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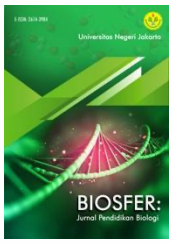

Research trends of augmented reality in biology learning: A systematic literature review from 2020-2024

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ABSTRACT

This study is a systematic literature review (SLR). The purpose of this study is to determine research trends related to the use of augmented reality (AR) in biology learning from 2020 to 2024. The method used is the PRISMA method. The database used for article searches is Google Scholar. The keywords used in the article search are "augmented reality," "biology education," and "biology learning". From the search results, 300 articles were obtained. Then, these articles were selected according to the inclusion and exclusion criteria, resulting in 57 articles being reviewed. The reviewed article is an article that comes from both national and international journals. The findings reveal that the trend of research related to the use of augmented reality in biology learning has experienced a significant increase. The highest number of articles related to augmented reality were published in 2024. The trend of the most commonly used research methods is the quantitative method. Cells, viruses, the human skeletal system, and the human digestive system are the most commonly used topics in developing augmented reality for biology learning. Based on the dependent variables examined in this SLR study, the most investigated variables are students' cognitive learning outcomes, motivation, and critical thinking skills. In terms of data collection instruments, the most commonly used instrument is the test instrument. Through this SLR, we hope that future studies related to augmented reality will continue to develop considering the rapid advancement of technology. For researchers, they can develop AR research using qualitative or mixed methods to obtain more detailed information or develop other research methods such as CAR or DDR, as they are not yet widely encountered.

INTRODUCTION

In the era of the 4.0 industrial revolution, technological development is very rapid. The rapid development of technology impacts various aspects of life, including the field of education. In line with this, innovations in the field of education have also developed significantly. This encourages teachers to continuously innovate by utilizing the existing technology in the classroom learning process. Augmented Reality (AR) is one of the rapidly developing modern technologies and has been proven to potentially enhance the quality of learning (Sirakaya & Sirakaya, 2018). Learning by integrating augmented reality can provide an engaging, interactive learning experience and create opportunities for students to actively participate (Kiryakova et al., 2018). The adoption of AR in learning can create interactive visual learning experiences to provide a better learning experience (Lam et al., 2023).

Augmented reality is one of the innovative technologies that combines virtual objects with the real world. AR is a technology that allows digital content to be inserted and combined with our real-world view in real-time (Billinghurst et al., 2014). Augmented reality combines the real world with computer-generated objects, allowing users to interact naturally in 3D form (Azuma, 1997). In the field of education, AR has one of its main advantages, which is its ability to present learning materials in a more concrete and relevant format (Tohir et al., 2024).

Augmented reality is a technology that can visualize objects into more attractive and easily understandable 3D forms (Damopolii et al., 2022). Augmented reality is a modern technology that can be used in biology education to explain abstract and complex material (Pamungkas et al., 2023). Augmented reality is often used as a tool in biology education to overcome the limitations of conventional approaches, such as difficulties in visualizing abstract concepts, lack of student interest and engagement in learning, and understanding complex and intricate material (Azzahra et al., 2024). Students can directly use AR to observe the microscopic structures of living organisms, which are difficult or even impossible to see with the naked eye (Kurnia et al., 2025).

Based on previous research, it has been mentioned that the use of augmented reality in learning has a positive impact, such as improving students' learning outcomes. According to (Hilman et al., 2024), there is a significant improvement in students' cognitive learning outcomes on the human skeleton material using augmented reality. AR can help students visualize the movement system more deeply through 3D models, thereby sharpening their understanding of abstract concepts. A similar point was made by Jaballudin & Khalid (2024) that through the AR application, students can easily learn plant physiology material, thereby improving student academic performance and interest in biology topics. In line with what was conveyed by Maharani et al. (2024) implementing the use of augmented reality-based poster learning media, Wahdatun et al., (2021) developed ARsaf (augmented reality nervous system), Maryana et al. (2022) used an AR-based arthropod book, Ozeren & Top (2023) used the CellAR application (AR application for cell and cell division), Pamungkas et al., (2023) used android-based augmented reality in biology learning, which can effectively improve students' learning outcomes.

The use of augmented reality can also enhance students' motivation in learning (Zhou et al., 2020); Nengsih et al., 2023); (Pranahadi et al., 2024); (Omurtak & Zeybek, 2022); Ozeren & Top, 2023; Chuang et al., 2023), can increase students' interest in learning (Fatmawati & Sari, 2024); Putri et al., 2022), can develop students' critical thinking skills (Damopolii et al., 2022); (Lismaya et al., 2022); (Azrai et al., 2023);(Tamam et al., 2020); (Oktafiani et al., 2024), and can develop students' creative thinking skills (Parani et al., 2023); (Mardiyah et al., 2020); (Baharu et al., 2024). The integration of AR usage in learning can also develop students' HOTS abilities (Sylvia et al., 2020), scientific literacy skills (Ahied et al., 2020); (Saputra & Octavia, 2024); (Agusta, 2022), biological literacy skills (Indriani et al., 2024), metacognitive skills (Agusta, 2022), and self-efficacy (Ciloglu & Ustun, 2023).

In recent years, there have been many studies reviewing augmented reality technology. The increase in popularity of research interest related to augmented reality is due to mobile devices providing users with simpler, cheaper, and more efficient access to using augmented reality than before (Dutta et al., 2022). However, there has not been much research focused on reviewing the use of augmented reality in biology learning. Permana et al. (2024) conducted an SLR related to AR in biology learning reviewed from 2015-2023, focusing only on journals indexed in Scopus and not reviewing articles within the national scope. In this systematic literature review, the aim is to provide an overview of the research trends regarding the use of augmented reality in biology learning, focusing on studies from the past five years. The articles reviewed come from national and international journals with the Google Scholar database. The aspects reviewed in this research are the trends in augmented reality

research based on publication years from 2020 to 2024, trends in research methods, trends in biology topics, trends in dependent variables investigated, and trends in data collection instruments used in the research. Here is the formulation of the problem used to address the issue:
RQ1 How is the development of research trends related to augmented reality in biology learning from 2020 to 2024?
RQ2 What research method trends are most widely used in AR-related research?
RQ3 What biology topics are most applied in the use of AR?
RQ4 What variables are most investigated in AR-related research?
RQ5 What data collection instrument trends are most widely used in AR-related research?

METHODS

This study is a systematic literature review (SLR). The method used in this SLR is the PRISMA (Preferred Reporting Items for Systematic Review and Meta-analysis) method. According to Moher et al. (2015) PRISMA method is a method used as a guideline to help authors prepare protocols in conducting reviews. This protocol is intended as a rationale for conducting the review and the methodological and analytical approach planned before starting the review. It is further explained that the PRISMA method can be used as a guideline for searching and selecting articles to be reviewed and analyzed. In this SLR study, the articles analyzed are those published from January 2020 to December 2024. The focus of this SLR is on research trends in the use of augmented reality in biology learning. Article search using Harzing's Publish or Perish (PoP) software. The database used in the article search is Google Scholar. The keywords used in the article search are "augmented reality," "biology education," "biology learning," and "*pembelajaran biologi*.". From the search results, 300 articles were obtained. Then these articles were selected according to the inclusion and exclusion criteria as follows in Table 1.

Table 1.
Criteria of Inclusion and Exclusion

Inclusion criteria	Exclusion criteria
Article published on Januari 2020 to December 2024	Articles is published outside of Januari 2020 to December 2024
Only use database from Google scholar	Other sources are not included
Only research/ articles that classified as article/ research	Books, reviews, proceeding, conference paper, workshop are not included
Only open-access article	Closed access
Written in English or Indonesian	Not written in English or Indonesian
Topic is the use of Augmented Reality in biology learning	Out of the topics (not relevant)
Available in full text	Unavailable in full text

Next, in Figure 1, these inclusion and exclusion criteria are used in the PRISMA method sequence to determine and select the articles to be analyzed. Figure 1 shows the initial stage of searching and collecting articles. The database used is Google Scholar. The total number of articles obtained is 300 articles. There are 58 duplicate articles, so these articles must be removed and will not enter the screening stage. 242 articles entered the screening process. In this screening process, inclusion and exclusion criteria are applied. The first criterion applied is that only research articles are included, while other types (books, reviews, proceedings, conference papers, workshops) are not included. 159 articles meet the criteria, meaning 83 articles were excluded. Next, only articles relevant to the topic of augmented reality in biology learning are used. 77 articles meet the criteria. 82 articles were excluded. The next criterion used is only open-access articles and those in Indonesian or English. 57 articles meet the criteria, meaning 20 articles were excluded. 18 articles are closed-access articles, 1 article is in Malay, and 1 article is in Arabic. Thus, 57 articles meet the inclusion criteria and will be analyzed in depth. The reviewed article is an article that comes from both national and international journals.

The next step in conducting the article review is to perform an in-depth analysis of 57 articles. Data analysis was conducted descriptively by grouping articles based on publication

year, type of research method, biology topics, data collection instruments, and dependent variables related to the use of augmented reality in biology learning. Then, the data from the article review were analyzed and summarized as the conclusion of the findings in this SLR research according to the research question.

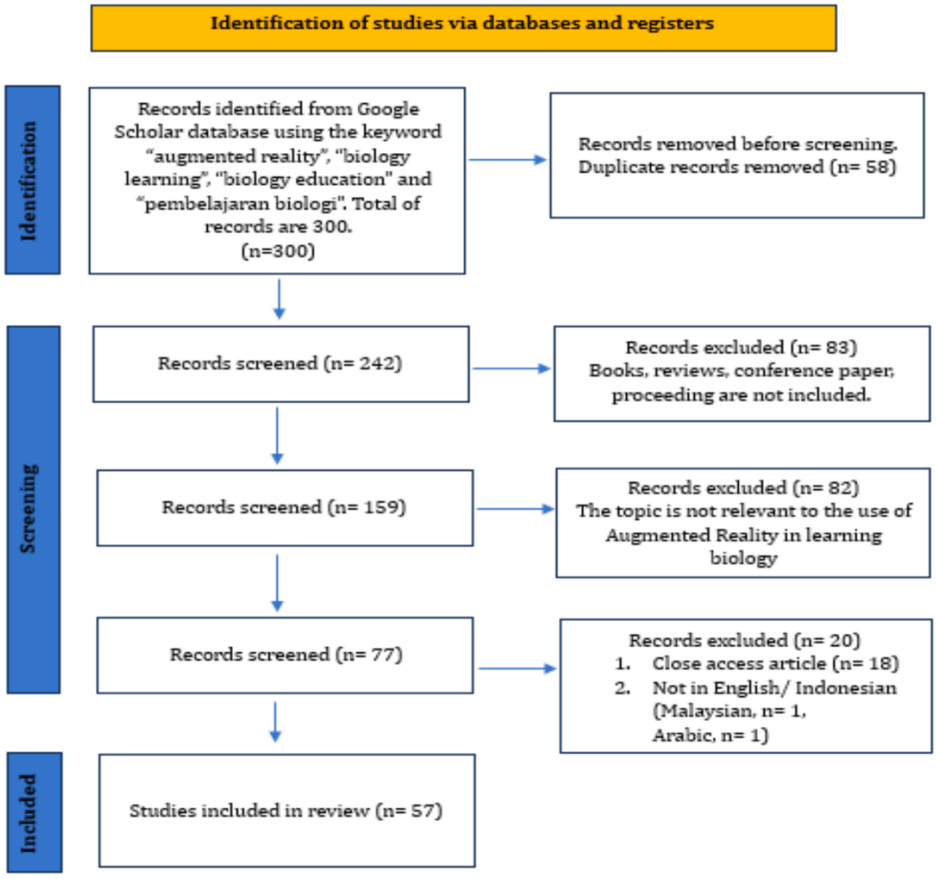

Figure 1. Flowchart of the PRISMA methodology for systematic literature review

RESULTS AND DISCUSSION

Trends in AR research based on publication year

In this SLR study, the number of articles reviewed is 57. The articles reviewed are those published from 2020 to 2024. Figure 2 shows the distribution of the number of articles published per year from 2020 to 2024. Based on Figure 2, it can be seen that the number of articles related to augmented reality in biology education has increased each year. From the graph, it can be explained that in 2020, 5 articles were found. In 2021, 8 articles were found. In 2020 and 2021, the research trend on augmented reality saw an increase, although not drastic. The trend of AR research significantly increased from 2022 to 2024. In 2022, the number of articles found was 13 per year. It appears that there was a significant increase from 2021 to 2022. In 2023, there were 14 articles found. The highest number of articles on AR published was in 2024, with a total of 17 articles. Thus, it can be concluded that the trend of using AR in biology learning has been increasing over the past five years. This is evidenced by the increasing number of articles published from 2020 to 2024.

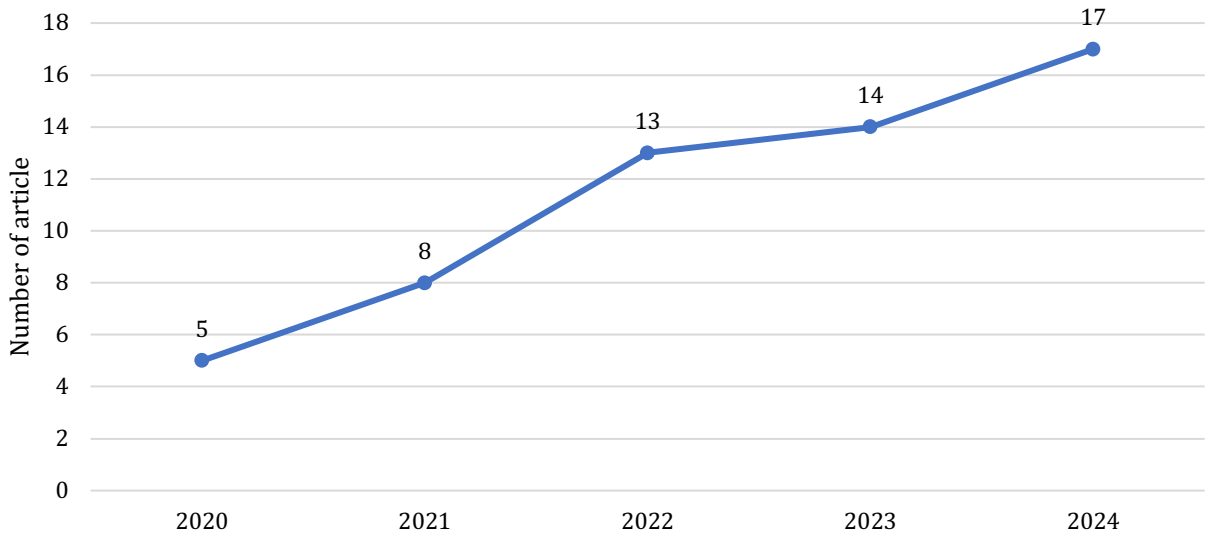

Figure 2. Trends of articles related to AR per year

Trends in Research Method

Based on the results of the article review, the trend of research methods related to augmented reality can be seen in Table 2.

Table 2.
Trends in research methods related to AR in biology learning

No.	Research Methods	Amount	References
1	Quantitative	25	(Jaballudin & Khalid, 2024; Maryana et al., 2022; Kamaruddin & Thahir, 2021; Laswi & Bungawati, 2024; Lismaya et al., 2022; Fitria et al., 2021; Ahied et al., 2020; Azrai et al., 2023; Mardiyah et al., 2020; Antoniadi, 2023; Alqarni, 2021; Ozeren & Top, 2023; Chuang et al., 2023; Tamam et al., 2020; Pamungkas et al., 2023; Tamam & Fikriyah, 2024; Indriani et al., 2024; Parani et al., 2023; Annisa & Wibisono, 2022; Stojsic et al., 2022; Gregorcic & Torkar, 2022; Maraza-Quispe et al., 2023; Lam et al., 2023; Morales & Regio, 2024; Oktafiani et al., 2024)
2	Qualitative	5	(Azrai et al., 2024; Rahmawati, et al., 2022; Yapici & Karakoyun, 2021; Chuang et al., 2023; Petrov & Atanasova, 2020)
3	Mixed method	7	(Ciloglu & Ustun, 2023; Arshad et al., 2024; Cakir et al., 2021; Omurtak & Zeybek, 2022; Schmidthaler et al., 2023; Rodriguez et al., 2023; Akbar et al., 2024)
4	RnD	18	(Damopolii et al., 2022; Zhou et al., 2020; Nengsih et al., 2023; Putri et al., 2022; Mahmudah et al., 2023; Nahri et al., 2024; Nurhayati et al., 2022; Primadona et al., 2024; Sari et al., 2023; Hamimi et al., 2021; Fatmawati & Sari, 2024; Rohmah & Anggraito, 2021; Susilo et al., 2021; Al Ghazi et al., 2022; Saputra & Octavia, 2024; Agusta, 2022; Laswi & Bungawati, 2024; Susanto et al., 2024)
5	DDR	1	(Putri & Pertiwi, 2022)
6	CAR	1	(Pranahadi et al., 2024)

Table 2 shows the results of the article review based on the research methods used in research related to augmented reality. The review results show that the trend of the most widely used research method is the quantitative method. Quantitative methods are widely used in research on AR during the period 2020-2024. A total of 25 articles were found using quantitative methods. Therefore, it can be said that over the past five years the dominant research method used that related to augmented reality is quantitative methods. Furthermore, the RnD (Research and Development) method is also often used in research related to augmented reality. The RnD method was found in 18 articles. This shows that articles related to the development of augmented reality in biology learning are also widely used by researchers. Mixed methods (quantitative and qualitative) were found in 7 articles. Mixed methods are also quite popular compared to qualitative methods which were only found in 5 articles. The least research

methods found in articles related to augmented reality are DDR (design and development research) and CAR (classroom action research) methods. Both were only found in 1 article during the period 2020 to 2024. For more details, it can be seen in Figure 3 below about the distribution of trends in research methods with the theme of augmented reality.

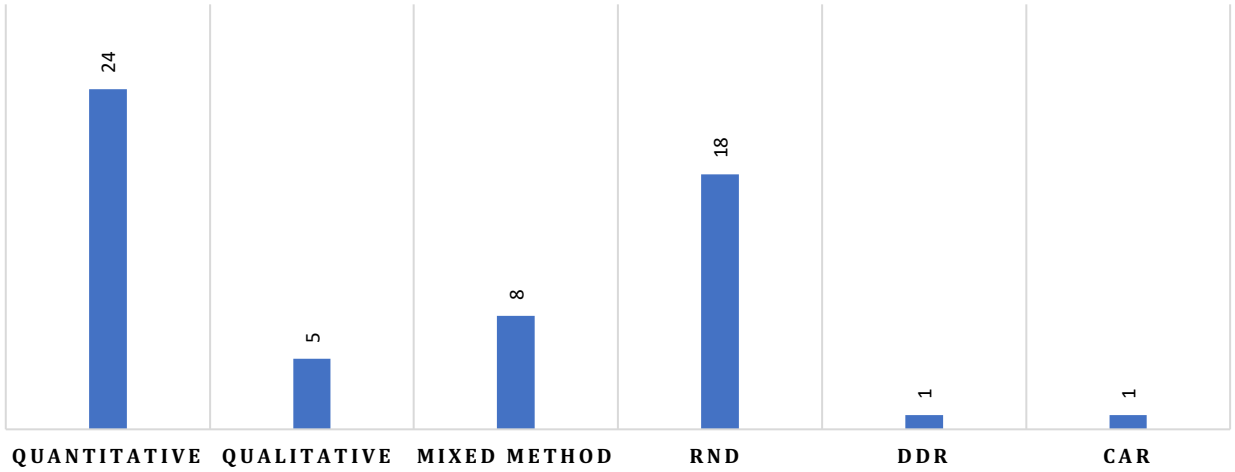

Figure 3. Trends of Research Methods

Trends of biology topics used in augmented reality implementation

The scope of biology topics that can be developed using augmented reality is quite wide. Biology topics that are abstract and complex require modern technology, such as augmented reality, to be able to visualize a particular topic. In Table 3 are the topics of biology that are developed using augmented reality based on the results of the article review. Based on Table 3, it can be seen that there are 21 topics developed with augmented reality. 2 biology topics are not explicitly mentioned in the article. The most popular topic developed using augmented reality is cell (f=10 with a percentage of 17.54%). The next topic that is quite dominant is viruses, with a total of 7 and a percentage of 12.28%. The topic of the human skeletal system and human digestive system is the third option that is often used in augmented reality-assisted biology learning, with a total percentage of 7, 02% (f = 4). And other biology topics as in Table 3, are still not widely used in the development of augmented reality. This allows for further research to develop augmented reality with topics that are still rarely used or with other different topics. Therefore, it can be said that the trend of biological topics developed with augmented reality is diverse, and the most dominant topic is the topic of cells.

The dependent variable being studied related to augmented reality in biology learning

The dependent variable in this review study is also one of the aspects being investigated. Figure 4 shows the results of the article review related to the dependent variable being studied in connection with the use of AR in biology learning.

Based on Figure 4, it can be seen that cognitive learning outcomes are the most investigated variable with the use of augmented reality in biology learning. A total of 32% of the articles reviewed show that this variable is the most investigated. The use of augmented reality in learning biology in addition to improving cognitive learning outcomes can also increase motivation (18%), critical thinking skills (7%) and student interest in learning biology (7%). The review also showed positive results on the development of students' attitudes (5%) towards augmented reality technology. The same thing is also shown by the increase in creative thinking skills (5%). The utilization of augmented reality in biology learning can provide a more positive learning experience and also learning independence. These two dependent variables were found as much as 4% in research related to augmented reality. The implementation of AR in biology learning can also improve several aspects as shown in Figure 4 including self-efficacy, creativity, student innovation, HOTS, scientific literacy, biological literacy skills, metacognitive, collaboration, student acceptance, and socio-scientific reasoning. Based on the data, cognitive learning outcomes, motivation, interest, and critical thinking are the most researched aspects in the use of augmented reality.

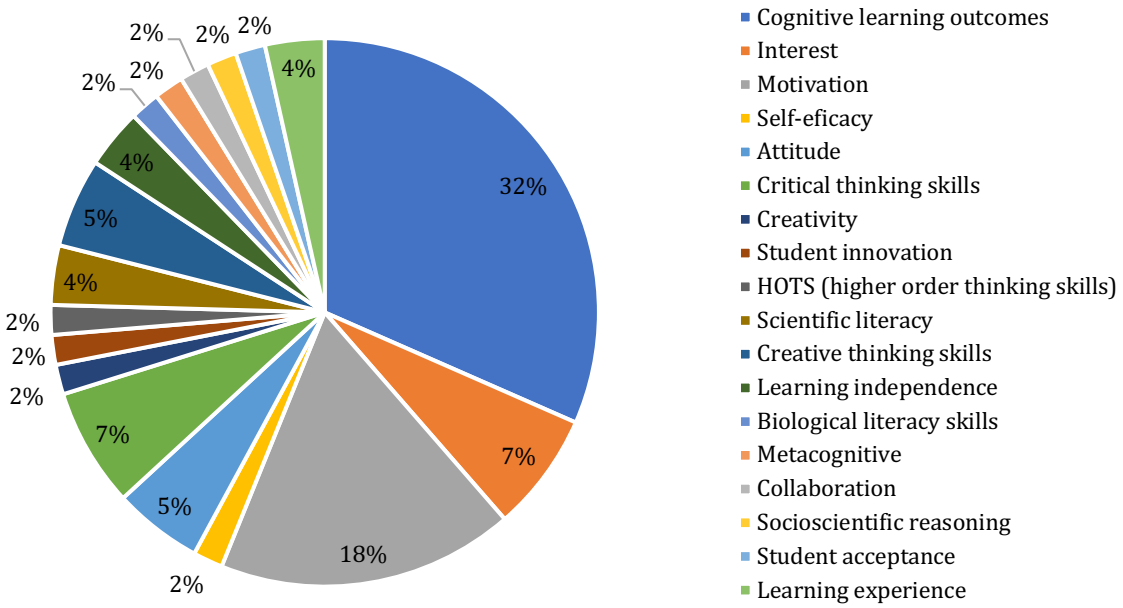

Figure 4. The trend of dependent variables related to AR in biology learning

Table 3.
Biology topics related to augmented reality

No.	Topic of Biology	Amount	Percentage (%)
1	Plant physiology	2	3,51%
2	Human skeletal	4	7,02%
3	Coordination system	3	5,26%
4	Biological microscope	1	1,75%
5	Animal	2	3,51%
6	Cellular respiration	1	1,75%
7	Ecosystem	1	1,75%
8	Human digestive system	4	7,02%
9	Circulatory system	3	5,26%
10	Cell	10	17,54%
11	Environmental pollution	2	3,51%
12	Genetic	1	1,75%
13	Sense organ	1	1,75%
14	Human respiratory	3	5,26%
15	Human reproductive	1	1,75%
16	Nervous system	1	1,75%
17	Metabolism	1	1,75%
18	Human anatomy	1	1,75%
19	Virus	7	12,28%
20	Structure and function of plant tissues	3	5,26%
21	Plantae	3	5,26%
22	Not mentioned	2	3,51%
	Total	**57**	100%

Trends of data collection instruments

Based on the review results, the data collection instruments used in the article include test instruments, questionnaires, interviews, observation sheets, and validation sheets. Figure 6 shows that

the test instrument (32%) is the most frequently used instrument in research related to the utilization of augmented reality in biology learning. Next are questionnaires (29%) which are widely used to measure the research variables being studied. Validation sheets (20%) are also widely used by researchers to measure the validity of a developed learning media, such as augmented reality media in biology education. Observation sheets (8%) and interviews (11%) are also commonly found in articles as instruments for data collection.

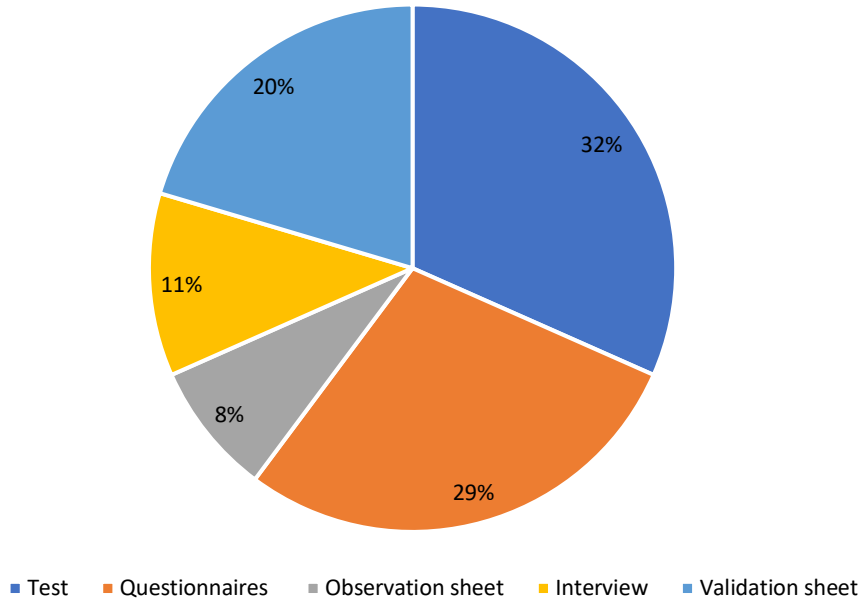

Figure 5. Trends of data collection instruments

The systematic literature review reveals that the trend of integrating augmented reality in biology learning from 2020 to 2024 has experienced significant growth. The significant increase in the number of articles began in 2021 and peaked in 2024. The increase in the number of articles over the past five years indicates that the trend of research on augmented reality in biology learning is becoming increasingly popular. Proven by the increasing number of published articles. Information about the advancements in augmented reality technology in biology learning can help teachers create more engaging and interactive learning experiences. Not only that, but the advancement of augmented reality technology can also help teachers more easily adjust to the needs of students in biology learning. Identifying trends in augmented reality research is considered important to provide insights into how augmented reality is implemented in biology learning, including the latest studies, changes in research methods, or new discoveries that can enhance the learning experience (Azzahra et al., 2024).

In line with previous research by Permana et al. (2024), it also mentions that the use of AR in learning increased in the years 2019 to 2023. The year 2019 marked an increase in AR-themed publications, and at the beginning of 2020, there was a drastic increase. The increase was triggered by the presence of technology-based learning that supports online learning. The use of AR in the education sector, especially in the learning process, has developed and shows new hope for the creation of interactive learning. Interactive visual learning can be utilized by teachers to provide an interactive learning experience and environment (Lam et al., 2023). Augmented reality is a technology that can visualize objects in more attractive and easily understandable 3D forms (Damopolii et al., 2022). Augmented reality is a modern technology that can be used in biology education to explain abstract and complex material (Pamungkas et al., 2023). Augmented reality is often used as a tool in biology education to overcome the limitations of conventional approaches, such as difficulties in visualizing abstract concepts, a lack of student interest and engagement in learning, and understanding complex and intricate material (Azzahra et al., 2024).

The review results show that the most commonly used of research method is quantitative. There are 25 articles reviewed using quantitative methods in their research related to the implementation of augmented reality. This SLR study found that the most commonly used quantitative method is experimental design, particularly quasi-experimental design. According to Creswell (2014), the

experimental research design (quantitative) aims to test the impact of a treatment or intervention on research outcomes, controlled by other factors that may influence the results of a study. In other words, the numerous quantitative methods used in this study are to examine the effectiveness of using augmented reality media in biology learning on learning achievement. In addition, the use of quantitative methods can also save time and costs (Küçük et al., 2014).

The research method that is also frequently used is research and development. The trends of R&D research were quite frequently found during the period 2020 to 2024, with a total of article is 18 articles. This indicates that during this period, the trend of R&D research is quite popular. The development of augmented reality in biology learning as a learning media can be used by teachers to create a more interactive and meaningful learning experience. Several models used in R&D research include ADDIE (Analyze, Design, Develop, Implementation, and Evaluation) as conducted by (Fatmawati & Sari, 2024), (Ghazi et al., 2022), (Saputra & Octavia, 2024), (Agusta, 2022), and (Damopolii et al., 2022); the Borg and Gall model conducted by (Nurhayati et al., 2022); the 4D model (Define, Design, Develop, and Disseminate) conducted by (Nengsih et al., 2023), Mahmudah et al. (2023), and Primadona et al. (2024); the Lee & Owens model conducted by (Hilman et al., 2024), and Susanto et al. (2024); the Hannafin and Peck model conducted by (Rahma Sari et al., 2023); and others where the specific model used in the R&D research is not mentioned. Qualitative and mixed methods are not commonly used in research related to AR. The qualitative methods found in the article review use a grounded theory approach as done by (Rahmawati et al., 2022) and case studies conducted by (Yapici & Karakoyun, 2021). Basically, in qualitative research, the researcher aims to reveal a problem holistically and in depth, thereby obtaining complex and comprehensive information. Mixed methods are a combination of quantitative and qualitative methods where researchers attempt to integrate or expand their findings to obtain a comprehensive analysis of the research problem (Creswell, 2014). The least used research methods are DDR (Design, Development, and Research) conducted by (Putri & Pertiwi., 2022) and CAR (Classroom Action Research) conducted by Pranahadi et al. (2024). The form of CAR used is collaborative action research. Collaborative action research is a CAR study that involves collaboration between teachers and universities (lecturers). Both collaborate to find solutions to a problem in the classroom. The teacher acts as a constructor of knowledge and agent of change (Pine, 2009).

Based on the review results, the most commonly used biology topic in the implementation of augmented reality is cell. Topics about viruses, the human skeletal system, and the human digestive system are also frequently used in developing augmented reality. By using augmented reality, abstract and complex topics can be visualized in 3D form, making it easier for students to understand a subject. Other topics such as plant physiology, coordination system, microscope, animal, cellular respiration, ecosystem, circulatory system, environmental pollution, genetics, sense organ, human respiratory, human reproductive, nervous system, human anatomy, structure and function of plant tissue, and plantae are topics that researchers have used in developing augmented reality. These topics will be difficult for students to understand due to their abstract, complex, and complicated. The integration of AR in biology learning is expected to create interactive and enjoyable learning for students, thereby providing them with meaningful learning experiences. Thus, it will be able to enhance their understanding of the topic. Augmented reality is indicated as a learning technology that can be integrated into biology learning to address various issues, including the lack of visualization of abstract topics, low student participation and interest in learning, and low student mastery of complex topics (Stojšić et al., 2022). Omurtak dan Zeibek (2022) mention that augmented reality is an enjoyable and entertaining application that can help students visualize abstract concepts and make the topics easier to remember.

In this SLR study, it can be seen that the most common dependent variable related to augmented reality is cognitive learning outcomes. Based on research conducted by Hilman et al. (2024) shows that there is a significant increase in students' cognitive learning outcomes on human skeleton material with augmented reality. AR can help students to visualize the motion system more deeply through 3D models so that it can sharpen students' understanding of abstract concepts. The same thing was also conveyed by Jaballudin and Khalid (2024) that the use of AR can improve learning outcomes and also student interest in learning biology. Through AR applications, students can easily learn plant physiology material so that it can improve student academic performance and student interest in biology topics. The use of AR technology can improve the quality of learning. In line with what was conveyed by Maharani et al. (2024) implemented the use of augmented reality-based poster learning media,

Wahdatun et al. (2021) developed ARsaf (augmented reality nervous system), Maryana et al. (2022) used AR-based arthropod book, Ozeren & Top (2023) used CellAR application (AR application for cell and cell division), Pamungkas et al. (2023) using android-based augmented reality in biology learning can effectively improve students' cognitive learning outcomes.

Previous studies also mention that the use of augmented reality can enhance student motivation (Zhou et al., 2020;); Nengsih et al., 2023); Pranahadi et al., 2024); Omurtak & Zeybek, 2022); Ozeren & Top, 2023; Chuang et al., 2023), can increase student interest in learning (Fatmawati & Sari, 2024); (Putri et al., 2022), can develop students' critical thinking skills (Damopolii et al., 2022; Lismaya et al., 2022; Azrai et al., 2023; Tamam et al., 2020; Oktafiani et al., 2024), and can develop creative thinking skills (Parani et al., 2023; Mardiyah et al., 2020; Arshad et al., 2024). The integration of AR use in learning can also develop students' HOTS abilities (Sylvia et al., 2020), scientific literacy skills (Ahied et al., 2020); (Saputra & Octavia, 2024); (Agusta, 2022), biological literacy skills (Indriani et al., 2024), metacognition (Agusta, 2022), and self-efficacy (Ciloglu & Ustun, 2023). In addition, the implementation of augmented reality can also positively improve students' attitude towards technology (Ciloglu & Ustun, 2023); (Kozcu Cakir et al., 2020) and students' attitude towards science (Alqarni, 2021). Annisa & Subiantoro (2022) explained that the integration of mobile augmented reality in socioscientific issues-based learning can improve socio-scientific reasoning skills. MARRS (Mobile Augmented Reality of Respiratory System) that implemented in socio-scientific issues-based learning is proven to be better in improving socio-scientific reasoning skills.

Based on the review results, the data collection instruments used in the articles include test instruments, questionnaires, interviews, observation sheets, and validation sheets. The review results show that the test instrument (32%) is the most widely used instrument in research related to the utilization of augmented reality in biology learning. Next are questionnaires (29%), validation sheets (20%), observation sheets (8%), and interviews (11%). Test instruments are widely used in research related to augmented reality considering that many studies are conducted using quantitative methods. Where in quantitative research, this instrument is used to measure the effectiveness of AR usage in biology learning across various variables. The selection of data collection instruments is adjusted to the researcher's needs to uncover a problem that will be studied. Thus, the selection of research instruments will greatly assist researchers in obtaining in-depth information.

CONCLUSION

This systematic literature review reveals that the research trends related to the use of augmented reality in biology learning from 2020 to 2024 has experienced a significant increase. The highest number of articles related to augmented reality were published in 2024. The trend in research methods most commonly used is the quantitative method. Cells, viruses, human skeletal, and human digestive system are the most commonly used topics in developing augmented reality in biology learning. Based on the dependent variables examined in this SLR study, the most investigated variables are students' cognitive learning outcomes, motivation, and critical thinking skills. In terms of data collection instrument, the most widely used is the test instrument. Through this SLR research, we hope that future studies related to augmented reality will continue to develop considering the rapid advancement of technology. For researchers, they can develop AR research using qualitative or mixed methods to obtain more detailed information or try to develop other research methods such as CAR or DDR, as they are not yet widely encountered. This research is limited to the search for article sources using only the Google Scholar database. In the future, it is necessary to expand the data sources in article searches, such as the Scopus, ERIC, and Web of Science databases.

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