JIPF (JURNAL ILMU PENDIDIKAN FISIKA)
p-ISSN: 2477-5959 | e-ISSN: 2477-8451 *Vol. 9 No. 2, May 2024, Page 161-171*

Integrating Augmented Reality Technology in Magnetic Field Learning: A Systematic Literature Review

Venny Haris [1], Siti Nursaila Binti Alias [2*)], Shahrul Kadri Bin Ayop [3]
Universiti Pendidikan Sultan Idris Malaysia[1,2,3], UIN Mahmud Yunus Batusangkar, Indonesia[1]
[*)]Corresponding E-mail: anasaila@fsmt.upsi.edu.my

Received: December 23th, 2023. Revised: March 28th, 2024. Accepted: April 1st, 2024

Keywords :
Augmented Reality; Magnetic Field; Systematic Literature

ABSTRACT
ABSTRACT
The aim of this study was to uncover research trends in the use of augmented reality (AR) in magnetic field learning from 2012 to 2023. The review in this study followed the guidelines of Kitchenham, B. and Charters, which consisted of three stages: planning, conducting, and reporting the review. During the planning stages of the review, 107 articles were identified using keywords. The remaining articles were examined according to inclusion and exclusion criteria, so that 21 articles were further processed. A review stage is then carried out, followed by reporting of the review results. The results of this study suggest that the use of augmented reality (AR) to teach magnetic fields is primarily focused on teaching high school students. The aspects that have attracted the most attention when analyzing the implementation of AR in magnetic field education are learning/academic performance, perception and attitude. The most commonly used forms of AR in the study of magnetic fields are mobile applications, AR-based learning experiments, 3D simulations, and real-time simulations, all of which aim to explain abstract concepts and facilitate experimental explorations. Quantitative research design is the most commonly used approach in this field. The primary data collection tools used in this study include achievement tests, surveys, and questionnaires.

INTRODUCTION

Physics is among the disciplines explored by students at the high school level in Indonesia. Physics encompasses comprehending theories and conducting experiments, which most students consider difficult [1] [2]. A subject of study considered difficult by students is the subject of magnetic fields, as highlighted by Neset Demirci [3] and Chasteen & Pollock [4]. This difficulty arises from the abstract nature of magnetic fields, which necessitates using visual aids to comprehend these abstract ideas.

Physics concepts of an abstract nature can be visually represented through the utilization of technological tools such as Augmented Reality [5] [6] [7] [8]. Augmented Reality (AR) is a technology that engrosses the user and allows for interaction, whereby computer-generated digital information, including video, graphics, animation, text, or sound, is seamlessly incorporated into real-world surroundings [9] [10] [11]. An extension or variation of virtual reality (VR), AR is a connection that effectively bridges the divide between actuality and virtual reality [12] [13].

In the last 11 years, namely from 2012 to 2023, there has been a growing trend in the field of science education, especially in physics, where the integration of Augmented Reality (AR) technology has been the focus of research [14] [15] [16] [17]. A notable development is the incorporation of AR into learning materials, with various studies exploring its application in various subject areas such as electrical concepts [18] [19], sound waves and optics [20], and planetary motion [21] [22]. The results of these studies have shown positive results indicating an improvement in student performance. Furthermore, Dünser et al. [23] developed an interactive physics textbook that uses AR technology to enhance learning experiences on electromagnetism and is specifically aimed at high school students. Previous research has shown that marker-based AR books are more effective at helping students understand complex 3D concepts than traditional books. As a result, further research has been conducted to explore the use of tablets as an alternative to smart glasses for AR applications [24] [25]. These studies aim to explore the potential of tablet-based AR to improve students' conceptual mastery while reducing their cognitive load.

In the field of educational research, the use of Augmented Reality (AR) can also be useful in the field of laboratory-based learning [26] [27] [28] [29] [30]. In addition, AR can increase the attractiveness and interactivity of physics laboratories. By using AR, students can participate in exploration and interaction with virtual objects in a safe laboratory environment. Furthermore, the implementation of AR has the potential to strengthen student engagement and improve learning outcomes in physics laboratory training [28]. Wang et al. [31] conducted a comprehensive study of student behavior in a collaborative environment for physics studies. The results of this study show that AR visualization can be a valuable tool for promoting student engagement and facilitating experimentation as a learning method, particularly in collaboration between students.

Since 2019, numerous review articles have been published on the use of augmented reality (AR) in education, particularly in the context of science teaching. These studies include the studies by various researchers [14] [15] [16] [17], which examine the integration of Augmented Reality (AR) in science education. In previous research, there have been several reviews on implementing AR in physics education and experimental environments [15] [32] [33]. Based on this review, no research has been conducted on integrating AR into physics education, particularly in magnetic fields involving abstract concepts.

Therefore, this research focuses on conducting an evaluation to identify and verify the use of AR in physics education, with a particular focus on the topic of magnetic fields. In a more specific context, we examine the variables, AR types, predominant methods, data collection tools, sampling techniques, and research participants commonly used in AR research in the field of magnetism education. The boundaries and scope of scientific publications included in the final review were determined by the inclusion and exclusion criteria of this study. Initially, the researchers only considered the papers that considered AR in the context of magnetic field learning – where the results could be quantified. Likewise, papers published before 2012 were excluded from this analysis in order to examine studies published in the last 11 years showing an increase in the use of augmented reality (AR) in physics education (i.e., between 2012 and 2023). This review only includes research published in indexed journals and proceedings, as such publications are believed to have greater credibility than non-indexed journals and proceedings.

The insights gained from this methodological review of the existing literature can help researchers and educators interested in implementing AR in the field of physics education, particularly in the context of magnetic fields. Therefore, a comprehensive investigation is conducted to elucidate the presence of AR in magnetic field learning and answer the following seven research queries.

1. How many articles have been published about the use of AR in magnetic field learning?
2. What population has been studied in articles about the use of AR in magnetic field learning?
3. What variables have been examined in the published articles on the use of AR in magnetic field learning?
4. How has AR been used in magnetic field learning?
5. What research methods were used in the published articles on the use of AR in magnetic field learning?
6. What instruments were used in the published articles on the use of AR in magnetic field learning?
7. What are the recommendations for future AR research in magnetic field learning?

METHOD

This research follows the guidelines of Kitchenham, B. and Charters [34], who suggest that systematic reviews include three main phases: planning the review, conducting the review, and reporting the review. The stages of the systematic review are shown in Figure 1.

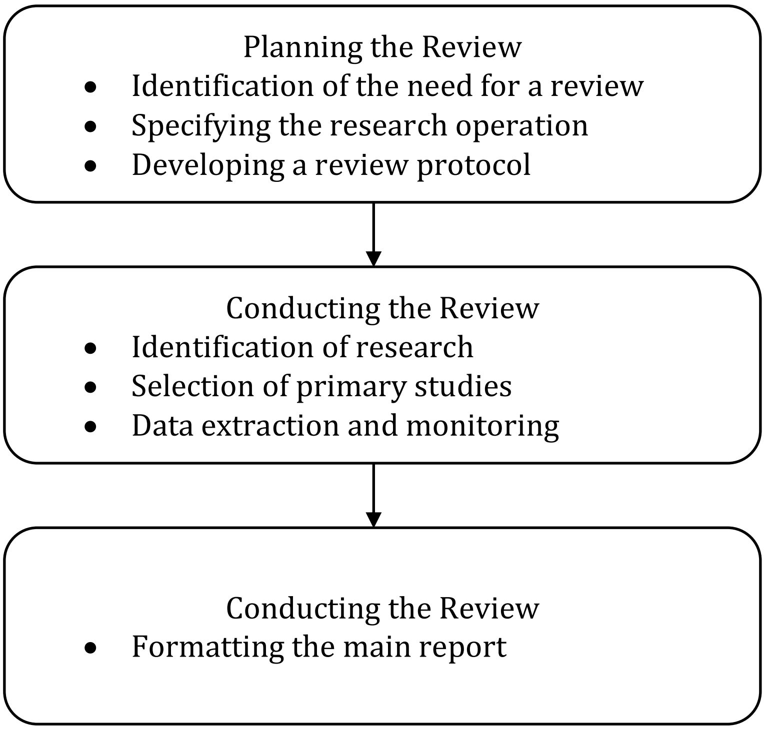

Fig 1. *The Stages in a Systematic Literature Review* [34]

Planning the review

This stage entailed formulating the methodology for identifying the most relevant literature to answer the research queries. We conducted a thorough and iterative verification process from 2012 to June 2023 focused on scientific journals on the use of augmented reality in magnetic field learning. We used Publish or Perish software to conduct the search. The search terms used were "Augmented Reality" AND "Magnetic Field" and "Augmented Reality" AND "Magnetism Learning" in the Google Scholar databases. The following search criteria were defined: Document type: "Article". Language: English. The initial search yielded a total of 200 articles. We then defined the following categories: article and proceeding type. After applying these additional filters, we identified 107 articles.

Researchers meticulously examined these articles to determine their suitability for inclusion in the study. Articles that did not meet the specified inclusion and exclusion criteria (see Table 1) were excluded. Ultimately, we identified 21 studies that were deemed relevant to the objectives of this review.

Table 1. Inclusion and Exclusion Criteria

Inclusion	Exclusion
Articles from indexed journal	Articles not indexed, book chapters, paten, etc
Conference proceedings indexed	Conference proceedings not indexed
Empirical articles	Editorials, meta-analysis, review articles on application developments
Articles focusing on AR in magnetic field learning	Articles on other topics
Timeline 2012 – June 2023	Less than 2012

Conducting the Review

This stage took place after the planning phase of the review was completed. We then designed a data extraction form (spreadsheet document) that consisted of the following elements: study name, publication type, publication year, publication journal, sample level, variables examined, type of AR, data collection tools, reported advantages, reported disadvantages, time dimension, and main results.

Reporting the Review

In the current stage, a comprehensive analysis, synthesis, and presentation of relevant information was carried out, which effectively addressed the research queries established in the initial planning phase. The results of the study were briefly and succinctly summarized in the "Results" section.

RESULTS AND DISCUSSIONS

Number of Publications

Among the 21 research studies on Augmented Reality in Magnetic Field Learning, 13 scientific journals and eight scientific conferences were analyzed. The tabular format referred to as Table 2, illustrates the allocation of articles from 2012 to June 2023.

Table 2. Publication Type and Number of Articles Selected in Each

Publication Type	Journal and Conference Selected	Number of Studies	Percentage (%)
Journal	Computers & Education: X Reality	1	4.76
Journal	International Journal of Science Education, Part B	1	4.76
Journal	Interactive Learning Environments	2	9.52
Journal	Journal of Computer-Assisted Learning	1	4.76
Journal	Computer Applications in Engineering Education	1	4.76
Journal	Technology, Pedagogy and Education	1	4.76
Journal	Procedia Computer Science	1	4.76
Journal	IEEE Transactions on Magnetics	2	9.52
Journal	Pegem Journal of Education & Instruction	1	4.76
Journal	Computers & Education	1	4.76
Journal	The Physics Teacher	1	4.76
Proceeding	Journal of Physics: Conference Series	3	14.29
Proceeding	CHI '19: CHI Conference on Human Factors in Computing Systems	1	4.76
Proceeding	2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)	1	4.76
Proceeding	2019 International Symposium on Educational Technology (ISET)	1	4.76
Proceeding	2017 IEEE 17th International Conference on Advanced Learning Technologies (ICALT)	1	4.76
Proceeding	OzCHI '12: Proceedings of the 24th Australian Computer-Human Interaction Conference	1	4.76

The results of the systematic literature search show that only 21 articles were published in international journals and proceedings indexed by Scopus and WOS in the period 2012-2023. Articles exploring the use of AR in learning magnetic fields have been published primarily in the proceedings of the Journal of Physics: Conference Series, followed by the journal Interactive Learning Environments and the journal IEEE Transactions on Magnetics. Additionally, journals such as Computers & Education and Technology, Pedagogy and Education only have one publication from 2012 to 2023.

Distribution of Sample Levels

Of the 21 studies on the use of AR in magnetic field learning, eight studies were conducted on high school students, six studies were conducted on university students, five studies were conducted on junior high school students, one study was conducted on teachers, and one study did not explain which sample was used. The distribution of sample quantities is shown in Table 3.

Table 3. Distribution of Sample Levels

Sample level	Number of Articles	Percentage (%)	Sample research
Junior High School students	5	23.81	Q.Liu et al. [27]
High school students	8	38.10	Abdusselam & Karal [35]
Undergraduate students	6	28.57	Radu & Schneider [36]
Teachers	1	4.76	Widyanti et al. [37]
Not mention	1	4.76	Matsutomo et al. [38]

The results of the literature analysis found that the use of AR in magnetic field learning was mainly carried out by high school students [23] [35] [39] [40] [41] [42]. Then the use of AR in learning magnetic fields was carried out in universities [36] [43] [44] [45], and then the use of AR in explaining abstract concepts in learning magnetic fields was also carried out in junior high school students [27] [46] [47] [48] [49].

Variables Examined in the Articles about the Use of AR in Magnetic Field Learning

The variables examined were examined as a separate category in this study and the results were presented in Table 4. The findings demonstrate that the primary benefits identified in the articles are as follows: "Learning/Academic Achievement" (f=13), "Perception" (f=4), and "Attitude" (f=4). Moreover, other variables, such as motivation, learning interaction, cognitive load, critical thinking, and satisfaction, were all thoroughly assessed within the scope of the analyzed literature.

Table 4. Frequency of the Examined Variables in the Articles

Examined Variables	Number of Articles	Percentage (%)	Sample Research
Learning/academic achievement	13	61.90	Cai et al. [49]
Perception	4	19.05	Abdusselam & Karal [35]
Attitude	4	19.05	Radu & Schneider [36]
Motivation	2	9.52	Ibanez et al. [50]
Learning interaction	2	9.52	Y. Wang [46]
Cognitive load	1	4.76	Q. Liu et al [27]
Critical Thinking	1	4.76	Faridi et al [44]
Inquiry styles	1	4.76	Radu et al. [43]
Scientific concepts	1	4.76	Radu et al. [43]
Satisfaction	1	4.76	Y. Wang [46]
Collaboration	1	4.76	Radu & Schneider [36]
Flow state	1	4.76	Ibáñez et al. [51]
Opinions	1	4.76	Abdusselam [41]

The review results also show that learning outcomes, perception, and attitude are often examined in these articles. Almost all articles examined included learning outcomes variables in their research. These variables were found in the research [43] [46] [47]. Most research states that using AR in magnetic field learning is effective in improving students' learning performance. In the literature discussed, learning success variables are often combined with perception, attitudes and motivation. This is because learning achievement is strongly influenced by students' attitudes, motivations and perceptions, so these variables are taken into account simultaneously in a study [52[[53] [54]. In the research of Cai et al. [49] and Radu et al. [43], the observed variables were students' learning achievement and their attitudes toward AR technology in magnetic field learning. Meanwhile, the research of Liu et al [27] and Abdusselam & Karal [35] examined the impact of using AR in the magnetic field learning on learning achievement and students' perceptions of the AR technology used. In addition, several studies have been conducted in the articles reviewed, the impact of using AR in magnetic field learning on students' interaction with the environment [46], the impact of AR on students' critical thinking abilities [44], the impact of AR on cognitive load [27], and several other variables mentioned in the "Results" section.

AR Applications Used in Magnetic Field Learning

This aim of this research was to investigate the different materials for AR in magnetic field learning examined in the reviewed articles. When reviewing the articles, it was found that mobile applications (f = 4), AR-based learning environments (f = 2), 3D simulation based on AR (f = 2), and a real-time visualization based on AR (f = 2) proved to be the most popular alternatives. The relevant findings on this topic are presented in Table 5.

Table 5. Types of AR Applications Used in Magnetic Field Learning

AR Applications	**Number of Articles**	**Percentage (%)**	**Sample research**
Mobile application	4	19.05	Q. Liu et al [27]
AR-based learning environments	2	9.52	Faridi et al [44]
3D simulation based on AR	2	9.52	Bakri et al. [40]
A real-time visualization based on AR	2	9.52	Matsutomo et al. [38]
Remote AR system	1	4.76	Radu et al. [43]
AR game system	1	4.76	Y. Wang [46]
Electronic worksheets integrate STEM AR	1	4.76	Zahara et al. [55]
STEM learning resources assisted by AR	1	4.76	Widyanti et al. [37]
AR instructional material	1	4.76	Abdusselam & Karal [35]
AR-based experiment	1	4.76	Harun et al. [39]
Interactive hardware system	1	4.76	Radu & Schneider [36]
AR-based inquiry courseware	1	4.76	Q. Liu et al. [48]
AR-based motion sensing software	1	4.76	Cai et al. [49]
Immersive visualization system	1	4.76	Matsutomo et al. [56]
AR books	1	4.76	Dünser et al [23]

The analysis results also show that mobile applications, AR-based learning environments, 3D simulation and real-time visualization based on AR are the types of AR that are widely used in magnetic field learning. This type makes it easier visualize abstract concepts from magnetic field material in classroom learning.

Method Trends

Based on Figure 2, 52% of articles used quantitative design, 24% used development design, 19% used mixed design, and 5% used qualitative design.

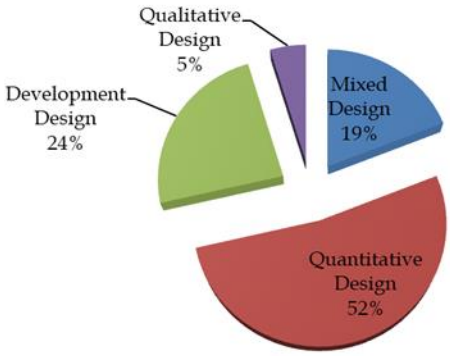

Fig 2. *Research method used in the reported studies*

According to a thorough literature review, researchers utilize quantitative methods more frequently than qualitative ones. The need to observe the immediate effects of utilizing AR in researching magnetic fields is likely the driving force behind researchers' widespread usage of quantitative designs. Due to the rise in research using quantitative designs and mixed techniques, particularly in using AR in physics learning in recent years [14] [32], this form of qualitative research is rarely conducted. A few articles also detail the design stage of employing AR for understanding magnetic fields. The impact of the emerging AR technology has not been examined through experimental study for this kind of article.

Data Collection Tools on the Use of AR in Magnetic Field Learning

The results demonstrate that achievement tests were employed in 61.90% of the articles, survey/questionnaires in 52.38%, and interviews in 23.81%. The distribution of data collection tools is shown in Table 6.

Table 6. Distribution of Instruments

Instruments	Number of Articles	Percentage (%)	Sample research
Achievement test	13	61.90	Cai et al. [49]
Survey / Questionnaire	11	52.38	Y. Wang [46]
Interview	5	23.81	Abdusselam & Karal [35]
Observation	2	9.52	Y. Wang [46]
Cognitive load scale	1	4.76	Q. Liu et al [27]
Validated rating scheme	1	4.76	Radu & Schneider [36]
Flow State Scale (FSL)	1	4.76	Ibáñez et al. [51]
Self assessment	1	4.76	Buesing & Cook [42]

The analysis results also show that assessment tests and surveys/questionnaires are the most commonly used data collection tools. This is consistent with the results showing that the quantitative research design is the most commonly used in the articles examined. The variable academic achievement appears most frequently in the papers in this study. This is consistent with the results of the study investigation [14] [57]. According to Sırakaya & Alsancak Sırakaya [57] and Mustafa & Arici et al. [14], tests, questionnaires, surveys, and interviews were the most commonly used data collection tools.

Based on the analysis of the articles discussed in this research, especially on the use of AR in magnetic field learning, we propose several suggestions for future AR research in magnetic field learning: 1) Previous research on the effects of using AR in the field of magnetic field learning focused mainly on the variables associated with learning outcomes, attitudes, perceptions, and motivation. In future research, it would be beneficial to expand the scope of these variables to understand the effectiveness of AR in the learning process. Additionally, future research can be conducted on how AR influences the cognitive load of students engaging in magnetic field learning, considering factors such as age and gender. In addition, future research could also focus on the influence of AR on students' engagement in magnetic field learning, so that the benefits of AR in learning can be understood. 2) There is potential for further improvements in integrating augmented reality (AR) technology into smartphone applications and games, particularly related to magnetic fields. This advance would serve to facilitate visualization of abstract concepts and experimentation. 3) To help explain conceptual ideas about magnetic fields, future research efforts must focus on developing printed educational materials. These materials, such as books and modules, should incorporate AR technology to visualize abstract concepts related to magnetic fields and experiments. This also follows the recommendations of the review results [58]. In addition, it is recommended to conduct experimental research to determine the effectiveness of using printed teaching materials in magnetic field learning.

CONCLUSION AND SUGGESTION

This work presents a systematic literature review of research articles that use AR applications for learning magnetic fields. It can be concluded: (1) There are 21 articles on the use AR in learning magnetic fields published in Scopus-indexed journals and conference proceedings. (2) The use of AR for magnetic field teaching primarily aimed at high school students. (3) The variables that have received the most attention when studying AR implementation in magnetic field learning are learning/academic achievement, perception, and attitude. (4) The most commonly used types of AR in the study of magnetic fields include mobile applications, AR-based learning experiments, 3D simulations, and real-time simulations, all of which aim to clarify abstract concepts and facilitate experimental explorations. (5) Quantitative research design is the most commonly used approach in this area. (6) The primary data collection tools of this study include tests, surveys and questionnaires. (7) Recommendations are made regarding variables that have not been examined in depth in the articles discussed. The implication of this research is to find the gap in research regarding the use of AR in learning magnetic fields through patterns of analysis results and frequently occurring keywords. For example, the research would examine the effects of AR on students' engagement in learning magnetic fields and examine the effects of gender on the learning outcomes of AR-based magnetic field learning. Future Research: There is a need to create teaching resources in the form of printed literature, including books and modules, that effectively connect augmented reality (AR) with the field of magnetic field learning, thus clarifying complicated theoretical constructs and experimental procedures.

ACKNOWLEDGMENTS

The first author would like to thank UIN Mahmud Yunus Batusangkar for providing a Ph.D. study scholarship in the Department of Physics, Faculty of Science and Mathematics, Sultan Idris Education University, Malaysia.

REFERENCES

[1] Handhika, J., Cari, C., Suparmi, A., & Sunarno, W. (2015). Exsternal representation to overcome misconception in physics. In *International Conference on Mathematics, Science, and Education* (Vol. 1, No. 1, pp. 1-4).

[2] Setyani, N. D., Cari, S., Suparmi, S., & Handhika, J. (2017). Student’s concept ability of Newton’s law based on verbal and visual test. In *International Journal of Science and Applied Science: Conference Series* (Vol. 1, No. 2, pp. 162-169).

[3] Demirci, N. (2006). Students’ conceptual knowledge about electricity and magnetism and its implications: an example of Turkish university. *Science Education International*, *17*(1), 49-64.

[4] Chasteen, S. V., & Pollock, S. J. (2009, November). A Research-Based Approach to Assessing

Student Learning Issues in Upper-Division Electricity & Magnetism. In *AIP Conference Proceedings* (Vol. 1179, No. 1, pp. 7-10). American Institute of Physics.
[5] 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.
[6] Kapp, S., Thees, M., Strzys, M. P., Beil, F., Kuhn, J., Amiraslanov, O., ... & Wehn, N. (2019). Augmenting Kirchhoff's laws: Using augmented reality and smartglasses to enhance conceptual electrical experiments for high school students. *The Physics Teacher*, *57*(1), 52-53.
[7] Kuit, V. K., & Osman, K. (2021). CHEMBOND3D e-module effectiveness in enhancing students' knowledge of chemical bonding concept and visual-spatial skills. *European Journal of Science and Mathematics Education*, *9*(4), 252-264.
[8] Zafeiropoulou, M., Volioti, C., Keramopoulos, E., & Sapounidis, T. (2021). Developing physics experiments using augmented reality game-based learning approach: A pilot study in primary school. *Computers*, *10*(10), 126.
[9] Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of science Education and Technology*, *18*, 7-22.
[10] Peddie, J. (2017). *Augmented reality: Where we will all live* (Vol. 349). Cham: Springer.
[11] Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & education*, *62*, 41-49.
[12] Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE computer graphics and applications*, *21*(6), 34-47.
[13] Weng, C., Rathinasabapathi, A., Weng, A., & Zagita, C. (2019). Mixed reality in science education as a learning support: A revitalized science book. *Journal of Educational Computing Research*, *57*(3), 777-807.
[14] Arici, F., Yildirim, P., Caliklar, Ş., & Yilmaz, R. M. (2019). Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis. *Computers & education*, *142*, 103647.
[15] Wulandari, S., Wibowo, F. C., & Astra, I. M. (2021, October). A review of research on the use of augmented reality in physics learning. In *Journal of Physics: Conference Series* (Vol. 2019, No. 1, p. 012058). IOP Publishing.
[16] Rahmat, A. D., Kuswanto, H., & Wilujeng, I. (2023). A systematic literature review of integrating augmented reality technology in science learning. *Jurnal Inovasi Teknologi Pembelajaran*, *10*(2), 172-181.
[17] Yilmaz, O. (2021). Augmented Reality in Science Education: An Application in Higher Education. *Shanlax International Journal of Education*, *9*(3), 136-148.
[18] Permana, A. H., Muliyati, D., Bakri, F., Dewi, B. P., & Ambarwulan, D. (2019, February). The development of an electricity book based on augmented reality technologies. In *Journal of Physics: Conference Series* (Vol. 1157, No. 3, p. 032027). IOP Publishing.
[19] Ropawandi, D., Halim, L., & Husnin, H. (2022). Augmented reality (AR) technology-based learning: the effect on physics learning during the covid-19 pandemic. *International Journal of Information and Education Technology*, *12*(2), 132-140.
[20] Bakri, F., Ambarwulan, D., & Muliyati, D. (2018). Pengembangan Buku Pembelajaran Yang Dilengkapi Augmented Reality Pada Pokok Bahasan Gelombang Bunyi Dan Optik. *Gravity: Jurnal Ilmiah Penelitian dan Pembelajaran Fisika*, *4*(2).
[21] Ibisono, H. S., Achmadi, H. R., & Suprapto, N. (2020). Efektivitas buku saku berbasis augmented reality pada materi gerak planet untuk meningkatkan prestasi belajar peserta didik SMA. *Inovasi Pendidikan Fisika*, *9*(02), 200-206.
[22] Suprapto, N., Ibisono, H. S., & Mubarok, H. (2021). The use of physics pocketbook based on augmented reality on planetary motion to improve students' learning achievement. *JOTSE: Journal of Technology and Science Education*, *11*(2), 526-540.
[23] Dünser, A., Walker, L., Horner, H., & Bentall, D. (2012, November). Creating interactive physics education books with augmented reality. In *Proceedings of the 24th Australian computer-human interaction conference* (pp. 107-114).
[24] Altmeyer, K., Kapp, S., Thees, M., Malone, S., Kuhn, J., & Brünken, R. (2020). The use of

augmented reality to foster conceptual knowledge acquisition in STEM laboratory courses—Theoretical background and empirical results. *British Journal of Educational Technology*, *51*(3), 611-628.

[25] 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.

[26] Akçayır, M., Akçayır, G., Pektaş, H. M., & Ocak, M. A. (2016). Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. *Computers in Human Behavior*, *57*, 334-342.

[27] Liu, Q., Yu, S., Chen, W., Wang, Q., & Xu, S. (2021). The effects of an augmented reality based magnetic experimental tool on students' knowledge improvement and cognitive load. *Journal of computer assisted learning*, *37*(3), 645-656.

[28] Sun, J. C. Y., Ye, S. L., Yu, S. J., & Chiu, T. K. (2023). Effects of wearable hybrid AR/VR learning material on high school students' situational interest, engagement, and learning performance: The case of a physics laboratory learning environment. *Journal of Science Education and Technology*, *32*(1), 1-12.

[29] Prastya, B. M. Y., Budiawanti, S., & Wahyuningsih, D. (2023). Development Of Physics Learning Media PHY-ART (Physics With Augmented Reality Technology) To Empower Student's Laboratory Skills. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, *8*(2), 192-199.

[30] Sun, J. C. Y., Ye, S. L., Yu, S. J., & Chiu, T. K. (2023). Effects of wearable hybrid AR/VR learning material on high school students' situational interest, engagement, and learning performance: The case of a physics laboratory learning environment. *Journal of Science Education and Technology*, *32*(1), 1-12.

[31] Wang, H. Y., Duh, H. B. L., Li, N., Lin, T. J., & Tsai, C. C. (2014). An investigation of university students' collaborative inquiry learning behaviors in an augmented reality simulation and a traditional simulation. *Journal of Science Education and Technology*, *23*, 682-691.

[32] Dewi, I. S., Mashurin, A. H., Anidhea, N. O., Jauhariyah, M. N., Prahani, B. K., Safitri, N. S., & Mubarok, H. (2021, December). Bibliometric Analysis of Research Developments in the Field of Augmented Reality in Physics Education (2012-2021*). In *International Joint Conference on Science and Engineering 2021 (IJCSE 2021)* (pp. 471-478). Atlantis Press.

[33] Al-Masarweh, R. Y. (2021). A Review of Augmented Reality in Physics Education and physics laboratory experiments (Applications, Advantages, Challenges). *Turkish Online Journal of Qualitative Inquiry*, *12*(9).

[34] Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering version 2.3. *Engineering*, *45*(4ve), 1051.

[35] 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.

[36] Radu, I., & Schneider, B. (2019, May). What can we learn from augmented reality (AR)? Benefits and drawbacks of AR for inquiry-based learning of physics. In *Proceedings of the 2019 CHI conference on human factors in computing systems* (pp. 1-12).

[37] Widyanti, R., Herlina, K., Zahara, M., & Agustina, L. (2021, February). Physics teachers' perceptions and anxieties about the use of technology-integrated learning resources on magnetic field material: A preliminary research on augmented reality-integrated STEM learning. In *Journal of Physics: Conference Series* (Vol. 1796, No. 1, p. 012082). IOP Publishing.

[38] Matsutomo, S., Miyauchi, T., Noguchi, S., & Yamashita, H. (2012). Real-time visualization system of magnetic field utilizing augmented reality technology for education. *IEEE transactions on magnetics*, *48*(2), 531-534.

[39] Harun, Tuli, N., & Mantri, A. (2020). Experience Fleming's rule in electromagnetism using augmented reality: Analyzing impact on students learning. *Procedia Computer Science*, *172*, 660-668.

[40] Bakri, F., Sumardani, D., & Muliyati, D. (2019, December). The 3D simulation of Lorentz Force based on augmented reality technology. In *journal of physics: Conference series* (Vol. 1402, No. 6, p. 066038). IOP Publishing.

[41] Abdüsselam, M. S. (2014). Teachers' and Students' Views on Using Augmented Reality Environments in Physics Education: 11th Grade Magnetism Topic Example. *Pegem Journal of Education & Instruction/Pegem Egitim ve Ögretim*, *4*(1).
[42] Buesing, M., & Cook, M. (2013). Augmented reality comes to physics. *The Physics Teacher*, *51*(4), 226-228.
[43] Radu, I., Huang, X., Kestin, G., & Schneider, B. (2023). How augmented reality influences student learning and inquiry styles: A study of 1-1 physics remote AR tutoring. *Computers & Education: X Reality*, *2*, 100011.
[44] Faridi, H., Tuli, N., Mantri, A., Singh, G., & Gargrish, S. (2021). A framework utilizing augmented reality to improve critical thinking ability and learning gain of the students in Physics. *Computer Applications in Engineering Education*, *29*(1), 258-273.
[45] Liu, X., Liu, Y., & Wang, Y. (2019, March). Real time 3d magnetic field visualization based on augmented reality. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)* (pp. 1052-1053). IEEE.
[46] Wang, Y. (2022). Effects of augmented reality game-based learning on students' engagement. *International Journal of Science Education, Part B*, *12*(3), 254-270.
[47] Yu, S., Liu, Q., Ma, J., Le, H., & Ba, S. (2023). Applying Augmented reality to enhance physics laboratory experience: does learning anxiety matter?. *Interactive Learning Environments*, *31*(10), 6952-6967.
[48] Liu, Q., Xu, S., Yu, S., Yang, Y., Wu, L., & Ba, S. (2019, July). Design and Implementation of an AR-Based Inquiry Courseware—Magnetic Field. In *2019 International Symposium on Educational Technology (ISET)* (pp. 134-138). IEEE.
[49] Cai, S., Chiang, F. K., Sun, Y., Lin, C., & Lee, J. J. (2017). Applications of augmented reality-based natural interactive learning in magnetic field instruction. *Interactive Learning Environments*, *25*(6), 778-791.
[50] Ibáñez, M. B., De Castro, A. J., & Kloos, C. D. (2017, July). An empirical study of the use of an augmented reality simulator in a face-to-face physics course. In *2017 IEEE 17th International Conference on Advanced Learning Technologies (ICALT)* (pp. 469-471). IEEE.
[51] Ibáñez, M. B., Di Serio, Á., Villarán, D., & Kloos, C. D. (2014). Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers & education*, *71*, 1-13.
[52] Indra, M., Munadi, S., & Widari, T. (2023). The Correlation of Motivation and Habit with Learning Outcomes in New Normal Era. *Jurnal Iqra': Kajian Ilmu Pendidikan*, *8*(1), 51-70.
[53] Alhadi, S., & Saputra, W. N. E. (2017, May). The relationship between learning motivation and learning outcome of junior high school students in Yogyakarta. In *1st Yogyakarta International Conference on Educational Management/Administration and Pedagogy (YICEMAP 2017)* (pp. 138-141). Atlantis Press.
[54] Manalu, S. A. (2014). The relationship among motivation, attitudes, and learning achievement of English as a foreign language at Del Institute of Technology. *Proceedings of ISELT FBS Universitas Negeri Padang*, *2*, 379-385.
[55] Zahara, M., Abdurrahman, A., Herlina, K., Widyanti, R., & Agustiana, L. (2021, February). Teachers' perceptions of 3D technology-integrated student worksheet on magnetic field material: A preliminary research on augmented reality in STEM learning. In *Journal of Physics: Conference Series* (Vol. 1796, No. 1, p. 012083). IOP Publishing.
[56] Matsumoto, S., Manabe, T., Cingoski, V., & Noguchi, S. (2017). A Computer Aided Education System Based on Augmented Reality by Immersion to 3-D Magnetic Field. *IEEE Transactrion on Magnetics*, *53*(6).
[57] Sırakaya, M., & Alsancak Sırakaya, D. (2022). Augmented reality in STEM education: A systematic review. *Interactive Learning Environments*, *30*(8), 1556-1569.
[58] Arzak, K. A., & Prahani, B. K. (2023). Practicality of Augmented Reality Books in Physics Learning: A Literature Review. *JPPS (Jurnal Penelitian Pendidikan Sains)*, *12*(2), 138-154.