing technology-based learning to support online learning activities or through the world. virtual. That's why in 2020 there began to be an increase in research trends with the theme of augmented reality because in 2020 many institutions have started to apply technology evenly in learning. Education and contemporary developments must immediately collaborate. because support in the form of technology will improve the quality of media, learning strategies and learning outcomes. Augmented reality is a technology that combines three-dimensional (3D) virtual reality into a three-dimensional real environment and displays it in real time so that it can be a new breakthrough to improve the quality of student learning (Suciliyana & Rahman, 2020).

4.2 Research types/methods

The AR research is predominantly carried out using a qualitative approach. namely 21 articles, 8 quantitative articles, 4 mixed method articles and 2 R&D articles. Augmented Reality can be approached with qualitative, quantitative, mixed method and R&D research paradigms. Electronic learning is a type of teaching and learning activity that allows teaching materials to be delivered to students using learning media such as the internet, intranet, or other computer network media (Pringgar et al., 2020). Augmented Reality is an interactive media that involves students actively interacting while taking part in learning so as to help students gain experience and knowledge.

The AR research is important because it improves the quality of educators in teaching using teaching materials. According to Mustaqim (2016) the use of educational media using Augmented Reality can stimulate students' mindsets in thinking critically about things and events that occur in everyday life, because the essence of educational media is to help students in the learning process in the presence or absence of educators in education.

In other cases, AR uses a mix method and R&D approach. R&D is a systematic method used to formulate, discover, improve, design new methods or strategies that are better, more effective and efficient. This method can help develop AR-based learning materials so you can find out the advantages and disadvantages.

4.3 Author and keywords

The author who has received the most attention in augmented reality studies is NF Saidin. NF Saidin is a researcher in the field of augmented reality, educational technology and multimedia education who has become a reference for many other researchers. Nor Farhan Saidin is a Doctor, Sultan Idris Education University, Malaysia. Based on Google Scholar searches, during the 2018-2023 period he has published 7 articles and to date has been published 471 times, both in scientific journals and in proceedings. He acts as the first author, as a corresponding author or as a member of the authors.

Based on the data, it can be seen that the keywords augmented reality, multimedia education and educational technology are dominantly used in publications. The keyword augmented reality is related to education, augmented reality tools, teaching, biology learning, learning performance, virtual reality, mobile learning and e-learning. If you search the data on Google Scholar, during his career NF Saidin has published at least 6 articles, both journals and proceedings. Published articles and he acted as first author in 5 publications (Saidin et al., 2015) and as many as one article NF Saidin became a member.

Of the several publications he has made, NF Saidin dominates the keywords regarding educational technology, multimedia education and augmented reality.

Researchers began to become interested in the AR theme, which began to intensify in 2013, which began to utilize many technologies. The use of AR links technology that combines the real world with the virtual world. In other words, Augmented Reality (AR) presents an object in the form of a video or photo/image into the real world in three dimensions (Alfitriani et al, 2021). The use of AR is increasing rapidly with the Covid-19 pandemic that emerged in the Wuhan area, China, and spread throughout the world. This means that in 2020, when the pandemic took place, which required online learning, various types of e-learning platforms were used. One of the e-learning media that allows for interactive and attractive learning is Augmented reality media. According to the statement Qumillaila et al (2017), the use of AR media as a learning medium is able to help students understand concepts and theories, stimulate students to think conceptually and experience 3D, improve representation and perception, create an interactive and attractive learning atmosphere and more fun. In the field of education, Augmented Reality has been widely used as a research tool in laboratories and can also be used as a learning medium in classrooms (Mauludin et al, 2017). One use of Augmented reality is in biology learning. Biology learning materials that are integrated with Augmented reality media include material on the respiratory system (Naim, 2020; Nugraha & Mahmud, 2022), the animal world (Kencana et al., 2020; Pratama et al., 2022), the plant world (Saefudin & Julisawati, 2016; Wijayatno & Samodra, 2021), movement system (Satryawati et al., 2022), ecosystem (Muhammad et al., 2021), digestive system, endocrine system (Fajriani et al., 2022), anatomical structure of the heart (Celik et al, 2020); Active application of Human Cell Division (Nasharuddin et al, 2021).

AR themes are also used as a medium for teacher training. Introducing AR is very important for teacher progress by utilizing interactive and innovative media. Through teacher training, a better and deeper understanding of the practical educational uses of this technology can be achieved. Currently not many teachers are implementing this novelty in their classes and as a result only a select few students are benefiting from the use of AR in the learning process. Meanwhile, currently, one of the skills of teachers in the 21st century is digital literacy. A teacher must have good skills in the application of technology, mastery of material concepts and presentation of material or teaching (Herizal et al., 2022). Apart from that, AR is related to VR. In terms of experience, AR expands the real world by adding a digital layer. Users remain in their real environment while viewing additional information or objects inserted via devices such as smartphones or AR glasses. For example, in biology subjects, movement system material is used, where students can see the characteristics of human movement systems in their surrounding environment through their cellphone screens, while VR creates a completely virtual world and separates the user from the real world. Users use special devices such as VR headsets to immerse themselves in digitally created environments. They can interact with objects and environments that are not part of the real world at all. Augmented Reality and Virtual Reality also have differences and similarities.

There are differences between AR and VR in terms of real-world engagement. AR expands the real world with digital elements, while VR creates an environment that is completely separate from the real world, while in terms of interaction, AR still interacts with the real environment, while VR users are fully involved in the virtual environment. And in terms of application AR tends to be more applied in situations where users need to stay connected to the real world while obtaining additional information. On the other hand, VR is generally used in simulations, games, or experiences that require isolation from the real world. Even though there are many differences between AR and VR, they also have similarities, even though they are few. In terms of immersion, both AR and VR aim to create an immersive experience for users. They present immersive and often realistic environments, albeit in different contexts. Meanwhile, in terms of technology use, these two technologies use advanced technology such as sensors, cameras, 3D graphics and intelligent algorithms to create interesting experiences.

From the above, there is a relationship between Augmented Reality and Virtual Reality, namely, there are similarities in the basic technology used to create AR and VR experiences, such as the use of sensors, 3D graphics and the latest computing. Then several companies or technology projects developed by integrating AR and VR elements to create interesting hybrid experiences. An example is a headset that supports both AR and VR.

4.4 Author's nationality and international collaboration

There are 28 countries of origin of authors who publish articles, predominantly from Europe, although the country with the most publications is Indonesia (Asia). This is in line with Agency et al (2012) that the European Commission has examined the organizational features of science teaching across Europe and has mapped the policies and strategies implemented to improve teaching and promote science learning in schools. One way to do this is by combining science learning with technology, namely Augmented Reality. Augmented Reality is a technology that combines the real world with the virtual world or presents an object in the form of a video or photo/image into the real world in three dimensions (Alfitriani et al., 2021).

The popularity of AR research has increased in recent years, as mobile devices have provided simpler, cheaper and more efficient access. In particular, it appears that in Indonesia, the AR theme has attracted quite a lot of attention from researchers. Research on AR learning media in biology learning in Indonesia shows that the AR application is effectively used as an alternative learning media to help teachers and students in learning biology (Febriza et al., 2021; Mauludin et al., 2017; Qumillaila et al., 2017). The scope of the problem that causes research on AR media in biology learning in Indonesia is the lack of interactive biology learning media.

Articles about AR are written by authors from all continents, showing that Augmented Reality is in the world spotlight or has become a global issue. Augmented reality is one of the tools used to improve science learning. Education and science learning are quickly becoming an important part of globalization (Deboer, 2011) and influencing country development (Kola, 2013). This is natural considering that technological developments for science learning are really needed. Data was obtained that more articles were published with no collaboration or single author status. There are 5 articles that have international collabs and 9 articles that have national collabs. Good articles should be written collaboratively. This is in accordance with the statement several researchers that good scientific articles should be written collaboratively, both within one scientific field and across scientific fields (Bellotti et al., 2016; Bennett & Gadlin, 2012; Frassl et al., 2018). Collaborative research encourages creativity rather than individual creativity, which in the context of publication will have a high impact because it is the result of cross-disciplinary thinking (Uzzi et al., 2013). so that collaborative publication encourages the emergence of group creativity to maximize innovation because it has gone through a process of individual reflection and brainstorming during the manuscript development process (Oliver et al., 2018).

4.5 Sponsor funding

In exploring 35 articles about AR, it is important to understand the funding aspects that support the research and writing. Funding plays a crucial role in facilitating these research projects and provides a valuable perspective on the research context. There are 15 institutions or institutions in the world that fund research and publications on Augmented Reality. Although only a few of the 35 articles mentioned funding sources, understanding these financial aspects remains important to provide further context to research and writing in the field of AR. Research funding is defined as grants obtained to conduct scientific research which generally goes through a competitive process (Neema & Chandrashekar, 2021). According to Wang and Shapira (2015), research that receives grant support from various countries will have a higher publication impact. Additionally, the more funding sources acknowledged in a paper, the more likely it is to be published in a highly ranked journal. Grant-sponsored articles are not only more likely to be published in high-

ranking journals, but also generate more research interest in the field. Moreover, the number of funding sources recognized in positive publications on placement in high-quality journals, research supported by funding from various countries does imply international value and potential, which may make it more acceptable to peer reviewers and the research community.

In general, the funding sources that can be identified in these articles are varied, including research institutions, universities, and technology companies. Most augmented reality projects appear to receive support from third parties, reflecting the complexity and costs involved in this research. Most publications have fulfilled one of the ethics in publication, namely clearly stating the name of the institution/institution that funds their research and publications. According to Ebadi and Schiffauerova (2015), funding is more often allocated to research teams than to single researchers. However, limited financial resources make it impossible to allocate the necessary research support to all researchers who request it. Apart from that, the research states that there has been no research that has explored the factors that can influence the amount of funding received by researchers.

So, it can be concluded that the level of funding can influence the quality of research. Articles that receive greater financial support may have greater access to resources, current technology, and cross-disciplinary collaboration. This could contribute to more in-depth and relevant research results. Even though most of the articles did not mention funding, even though only a few of the 35 articles mentioned funding sources, understanding this financial aspect is still important to provide further context for research and writing in the field of augmented reality, because journals do not include information about funding. can create uncertainty regarding the resources used in research and this lack of transparency can affect readers' confidence in the objectivity and quality of the research.

4.6 Forms of using Augmented Reality in learning

From the results obtained, a contribution to the use of AR in learning can be used by combining 3D model printing with AR to layer additional information on physical models showing interactions mediated by proteins and small molecules; the physical model of an animal or plant cell and its explanation. Use of AR to flexibly create and introduce multiple 3D protein and cell shapes at a scale that students can dynamically explore in class. Augmented Reality is a virtual object that is able to convey information so that it can help humans in carrying out their daily work (Pradana, 2020).

The use of AR in the development of sessions in the teaching-learning process evokes emotions in students which allows them to improve their learning (Maraza-Quispe et al, 2023; Lam et al, 2023; Fuchsova & Korenova, 2019). This AR method has the advantage of being interactive because it uses markers to display certain three-dimensional objects directed at the camera. These three-dimensional objects will display an attractive interface that is close to the real shape (Pradana, 2020). This is supported by the opinion of Ashari et al. (2022) which states that the advantages AR are as follows: 1) More interactive, 2) Effective in use, 3) Can be implemented widely in various media, 4) Simple object modeling, because it only displays a few objects, 5) Manufacturing that doesn't cost too much, 6) Easy to operate. Meanwhile, the disadvantages of Augmented Reality are: 1) Sensitive to changes in viewpoint, 2) Not many creators, 3) Requires a lot of memory on the installed equipment.

Augmented Reality can be used in various activities, such as presentations, estimating an object, stimulating equipment performance, simulating equipment performance, and so on. Some of these examples are illustrations of the use of AR in general (Ashari et al., 2022). According to Riskiono et al (2020), augmented reality has a working principle that is interactive, real-time and objects are displayed in 3-dimensional form. The advantage of augmented reality technology itself is that its development is easier and cheaper. Another added value is that AR technology can be implemented widely in various media. Students can be involved interactively, which causes AR to become a learning

medium that can provide feedback to students so that students feel comfortable in using this media.

In this regard, augmented reality learning is very important for teachers and students because AR presents digital content in a real physical environment, creating an immersive learning experience. For teachers, AR enables the delivery of more dynamic and interesting material, making learning more interactive. Students can "see" and interact with learning objects or concepts directly, deepening their understanding. In addition, AR can stimulate students' curiosity and increase their motivation in exploring subject matter. Thus, the use of AR in learning can increase the effectiveness and quality of learning. Apart from that, in biology learning, the use of AR can display 3D visualizations which can help students understand abstract biological concepts more realistically, especially in the study of human anatomy such as the concept of the nervous system (Aripin & Suryaningsih, 2019).

5. Conclusions

The focus of researchers will continue to increase regarding the AR theme, supported by the modern era which continues to prioritize technology and can be based on distribution year, research types/methods, instruments, study aspects, author, keywords, author's nationality, and collaboration. The trend of publications regarding AR continues to increase from 2019 to 2023. This is proven by the increase in articles published in reputable journals since 2019. Articles with the AR theme can use qualitative, quantitative, R&D approaches and even use mix-methods. The articles analyzed mostly used qualitative methods, followed by quantitative methods, mixed methods and a few of them used R&D as a method or approach in their articles.

The author in the spotlight is NF Saidin because many of his publications focus on augmented reality, educational technology and multimedia education. NF Saidin is a researcher who researches the field of technology and its relationship to the application of learning. Based on the data, it can be seen that the keyword augmented reality is closely related to the keywords education and biology. The keywords biology and education are related to teacher training, augmented reality tools, teaching, biology learning, learning performance, e-learning, virtual reality and learning performance. The AR theme is related to education for biology teacher training which applies e-learning or mobile learning based on AR and VR. Its implementation requires augmented reality tools as support for biology learning, so that the teaching process will also be related to the keyword learning performance.

Based on the data we collected, we found that there were 28 countries of origin of authors who published articles. Articles about AR have been published by authors from major continents. The dominant author comes from the Asian continent. Countries from the Asian continent is predominantly from Indonesia. Then, more published articles were written by more than one author and many articles were written by authors at the same university (no collaboration) and some of them were collaborative authors from the same country but at different institutes or universities (national collaboration). . Based on the articles analyzed, not many articles were written by a single author. There are 15 institutions in the world that fund AR-themed research and publications. These institutions can be identified by writing the name of the institution or institution in the published articles.

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