Jurnal Inovasi dan Teknologi Pembelajaran
Vol 10, No 2, (2023), page 172-181
https://doi.org/10.17977/um031v10i22023p172
P-ISSN: 2406-8780 E-ISSN: 2654-7953
Open access: http://journal2.um.ac.id/index.php/jinotep/index

A systematic literature review of integrating augmented reality technology in science learning

Anggi Datiatur Rahmat[1*], Heru Kuswanto[2], Insih Wilujeng[3]

[1]Sciences Education Postgraduate Program, Universitas Negeri Yogyakarta
[2]Department of Physics Education, Universitas Negeri Yogyakarta
[3]Department of Science Education, Universitas Negeri Yogyakarta
Jl. Colombo No.1 Karangmalang Yogyakarta 55281
**Corresponding author, e-mail: anggidatiatur.2022@student.uny.ac.id*

ARTICLE INFO

Article history:
Received: 03-04-2023
Revised: 09-05-2023
Accepted: 05-06-2023

Kata kunci:
Augmented reality; Pendidikan IPA; Systematic literature review

Keywords:
Augmented reality; Science Education; Systematic literature review

ABSTRAK

Penelitian ini bertujuan untuk mengungkap tren penelitian selama sepuluh tahun terakhir pada penggunaan teknologi augmented reality (AR) dalam pembelajaran IPA. Review pada studi ini mengikuti pedoman PRISMA. Ditemukan 154 artikel pada tahap identifikasi, kemudian dilakukan screening berdasarkan kriteria inklusi dan eksklusi sehingga menjadi 50 artikel untuk direview. Hasil review menunjukkan bahwa pembelajaran/prestasi akademik, motivasi, dan sikap merupakan variabel yang paling banyak diteliti dalam artikel, Di mana prestasi akademik sangat dipengaruhi oleh motivasi dan sikap, sehingga sering dipertimbangkan dalam penelitian. Aplikasi mobile dan buku bergambar AR merupakan jenis AR yang sering diimplementasikan karena mudah digunakan dan dapat dikembangkan dengan cepat dan praktis. Kecenderungan metodologi adalah desain kuantitatif. Alat pengumpulan data yang sering digunakan adalah tes kognitif. Metode pengambilan sampel yang paling sering digunakan adalah convenience sampling, dan populasi sampel yang sering diidentifikasi adalah siswa sekolah menengah. Rekomendasi penelitian yang sering diberikan oleh peneliti adalah melakukan identifikasi pengaruh penggunaan AR terhadap kemampuan afektif siswa dan mengidentifikasi persepsi guru. Hasil penelitian ini akan menjadi sebuah referensi bagi para peneliti yang tertarik untuk mengimplementasikan AR dalam pembelajaran.

ABSTRACT

This study aimed to explore research trends over the past decade regarding the use of augmented reality (AR) technology in science learning. The study followed the PRISMA guidelines. A total of 154 articles were found at the identification stage and then screened based on inclusion and exclusion criteria so that 50 articles were to be reviewed. The review results show that learning achievement, motivation, and attitudes are the variables most researched in the article. Learning achievement is strongly influenced by motivation and attitude, so it is often considered in research. Mobile applications and AR picture books are often implemented because they are easy to use, fast, and have practical development. The methodological trend is a quantitative design. Data collection tools that are often used are cognitive tests. The frequently used sampling method is convenience sampling, and the sample population often identified is high school students. Researchers often give research recommendations to identify the effect of using AR on students' affective abilities and teacher perceptions. The results of this study will be a reference for researchers interested in implementing AR in education.

INTRODUCTION

The tremendous development of technology has influenced all aspects of life, including education. Augmented Reality (AR) is one of the technologies that has developed significantly and attracted the attention of researchers. It simultaneously combines real images and virtual objects placed at specific points as well as the interaction of the resulting program (Azuma, 1997). In the application of AR, the actual environment does not occur directly (Erbas & Demirer, 2019). Based on the *Horizon Report*, AR technology will influence future education (Cai et al., 2014). The report also highlighted in 2012 that AR technology in learning process have a significant impact in the next four to five years. The use of AR has the potential to change education (Johnson et al., 2013).

AR technology has positively impacted mathematics and science learning in recent years. The combination of virtual and real objects, real-time interaction, and three-dimension (3D) simulation presentation are important features of AR technology for providing authentic learning experiences to students. Learning environments using AR technology can create concrete information (Wojciechowski &; Cellary, 2013). AR technology has the opportunity to provide new experiences for students that are difficult to find in real life, for example, the solar system (Cai et al., 2021; Chang et al., 2018; Wojciechowski & Cellary, 2013; Yen et al., 2013), increased student participation in classroom (Abdusselam & Karal, 2020), create fun learning (Yoon et al., 2017), saving time and space for learning environment (Rahmat et al., 2022) and increase attention on learning activities (Roumba & Nicolaidou, 2022). In addition, AR also supports approaches in learning that aim to actively involve students in the learning process (Díaz-Noguera et al., 2017; Yilmaz, 2021).

In science learning, AR technology has a crucial role in presenting content. Students think learning science is challenging because many contain abstract concepts (Sahin et al., 2020). Science learning enriched with technology to teach visual phenomena increased students' interest in the classroom (Kiryakova et al., 2018; Salmi et al., 2017). In addition, using virtual simulated objects and real-world environments in AR technology helps students understand complex and abstract concepts (Rahmat, et al., 2023). Using three-dimensional representations of events that are invisible and difficult to visualize, AR technology facilitates topic realization and understanding of subjects that are usually difficult to understand for students (Medina Herrera et al., 2019).

In recent years, many reviews on AR technology have been published. But it is still rare to find reviews that focus on implementing AR in science learning. The purpose of this study is to provide an overview of the use of AR in science learning. Previous research has explored AR use and Research on AR technology highlights specific aspects of recent developments, implementation and identifies the use of AR in education (İçten & Bal, 2017). This study focuses on using AR in science learning, including physics, chemistry and biology. Because a few reviews on topics AR in science education. This study conducted this review to identify and analyze AR in science education. In particular, we reviewed the variables, type AR, trend methods, data collection tools, sampling methods, and research participants often used in AR research in science learning. The findings of this systematic literature review can help researchers and educators interested in implementing AR in science learning. They performed a systematic review to identify AR in science learning to answer the following five research questions.

RQ1. What variables have been examined on using AR in science learning?
RQ2. What types of materials are used to implement AR in science learning?
RQ3. What the methodological trends on using AR in science learning?
RQ4. What are the most popular data collection tools in articles on the use of AR in science learning?
RQ5. What is the most preferred sampling method and sample population in articles on the use of AR in science learning?
RQ6. What are the recommendations for future AR research in science learning?

METHOD

This systematic literature review was performed in accordance with PRISMA (Preferred reporting items for systematic review and meta-analysis) guidelines. The PRISMA guidelines

provide a diagram to describe and visualize the identification and selection of research findings under consideration. The PRISMA methodology is typically used as a guide to describing the eligibility criteria, data collection process, data details, and synthesis of results (Surahman & Wang, 2022). This study relates to AR in science learning. The flowchart for this study is shown in Figure 1.

Figure 1 shows that 154 articles were found at the identification stage, and 45 did not fulfil the criteria. Furthermore, screening was carried out based on inclusion and exclusion criteria to be able to answer research questions, as shown in Table 1. Some articles were not explicitly related to the research questions. Based on the screening stage, 50 articles met this study's criteria for review. Then, the 50 articles were reviewed in a quest to answer research questions. Then the results of the review are analyzed, and conclusions are drawn on each research question as a result of the findings in this literature study.

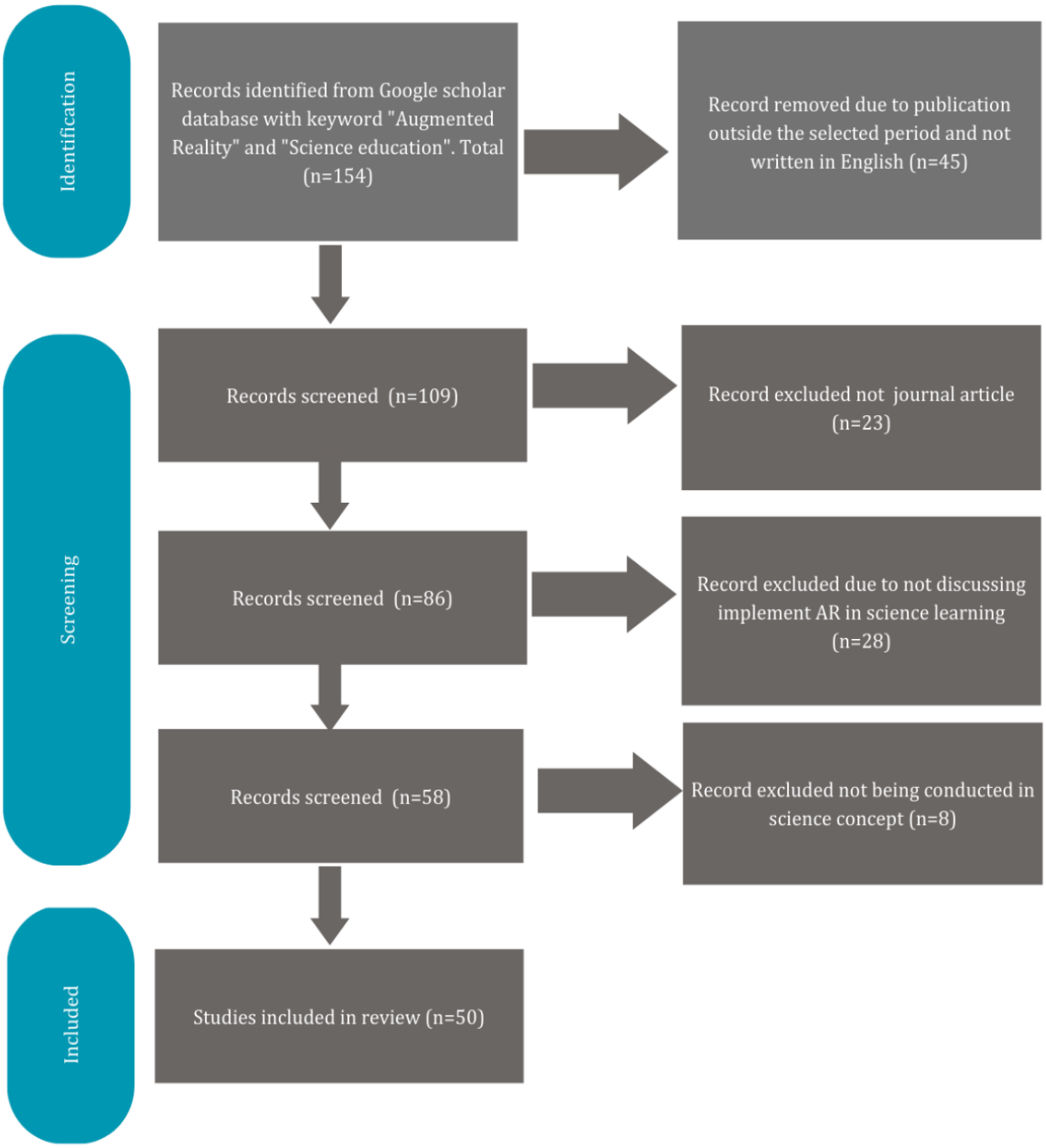

Figure 1. Flowchart of the included in this study

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Publish between 1 January 2012 and 1 December 2022	Publish outside of 1 January 2012 and 1 December 2022
Publish in Google scholar indexed databases journals	Books, reviews, short articles, and proceedings
Written in English	Not written in English
Focus on implementing AR technology in science learning	Not focus on the use of AR technology in science learning
The concepts contained in AR are science concepts	The concepts contained in AR are not science concepts
Available in full text	Unavailable in full text

RESULT

Examined variables on AR in science learning

In this review, the investigated variables were investigated as categories. The results show that the significant benefits reported in the articles were: "Learning achievements" (f=22), "motivation" (f=10), "attitude" (f=5), and many other variables, as shown in Table 2.

Material types on AR in science learning

The types of materials used for AR in science learning were discussed in this review. The result of the study showed that *mobile* applications (f = 19) and AR picture books (f = 14) were the most frequently used options in science learning; the overall results are shown in Figure 2.

The study found that mobile apps and AR picture books are the most popular, especially in secondary school. "Mobile application" refers to an AR application used on mobile phones, and "AR picture book" refers to an AR application designed in the form of a book, with virtual objects defined based on the pictures in the book. "AR game system" refers to an AR application placed on a mobile phone, computer, or mobile games. Also, "marker-based material on paper" refers to implementing AR using images or scanning barcode on paper. Although many types of AR are developed with mobile systems, the content developed differs, and the type of AR used is a mobile application.

Method trends

Methodological trends are shown in Figure 3. As a result, 40% used a quantitative design, 12% preferred a qualitative design, 18% preferred a mixed design (quantitative and qualitative), and 9% preferred a review/meta-analysis study.

Table 2. The result of variables examined in the articles

Examined Variables	Number of articles	Percentage (%)
Learning achievements	22	44
Motivation	10	20
Attitude	5	10
Cognitive aspect	3	6
Perception	1	2
Self-regulation	1	2
Critical thinking skill	1	2
Self-efficacy	1	2
Interest	1	2
Scientific literacy	1	2
Problem-solving skills	1	2
Scientific Imagineering	1	2
Misconceptions	1	2
Interaction of students	1	2
Total	50	100%

.

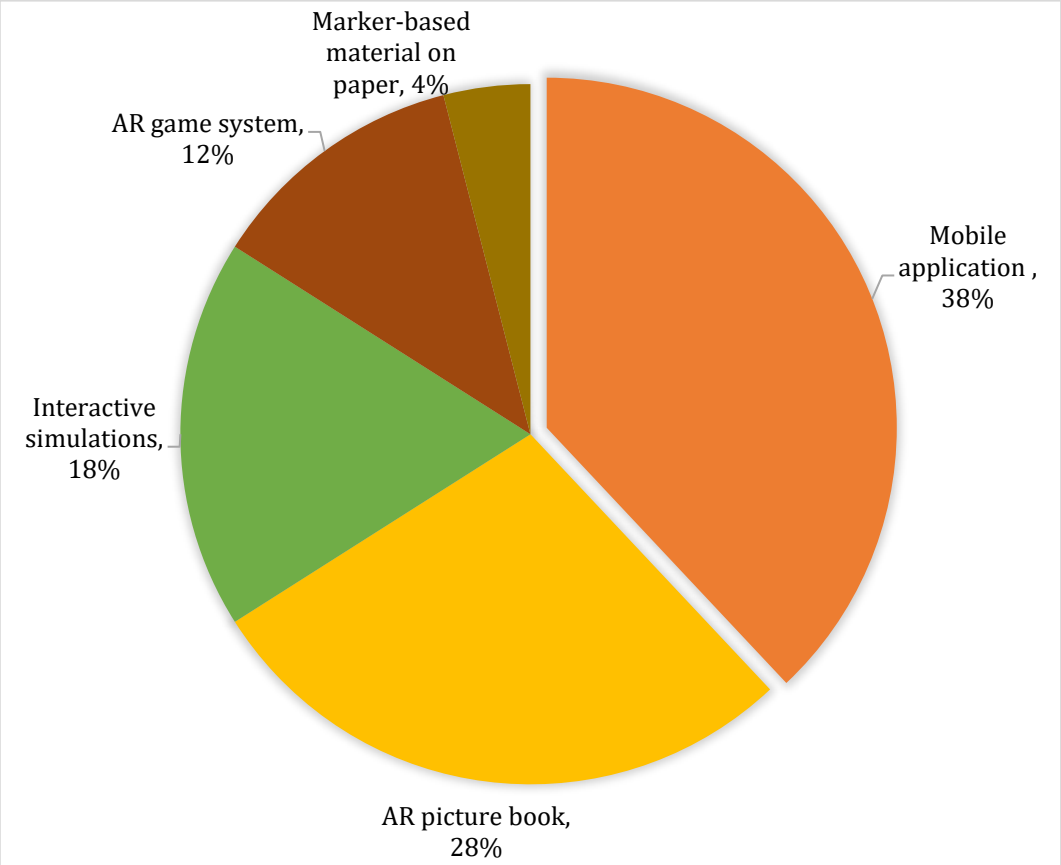

Figure 2. The percentage of AR types used in science learning

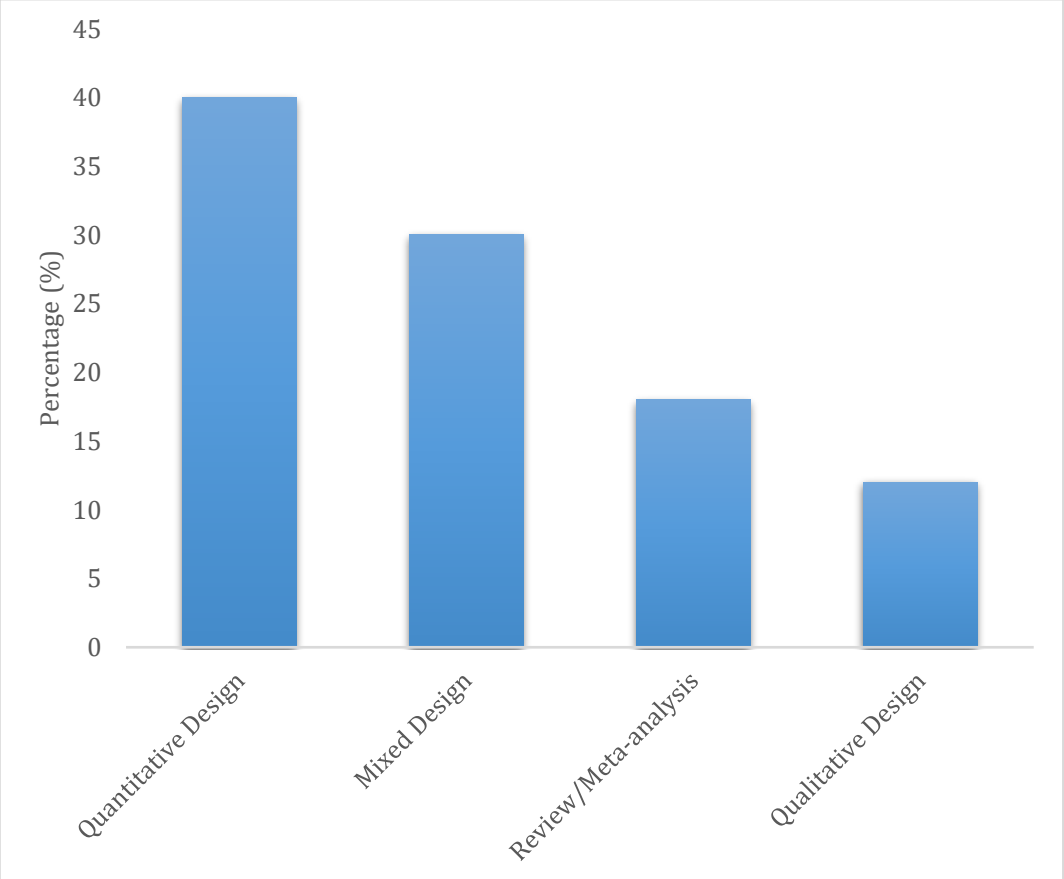

Figure 3. The percentage of methods trends

Data collection tools

As a result, we found that achievement tests (58%), questionnaires (20%), and surveys (14%) were frequently used in articles. The study results are shown in Figure 4.

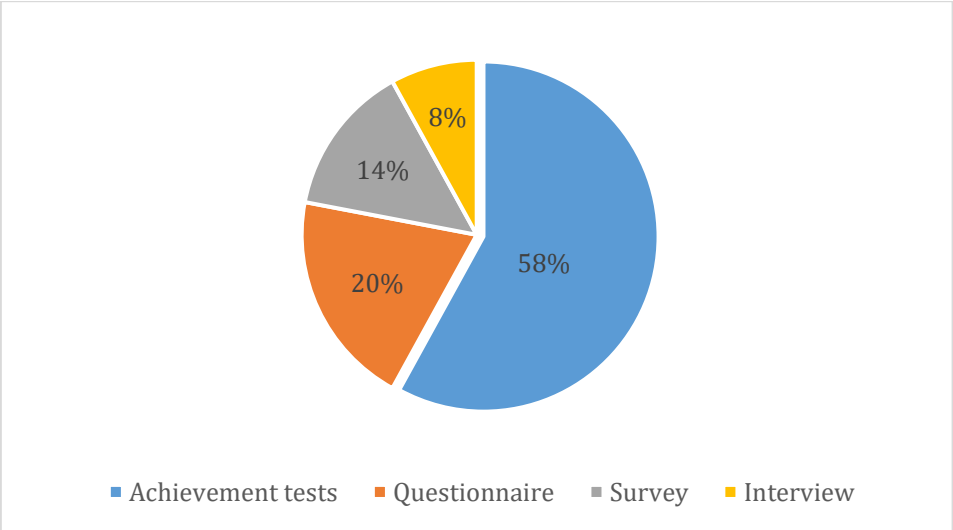

Figure 4. The percentage of data collection tools trends

Sampling methods and sample populations

The sampling method used often is convenience sampling (40%), as shown in Table 3. Research participants who often appear in research on the use of AR in science learning are elementary school students (6%), secondary schools (56%) consisting of junior high school students (24%) and senior high school students (32%), college students (22%), and teachers (16%).

Table 3 demonstrates that the sampling methods that are often used are convenience sampling and random sampling. Two articles did not mention their sampling method. The sampling populations are commonly identified, as shown in Figure 5.

Table 3. Frequency of sampling methods

Sampling method	Number of articles	Percentage (%)
Convenience sampling	20	40
Random sampling	18	36
Purposive sampling	10	20
Unknown	2	4
Total	50	100

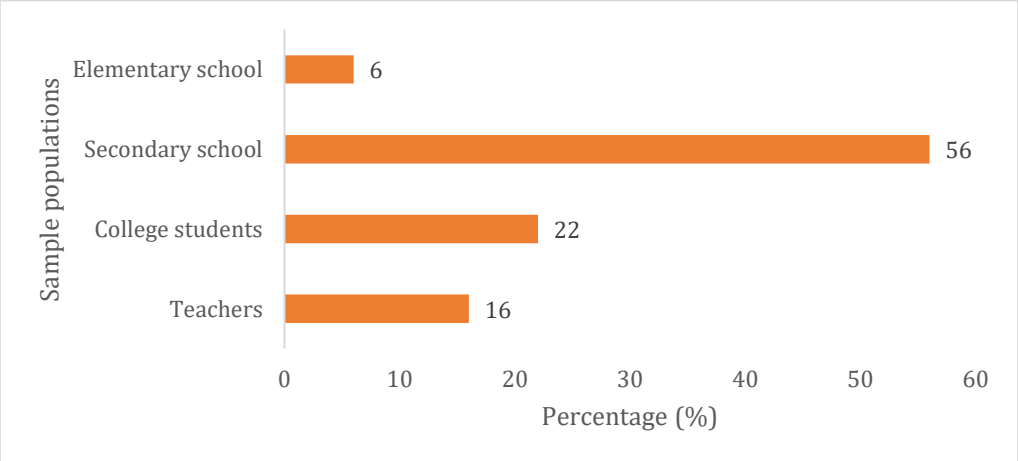

Figure 5. Percentage of sampling populations

Recommendations for future research AR in science education

Based on the articles reviewed in this study, several researchers' recommendations were found for future research on AR in science education. Current research objectives mainly focus on cognitive abilities such as critical thinking, creative thinking, multi-representational abilities, or problem-solving. Besides, the potential of AR technology to improve cognitive abilities also positively impact students' affective abilities, such as attitudes, behaviour, character, and how to manage emotions. Mostly, the recommendation is to identify the effect of applying AR in science education on students' attitudes.AR is a new technology for teachers, students, and college students. The training is needed to implement AR well in the learning process. Current research focuses mainly on students; teachers are rarely highlighted. Therefore, recommendations from several articles are for further research to be carried out by conducting surveys regarding teacher interest in AR, training to implement AR for teachers, and the positive and negative impacts of AR if applied in classroom learning based on the teacher's perspective. Besides, several other recommendations were also found, including using AR technology as an alternative to learning abstract concepts, using a wide sample when implementing AR, comparing AR and 3D simulation so that it can determine the effectiveness of AR in the learning process, and creating a measurement scale rubric in AR applications on attitude, motivation, and managing emotions that are valid and reliable.

DISCUSSION

The systematic literature review found that learning achievement, motivation, and attitude were the most examined variables for implementing AR in science learning. This is to be expected as before because the variables are most commonly found in previous studies (Chang & Hwang, 2018; Fidan & Tuncel, 2019; Hsu & Huang, 2011; Hwang et al., 2016; Sahin et al., 2020; Yilmaz, 2021). The results also align with previous studies (Borrero & Márquez, 2012; Cai et al., 2012; Yen et al., 2013). On the other hand, learning achievement positively correlates with motivation and attitude. Therefore, these variables are considered in research (Cai et al., 2021; Yen et al., 2013). Besides, motivation and attitude are significant in implementing new technologies (Georgiou & Kyza, 2018; Küçük, et al., 2014). Many studies align with the previous research about the impact of AR apps on motivation and attitudes. The results also support context in education (Akçayır & Akçayır, 2017; Delello, 2014; Hwang et al., 2016; Martin-Gutierrez et al., 2012; Salmi et al., 2017). Introducing new technologies in education must question whether they contribute to learning achievement (Fidan & Tuncel, 2019; Rahmat, et al., 2023). Several studies examining the impact of AR use on learning achievement (Cai et al., 2014; Chen et al., 2015; Zhang et al., 2014)

The study shows that mobile applications and AR picture books are the AR types most often used in science learning. This type of AR may be chosen because it is easy to use and can be developed quickly and practically. In addition, mobile learning in secondary schools is considered ready both from smartphone ownership and students who are used to it in daily life (Rahmat, et al., 2023). A frequently used method based on the results of systematic literature searches is quantitative design. The rationale for using quantitative methods can be attributed to researchers' desire to objectively examine the impact of AR technology on learning achievement (Baydas et al., 2015). Another assumption is that using quantitative techniques is time and cost-efficient. A low proportion of studies used mixed methods (quantitative and qualitative), suggesting that these studies are challenging and time-consuming (Küçük, et al., 2014). The study also find that there are very few qualitative studies. This is probably due to the increasing trend of using mixed and quantitative studies (Bacca et al., 2014; Chen & Wang, 2015)

The review results show that cognitive tests, questionnaires, surveys and interviews are often data collection tools used. The trend of most quantitative designs is an increasing preference for data collection tools. The relatively high prevalence of interviews is due to the widespread use of mixed methods in research. Learning achievement emerged as the most studied variable in this study as one of the most studied variables in literature (Chang & Hwang, 2018; Hsu & Huang, 2011; Hwang et al., 2016). This study also found that research used tests, interviews, video observations, and surveys more frequently. The sampling method trend used in AR technology in

science learning is convenience sampling because researchers can easily access sample groups (Baydas et al., 2015). Research participants often used are a student in secondary school.

Recommendations from several articles reviewed in this study are to add literature related to the teacher's point of view on the use of AR in science learning. Science teachers with different educational backgrounds view implementing AR in teaching a science concept (Rahmat, et al., 2023). Another recommendation is to identify the effects of using AR in class on affective abilities such as attitude, character, or controlling students' emotions during the learning process. Future research can assess the impact of AR applications on students' attitudes during the learning process. Currently, the rubric that can be adapted is *Augmented Reality Applications Attitude Scales (ARAAS)* (Díaz-Noguera et al., 2017; Küçük, et al., 2014).

The systematic review of the literature in this study remains a minimal number of qualitative studies over the past six years. It is suggested that more qualitative studies will be conducted in the future. Hopefully, the review result can provide new insights for researchers interested in implementing AR in science learning. This study presents recommendations from previous researchers and can be an idea for researchers to conduct future research.

CONCLUSION

A systematic literature review revealed that learning achievement, motivation, and attitude were AR's most frequently investigated variables in science learning. Learning achievements correlate with motivation and attitude. Mobile applications and AR picture books are the most popular AR materials because they are easy to use, quick, and convenient to develop. The methodological trend is quantitative design. The data collection tool often used is an achievement test. The sampling method often used is convenience sampling, and the research participant frequently identified is secondary school students. The recommendations from previous researchers are to identify the effect of implementing AR technology on students' affective abilities and identify the teacher's perspective. The study's limitations are the minimal number of publications and qualitative studies conducted in the last six years. Further qualitative research is proposed to identify more detailed information on the use of AR in science learning.

Author contributions

The authors made significant contributions to the study's conception and design. The authors were in charge of data analysis, interpretation, and discussion of results. The final manuscript was read and approved by the authors.

Funding

This study is funded by the Indonesian Ministry of Education, Culture, Research and Technology through a PMDSU (*Program Magister Menuju Doktoral untuk Sarjana Unggul*) scheme with grant number T/15/1.34/UN34.21/PT.01.03/2022

Conflict of interest

No potential conflict of interest.

Data availability statement

All data are available from the authors.

REFERENCES

Abdusselam, M. S., & Karal, H. (2020). The effect of using augmented reality and sensing technology to teach magnetism in high school physics. *Technology, Pedagogy and Education*, *29*(4), 407–424. https://doi.org/10.1080/1475939X.2020.1766550

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, *20*, 1–11. https://doi.org/10.1016/j.edurev.2016.11.002

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators & Virtual Environments*, *6*(4), 355–385. https://doi.org/10.1162/pres.1997.6.4.355

Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk, G. (2014). *Augmented Reality Trends in Education: A Systematic Review of Research and Applications. Educational Technology & Society, 17 (4), 133-149.* http://www.jstor.org/stable/jeductechsoci.17.4.133

Baydas, O., Kucuk, S., Yilmaz, R. M., Aydemir, M., & Goktas, Y. (2015). Educational technology research trends from 2002 to 2014. *Scientometrics*, *105*, 709–725. https://doi.org/10.1007/s11192-015-1693-4

Billinghurst, M. (2002). Augmented reality in education. *New Horizons for Learning*, *12*(5), 1–5.

Borrero, A. M., & Márquez, J. M. A. (2012). A pilot study of the effectiveness of augmented reality to enhance the use of remote labs in electrical engineering education. *Journal of Science Education and Technology*, *21*(5), 540–557. https://doi.org/10.1007/s10956-011-9345-9

Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J. C. (2021). Effects of learning physics using Augmented Reality on students' self-efficacy and conceptions of learning. *British Journal of Educational Technology*, *52*(1), 235–251. https://doi.org/10.1111/bjet.13020

Cai, S., Wang, X., & Chiang, F.-K. (2014). A case study of Augmented Reality simulation system application in a chemistry course. *Computers in Human Behavior*, *37*, 31–40. https://doi.org/10.1016/j.chb.2014.04.018

Cai, S., Wang, X., Gao, M., & Yu, S. (2012). Simulation teaching in 3D augmented reality environment. *2012 IIAI International Conference on Advanced Applied Informatics*, 83–88. http://dx.doi.org/10.1109/IIAI-AAI.2012.25

Chang, S. C., & Hwang, G. J. (2018). Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions. *Computers and Education*, *125*, 226–239. https://doi.org/10.1016/j.compedu.2018.06.007

Chang, S. C., Hwang, G. J., Yoon, S. A., Anderson, E., Park, M., Elinich, K., Lin, J., Cheng, K. H., Cai, S., Chiang, F. K., Sun, Y., Lin, C., & Lee, J. J. (2018). Surveying students' conceptions of learning science by augmented reality and their scientific epistemic beliefs. *Interactive Learning Environments*, *25*(6), 226–239. https://doi.org/10.1080/02635143.2017.1386645

Chen, C., & Wang, C.-H. (2015). Employing augmented-reality-embedded instruction to disperse the imparities of individual differences in earth science learning. *Journal of Science Education and Technology*, *24*(6), 835–847. https://doi.org/10.1007/s10956-015-9567-3

Chen, X., Xu, L., Wang, Y., Wang, H., Wang, F., Zeng, X., Wang, Q., & Egger, J. (2015). Development of a surgical navigation system based on augmented reality using an optical see-through head-mounted display. *Journal of Biomedical Informatics*, *55*, 124–131. https://doi.org/10.1016/j.jbi.2015.04.003

Delello, J. A. (2014). Insights from pre-service teachers using science-based augmented reality. *Journal of Computers in Education*, *1*(4), 295–311. https://doi.org/10.1007/s40692-014-0021-y

Díaz-Noguera, M. D., Toledo-Morales, P., & Hervás-Gómez, C. (2017). Augmented reality applications attitude scale(ARAAS): Diagnosing the attitudes of future teachers. *New Educational Review*, *50*(4), 215–226. https://doi.org/10.15804/tner.2017.50.4.17

Erbas, C., & Demirer, V. (2019). The effects of augmented reality on students' academic achievement and motivation in a biology course. *Journal of Computer Assisted Learning*, *35*(3), 450–458. https://doi.org/10.1111/jcal.12350

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers & Education*, *142*, 103635. https://doi.org/10.1016/j.compedu.2019.103635

Georgiou, Y., & Kyza, E. A. (2018). Relations between student motivation, immersion and learning outcomes in location-based augmented reality settings. *Computers in Human Behavior*, *89*, 173–181. https://psycnet.apa.org/doi/10.1016/j.chb.2018.08.011

Hsu, J.-L., & Huang, Y.-H. (2011). The Advent of Augmented-Learning: A Combination of Augmented Reality and Cloud Computing. *E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*, 1328–1333. https://www.learntechlib.org/primary/p/38900/

Hwang, G.-J., Wu, P.-H., Chen, C.-C., & Tu, N.-T. (2016). Effects of an augmented reality-based educational game on students' learning achievements and attitudes in real-world observations. *Interactive Learning Environments*, *24*(8), 1895–1906. http://doi.org/10.1080/10494820.2015.1057747

İçten, T., & Bal, G. (2017). A content analysis of the academic works on the augmented reality technology. *Journal of Information Technologies*, *10*(4), 401–415. https://doi.org/10.17671/gazibtd.290253

Johnson, L., Adams Becker, S., Cummins, M., Estrada, V., Freeman, A., & Hall, C. (2013). NMC Horizon report: higher education edition. *Report. The New Media Consortium*.

Kiryakova, G., Angelova, N., & Yordanova, L. (2018). The potential of augmented reality to transform education into smart education. *TEM Journal*, *7*(3), 556. https://doi.org/10.18421/TEM73-11

Küçük, S., Yilmaz, R., Baydas, Ö., & Göktas, Y. (2014). Augmented reality applications attitude scale in secondary schools: Validity and reliability study. *Egitim ve Bilim*, *39*(176).

http://doi.org/10.15390/EB.2014.3590
Martin-Gutierrez, J., Guinters, E., & Perez-Lopez, D. (2012). Improving strategy of self-learning in engineering: laboratories with augmented reality. *Procedia-Social and Behavioral Sciences*, *51*, 832–839. https://doi.org/10.1016/j.sbspro.2012.08.249
Medina Herrera, L., Castro Pérez, J., & Juárez Ordóñez, S. (2019). Developing spatial mathematical skills through 3D tools: augmented reality, virtual environments and 3D printing. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *13*(4), 1385–1399. https://doi.org/10.1007/s12008-019-00595-2
Rahmat, A. D., Kuswanto, H., & Wilujeng, I. (2022). The Advantages and Applications of Augmented Reality in Science Education. *Nusantara Science and Technology Proceedings*, 1–7. http://doi.org/10.11594/nstp.2022.2501
Rahmat, A. D., Kuswanto, H., & Wilujeng, I. (2023). *Mobile Learning Readiness of Junior High School Students in Science Learning*. *25*(April), 54–61. https://doi.org/10.21009/jtp.v25i1.34063
Rahmat, A. D., Kuswanto, H., Wilujeng, I., Ilma, A. Z., & Putranta, H. (2023). Teachers' perspectives toward using augmented reality technology in science learning. *Cypriot Journal of Educational Sciences*, *18*(1), 215–227. https://doi.org/10.18844/cjes.v18i1.8191
Rahmat, A. D., Kuswanto, H., Wilujeng, I., & Perdana, R. (2023). Implementation of mobile augmented reality on physics learning in junior high school students. *Journal of Education and E-Learning Research*, *10*(2), 132–140. https://doi.org/10.20448/jeelr.v10i2.4474
Roumba, E., & Nicolaidou, I. (2022). Augmented Reality Books: Motivation, Attitudes, and Behaviors of Young Readers. *International Journal of Interactive Mobile Technologies (IJIM)*, *16*(16), 59–73. https://doi.org/10.3991/ijim.v16i16.31741
Sahin, D., Yilmaz, R. M., Yilmaz, O., Karagozlu, D., Abdusselam, M. S., Karal, H., Fidan, M., & Tuncel, M. (2020). The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. *Computers and Education*, *52*(4), 407–424. https://doi.org/10.1016/j.compedu.2019.103710
Salmi, H., Thuneberg, H., & Vainikainen, M. P. (2017). Making the invisible observable by Augmented Reality in informal science education context. *International Journal of Science Education, Part B: Communication and Public Engagement*, *7*(3), 253–268. https://doi.org/10.1080/21548455.2016.1254358
Surahman, E., & Wang, T. H. (2022). Academic dishonesty and trustworthy assessment in online learning: A systematic literature review. *Journal of Computer Assisted Learning*, *38*(6), 1535–1553. https://doi.org/10.1111/jcal.12708
Wojciechowski, R., & Cellary, W. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. *Computers & Education*, *68*, 570–585. https://doi.org/10.1016/j.compedu.2013.02.014
Yen, J.-C., Tsai, C.-H., & Wu, M. (2013). Augmented reality in the higher education: Students' science concept learning and academic achievement in astronomy. *Procedia-Social and Behavioral Sciences*, *103*, 165–173. https://doi.org/10.1016/j.sbspro.2013.10.322
Yilmaz, O. (2021). Augmented Reality in Science Education: An Application in Higher Education. *Shanlax International Journal of Education*, *9*(3), 136–148. https://doi.org/10.34293/education.v9i3.3907
Yoon, S., Anderson, E., Lin, J., & Elinich, K. (2017). How augmented reality enables conceptual understanding of challenging science content. *Journal of Educational Technology & Society*, *20*(1), 156–168.
Zhang, J., Sung, Y.-T., Hou, H.-T., & Chang, K.-E. (2014). The development and evaluation of an augmented reality-based armillary sphere for astronomical observation instruction. *Computers & Education*, *73*, 178–188. https://doi.org/10.1016/j.compedu.2014.01.003