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# *The Opportunity of Augmented Reality (AR) Technology as an Immersive Learning Medium in Physics Subjects*

Sigit Dwi Saputro[a], Naelur Rohmah[b]
[a,b] *Faculty of Teacher Training and Education, Trunodjoyo Madura University, Bangkalan, Indonesia*
*Email: [a]sigitd.saputra@trunojoyo.ac.id, [b]naelur.rohmah@trunojoyo.ac.id*

## *Abstract*

*Deep learning demands high cognitive engagement and contextual understanding of concepts. Learning media that is able to present contextual experiences is believed to improve the quality of deep learning. Deep Learning in this research is the implementation of the curriculum that has been determined by the Ministry of Primary and Secondary Education of the Republic of Indonesia. Augmented Reality (AR) is emerging as a potential medium due to its ability to visualize abstract concepts interactively and contextually. This study conducted a literature review of 20 Scopus indexed articles in the last 5 years (2019–2024) that examined the implementation of AR in physics learning, with the exception of articles that are more than 5 years old and articles outside the field of physics. The analysis shows that AR significantly improves concept understanding, learning engagement, and the ability to apply physics concepts in real contexts. Based on various studies, the use of Augmented Reality (AR) in physics learning has been proven to support deep learning through increased concept understanding and critical thinking (mindful learning), visualization of abstract concepts that are more contextual (meaningful learning), and increased motivation, engagement, and joyful learning experiences (joyful learning). The implications of this research are as a reference for researchers to test the impact of using AR media. As future research needs to test the contribution of AR to deep learning*

***Keywords: Augmented Reality, Media, Deep Learning, Physics***

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## INTRODUCTION

Deep learning consistently contributes positively to concept understanding, students' academic achievement, active participation in learning, as well as the strengthening of higher-level thinking skills such as critical thinking, reflectiveness, and the ability to transfer knowledge to new situations, making them relevant for meaningful and contextual learning in primary to secondary education (Komara et al., 2026). The principles of deep learning include meaningful, mindful, and joyful learning elements that must be implemented together to create a learning experience that is not only cognitive but also affective and contextual (Ratri et al., 2025). Other studies have also shown that this approach demands full involvement of students in building meaning through real-life learning experiences, thus encouraging more meaningful and in-depth learning in the context of formal education (Rosyidah et al., 2026).

Contextualization Learning is a fundamental aspect when dealing with abstract material, such as in physics, where the relationship between theory and real phenomena needs to be strengthened to deepen students' understanding. The results of the study obtained the results that the integration of deep learning principles with Real context Learning through the use of adaptive environments, interactive simulations, and personalized feedback encourages better learning engagement, conceptual understanding, and critical thinking skills than conventional learning (Sumarni & Kadarwati, 2020). In addition, other literature emphasizes that contextual learning helps students relate scientific concepts to their real experiences thereby increasing motivation and retention of knowledge. Thus, the use of media and learning strategies that are able to present real context is key in supporting the deep learning process, especially in the fields of science and physics which rely heavily on the visualization of real phenomena and applications in daily life (Komara et al., 2026)

Along with the development of technology, Augmented Reality (AR) has emerged as a potential medium to present the context of physics learning visually. AR development to visualize *Fleming's rule* in electromagnetism, where students can see the magnetic field line, the direction of the electric current, and the force on the conductor in real-time. The results showed that the use of AR significantly improved students' understanding of the concept of electromagnetism because the previously abstract phenomenon becomes interactive and easy to visualize (Faridi et al., 2021) (Ashhari et al., 2024). AR can also facilitate the understanding of abstract magnetic field concepts through interactive simulations, making learning more effective and engaging (Sholeh et al., 2024)

The same is true for motion kinematics material. This research shows that the integration of AR into teaching materials make the concepts of force and motion easier to understand, increase student engagement, and strengthen their ability to apply physics theory to real-world situations (Ramadhani et al., 2025). This is because AR is able to overcome the limitations of conventional media in presenting abstract physical phenomena, because it provides contextual interactive visualization (Socrates & Mufit, 2022).

Based on the review, this study aims to review the latest literature related to the use of AR as a learning medium that supports deep learning in physics. The focus of this research is to analyze the contribution of AR in improving contextualization, concept understanding, and student learning engagement through literature.

## METHOD

This study uses the literature review method with the aim of analyzing opportunities for the use of Augmented Reality (AR) media as an in-depth learning medium in physics learning. Literature review was chosen because it allows researchers to identify, compare, and synthesize various findings of previous research in a systematic manner. The focus of the study is directed at articles that discuss the use of AR in physics learning, especially those related to the ability of AR in presenting contextual

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visualizations, improving concept understanding, and supporting the active involvement of students in the learning process. The stages of the research are shown in Figure 1.

The data sources in this study come from 20 Scopus indexed scientific articles that are relevant to the topic of AR in physics learning. The article search process is carried out using keywords such as augmented reality, physics learning, physics education, deep learning, conceptual understanding, and contextual learning. The selection of this year's range is due to the fact that in 2025 the implementation of deep learning has begun, so it is assumed that before 2025 AR has not been established as a medium for achieving deep learning. The selected articles are publications in the last five years so that the studies carried out represent the latest developments in AR technology in physics learning. The selection of the latest articles also aims to ensure that the technology, learning approaches, and empirical findings analyzed are still relevant to current learning needs.

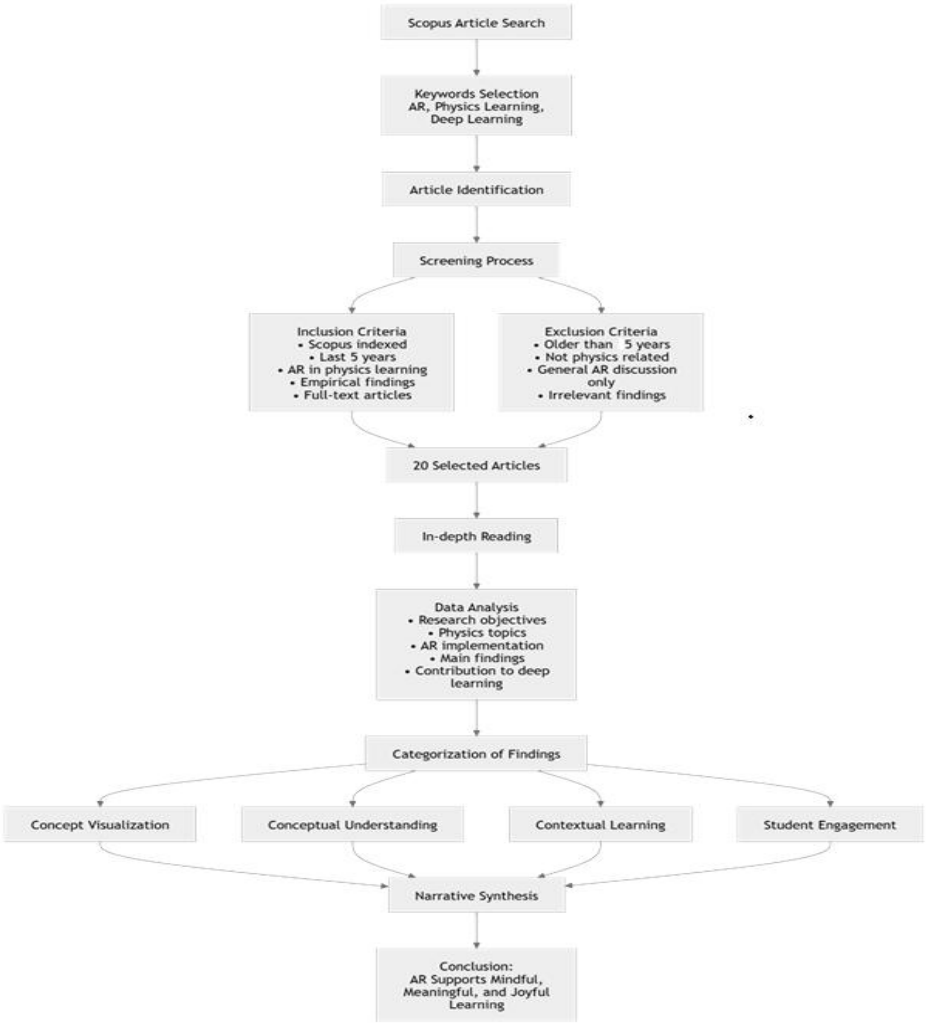



Figure 1. Stages of research

The inclusion criteria in this study include articles that: 1) are indexed by Scopus, 2) published in the last five years, 3) discuss the use of AR in physics learning, 4) contain the results of empirical research or scientific studies that are relevant to learning media, concept understanding, visualization, or contextual learning, and 5) are available in the form of a complete article. Meanwhile, the exclusion criteria include articles that are more than 5 years old, articles that are not related to the field of physics,

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articles that only discuss AR in general without the context of physics learning, and articles that do not provide data or findings that can be analyzed according to the focus of the research. The selection process is through an abstract review of each study that appears in the Scopus database.

Data analysis was carried out through several stages, namely article identification, selection based on inclusion and exclusion criteria, in-depth reading of the content of the article, grouping of findings, and narrative synthesis. Each article is analyzed based on the research objectives, the physics material studied, the form of use of AR, the main results of the research, and its contribution to deep learning. The findings of the 20 articles are then categorized into several aspects, such as AR's ability to visualize abstract concepts, improve conceptual understanding, build contextual learning experiences, and encourage student engagement in physics learning.

The results of the analysis of these articles were used to obtain a comprehensive picture of the opportunities of AR as a medium of deep learning. With this approach, the research not only describes the effectiveness of AR in physics learning, but also examines how AR can act as a contextual medium that helps students connect physics concepts with real phenomena. Therefore, this literature review method is expected to provide a conceptual basis for the development of AR-based learning media that is more relevant, interactive, and supports deep learning in physics.

## RESULTS AND DISCUSSION

After analyzing the 42 articles indexed by Scopus, a verification process was carried out to find out which articles fit into the category. The summary of each journal selected as a source of research data is as shown in Table 1.

Table 1. Summary of Research with AR Technology

| No | Name & Year | Research subjects | Methods used | Research results |
|---|---|---|---|---|
| 1 | (Cai et al., 2021)— | Students studying physics using AR | AR learning experiments | AR improves students' self-efficacy and conception of physics learning. |
| 2 | (Faridi et al., 2021) | Students in physics learning | Development of AR learning frameworks and tests | AR helps improve students' critical thinking skills and learning gains. |
| 3 | (Liu et al., 2021) | Students on magnetic materials | Experiment of AR tools for magnet practicum | AR helps improve knowledge, but it is necessary to pay attention to the cognitive load of students. |
| 4 | (Vidak et al., 2021) | Students/participants learn the concept of gravitational force | AR application development and evaluation | AR helps visualize abstract concepts of gravitational force into more concrete. |
| 5 | (Sriadhi et al., 2022) | Physics Engineering Student | Experiment on the effectiveness of AR media | AR media effectively supports engineering physics learning through visualization and interaction. |

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| No | Name & Year | Research subjects | Methods used | Research results |
|---|---|---|---|---|
| 6 | (Volioti et al., 2022) | K-12 students on physics concepts | AR platform development | AR platforms provide more visual and interactive physics learning opportunities. |
| 7 | (Sun et al., 2023) | High school students in a physics laboratory environment | AR/VR hybrid learning material experiment | AR/VR improves situational interest, engagement, and learning performance. |
| 8 | (Yu et al., 2023) | Physics practicum participants | AR laboratory experiments/tests | AR enriches the physics laboratory experience; Learning anxiety is a factor that needs to be considered. |
| 9 | (Lyrath et al., 2023) | Experimental physics laboratory | Development/application of AR in the laboratory | AR supports visualization and procedures of physics experiments to make them easier to understand. |
| 10 | (Ferdiman et al., 2023) | Learning Newton's laws and object interactions | Research and development aplikasi AR | AR applications improve the quality and effectiveness of physics learning through interactive visualization. |
| 11 | (Dewi & Kuswanto, 2023) | High school students on circular motion material/pedicab context | 4D model, experiment, MANOVA | The context-based AR e-module is effective in improving mathematical communication and critical thinking. |
| 12 | (Radu et al., 2023) | Students in AR-assisted remote physics tutoring | 1-on-1 AR learning study | AR influences inquiry styles and the way students build an understanding of physics concepts. |
| 13 | (Radu & Schneider, 2022) | Students on collaborative electromagnetism learning | AR-assisted collaborative studies | AR can help collaboration and understanding electromagnetism, but the design of the activity should reduce potential coordination barriers. |
| 14 | (Rizki et al., 2023) | Students on AR game-based physics learning | Research and development media Android | AR-integrated adventure games are considered valid/practical and interesting for physics learning. |
| 15 | (Nasir et al., 2019) | Students on mobile physics learning | AR mobile multimedia design and analysis | AR-based mobile learning has the potential to improve physics learning outcomes. |
| 16 | (Alfianti et al., 2023) | Students in physics learning based on local wisdom | Research and development DICTY-AR | AR integrated local wisdom helps with dual representation and problem-solving capabilities. |

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| No | Name & Year | Research subjects | Methods used | Research results |
|---|---|---|---|---|
| 17 | (Alé-Silva & Huerta-Cancino, 2024) | Physics learning about the Sun | Development of AR interactive learning resources | AR provides contextual visualization of the physical concepts of the Sun. |
| 18 | (Arymbekov et al., 2024) | High school students on nuclear physics material | Experiment with AR learning activities | AR increases academic success and motivation to study nuclear physics. |
| 19 | (Rahmayani et al., 2024) | Students in STEM-based physics learning | ADDIE / research and development | STEM-based AR e-books enhance critical thinking and dual representation skills. |
| 20 | (Rizki et al., 2024) | Students on cooperative-based physics, games, and AR learning | Educational Design Research; non-equivalent control group design | The cooperative-based, digital game, and AR CAP model is valid/practical and is directed to increase critical thinking and learning motivation. |

Based on the research results in Table 1, three research findings were obtained by paying attention to deep learning. The three findings are contained in Table 2.

Table 2. Grouping of AR Findings Based on Deep Learning

| Discovery Group | Focus of Findings | Supporting Research | Results |
|---|---|---|---|
| 1. AR improves students' learning outcomes and cognitive abilities | The Effect of AR on Concept Understanding, Learning Outcomes, Critical Thinking, Multiple Representation, and Problem Solving | Cai et al. (2021); Faridi et al. (2021); Liu et al. (2021); Dewi & Kuswanto (2023); Nasir & Fakhruddin (2023); Alfianti et al. (2023); Arymbekov et al. (2024); Rahmayani et al. (2024); Rizki et al. (2024) | AR-based learning has been proven to improve understanding of physics concepts, critical thinking skills, mathematical communication, multiple representations, and students' academic achievement. |
| 2. AR helps visualize abstract concepts and physics practicum experiences | The use of AR to visualize abstract concepts and support laboratories/practicums | Vidak et al. (2021); Sriadhi et al. (2022); Volioti et al. (2022); Sun et al. (2023); Yu et al. (2023); Lyrath et al. (2023); Ferdiman et al. (2023); Alé-Silva & Huerta-Cancino (2024) | AR is able to transform abstract physics concepts into more concrete through 3D visualizations, interactive simulations, and virtual lab experiences that are more engaging and easy to understand. |

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| | | | |
|---|---|---|---|
| 3. AR increases student motivation, engagement, and learning interaction | The effect of AR on motivation, self-efficacy, engagement, collaboration, and interest in learning | Cai et al. (2021); Sun et al. (2023); Radu et al. (2023); Radu & Schneider (2023); Rizki et al. (2023); Arymbekov et al. (2024) | The use of AR increases learning motivation, self-efficacy, student engagement, and supports more interactive collaborative and game-based learning. |

The first findings show that the use of Augmented Reality (AR) in physics learning is able to improve students' understanding of concepts, learning outcomes, critical thinking skills, multiple representation, and problem-solving skills. Research by Su Cai and colleagues found that AR improves students' self-efficacy and conception of physics learning. Other research has also shown that AR can increase students' critical thinking, learning gain, and dual representation abilities in physics learning. These findings are in line with the concept of deep learning, especially in the aspect of mindful learning, which is learning that encourages students to think reflectively, understand concepts in depth, and build relationships between conceptual representations. In this context, AR not only helps students memorize formulas, but also understands the meaning of concepts through visual and interactive exploration so that the learning process becomes more cognitively conscious and meaningful. This approach supports deep learning because students actively construct knowledge through visual and contextual rich learning experiences.

The second finding shows that AR is effectively used to visualize abstract concepts of physics as well as support laboratory and practicum activities. Various studies report that AR helps students understand the concepts of gravitational force, electromagnetism, Newton's laws, and the physics of the Sun through three-dimensional visualization and interactive simulations. In addition, AR also enriches the physics practicum experience because students can observe the experimental process in a more concrete and safe way. This finding is relevant to the concept of deep learning in the aspect of meaningful learning, which is learning that connects concepts with real experiences and the context of students' lives. Through AR, abstract physics concepts become more easily associated with real phenomena so that students can build more meaningful conceptual understandings. Interactive visualization in AR also helps students reduce misconceptions because concepts that are difficult to visualize conventionally can be observed directly in a contextual and realistic virtual form.

The third finding shows that the use of AR in physics learning can increase student learning motivation, self-efficacy, engagement, collaboration, and interest in learning. Research shows that the integration of AR and educational games creates a more engaging, interactive, and challenging learning experience so that students become more active in the learning process. In addition, the use of collaborative-based AR also helps students build social interaction and discussion in understanding physics concepts. These findings support the concept of deep learning in the aspect of joyful learning, which is learning that brings a sense of joy, enthusiasm, and emotional involvement of students during learning. A fun learning environment through AR can boost students' confidence and reduce learning anxiety, especially in physics learning that is often considered difficult and abstract. Thus, AR not only serves as a visualization medium, but also as a means to create a more positive, interactive, and motivating learning experience for students to learn independently or collaboratively.

Limitations in the use of AR are not solely applied to the same research design and also as a learning medium in certain models. Research using cooperative models with AR assistance (Rizki et al., 2024), STEM-based physics learning (Rahmayani et al., 2024), physics learning based on local wisdom (Alfianti et al., 2023), even as a supporting medium for physics practicums (Sun et al., 2023) (Yu et al.,

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2023). This means that AR is not the only research variable that determines significant results. Therefore, agreement needs to be tested for specific contributions related to research using AR media.

## CONCLUSIONS

Based on various research results, the use of Augmented Reality (AR) in physics learning shows a strong contribution to the implementation of deep learning. AR not only functions as a visual technology medium, but is also able to support the three main characteristics of deep learning, namely mindful, meaningful, and joyful learning. In the aspect of mindful learning, AR helps improve understanding of concepts, learning outcomes, critical thinking skills, multiple representation, and problem-solving so that students can build knowledge more reflective and deep. In the aspect of meaningful learning, AR makes it easier to visualize abstract concepts and supports laboratory activities so that learning becomes more contextual and easily connected to real phenomena. Meanwhile, in the aspect of joyful learning, AR is able to increase motivation, engagement, self-efficacy, learning interest, and collaborative interaction of students through an interactive and fun learning experience. Thus, the integration of AR in physics learning has great potential to create a more effective, meaningful, and student-centered learning experience in accordance with the 21st century learning paradigm.

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