JoTaLP: Journal of Teaching and Learning Physics 10, 1 (2025): 1-8
Website: http://journal.uinsgd.ac.id/index.php/jtlp/index
ISSN 2580-3107 **(online) ISSN** 2528-5505 **(print)**

[Research Article]

THE DEVELOPMENT OF MAGNETIC FIELD LEARNING MODULE INTEGRATED WITH AUGMENTED REALITY (AR) FOR SENIOR HIGH SCHOOL: A NEED ANALYSIS

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DOI: https://doi.org/10.15575/jotalp.v10i1.40684
Received: 19 November 2024 ; Accepted: 5 February 2025 ; Published: 28 February 2025

ABSTRACT

The aim of this study was to provide empirical data for the development of an augmented reality (AR) integrated physics learning module that focuses on difficult topics among high school students. Using a quantitative approach, 131 students and 26 physics teachers from West Sumatra completed a needs assessment questionnaire. Magnetic fields were identified as the most difficult topic, cited by 34% of students and 65% of teachers due to their abstract nature and lack of visualization tools. Current teaching methods and materials do not adequately support students' understanding. Both teachers and students expressed a strong preference for modules that integrate AR to visualize abstract concepts, increase engagement, and provide clear explanations, practical activities, and problem-solving examples. Although the potential of AR is recognized, it is underutilized as there is currently no integration with physics modules. This study highlights the urgent need for AR-based modules to improve learning outcomes, especially on complex topics such as magnetic fields.

Keywords: : Need Analysis, Magnetic Field, Learning Module, Augmented Reality, AR

How to cite: Haris, V., Alias, S.N., Ayop, S.K. (2025) The Development of Magnetic Field Learning Module Integrated with Augmented Reality (AR) for Senior High School: A Need Analysis, *Journal of Teaching and Learning Physics 10* (1), 1-8. DOI: https://doi.org/10.15575/jotalp.v10i1.40684

1. INTRODUCTION

The advancement of educational technology has opened up tremendous opportunities to improve the teaching and learning process, especially in subjects with complex and abstract concepts such as physics. Physics, one of the science subjects in secondary schools (SMA) in Indonesia, requires an understanding of concepts and experiments that are often considered by many students (Handhika et al., 2015; Setyani et al., 2017).

One of the physics topics studied in 12th-grade high school is magnetic fields. This topic is known for its complexity, mainly due to its abstract spatial concepts that are not easy to visualize (Cai et al., 2017; Lemmer et al., 2020; Ürek & Çoramık, 2021). Studies have shown that students have difficulty understanding magnetic fields due to the abstract nature of this subject and the lack of adequate visualization in traditional teaching methods (Li & Singh, 2017; Neset Demirci, 2006).

A study conducted in Indonesia found that many 12th-grade students had difficulty understanding the concept of magnetic fields, which often resulted in poor learning outcomes (Setyaningsih, 2018). The main factor for this difficulty is the dominance of mathematical formulas in textbooks compared to detailed concept explanations (Astuti et al., 2021; Maison et al., 2022; Setyaningsih, 2018). Furthermore, there is a lack of information and communication technologies (ICT) in textbooks to support visualization. Current textbooks are only able to provide two-dimensional images, which are less effective in helping students understand abstract content. It is expected that more interactive 3D visualizations, such as those offered by augmented reality (AR) technology, can solve this problem.

AR technology enables the fusion of the real world with virtual objects in 3D form, which can be visualized interactively and in real-time (Azuma et al., 2001; Nakamura & Mizuno, 2022). By integrating AR into textbooks or learning modules, students can experience a significant increase in visual interaction, which in turn can improve their understanding of complex and abstract concepts (Dünser et al., 2012; Farhani Isty et al., 2021; Permana et al., 2023).

A module is a self-contained teaching material and teaching method based on the development of skills and knowledge in separate units (Sejpal, 2013). Physics learning modules integrated with AR offer a more independent and interactive approach, allowing students to visualize abstract concepts such as magnetic fields more clearly. Learning physics using modules can improve students' conceptual understanding and learning outcomes (Khuzaimah et al., 2022; Purnama et al., 2021; Suma et al., 2019).

Therefore, this study aimed to conduct a needs analysis to identify essential elements in the development of an AR-integrated magnetic field learning module so that it can effectively meet the needs of 12th-grade high school students.

2. METHOD

This study uses a quantitative descriptive approach with data collected via an online questionnaire using Google Form. The study respondents were physics teachers and 12th-grade high school students in West Sumatra. This questionnaire was developed to identify needs in the development of learning modules with integrated augmented reality, particularly on the topic of magnetic fields, for high school students.

3. RESULT AND DISCUSSION

3.1 Respondent Demographics

This study involved 157 respondents, 112 of whom were females and 45 males, as shown in Table 1. In terms of profession, 26 respondents were physics teachers, while the other 131 were grade XII high school students in West Sumatra. The majority of the teachers had 11 to 15 years of experience (9 teachers), followed by more than 20 years of experience (5 teachers). However, the teachers' experiences varied widely.

Table 1. Demographics of Respondents

No	Respondent's Profiles	Description	Numbers
1	Sex	Female	112
		Male	45
2	Profession	Teacher	26
		Student	131
3	Teacher teaching experience (years)	0 - 5	5
		6 - 10	1
		11 - 15	9
		16 - 20	6
		> 20	5

3.2 Difficult Topics Identification

Based on the questionnaire results shown in Table 2, the topic "magnetic field" is considered the most difficult topic for students to understand, with a share of 33.6%. Followed by Electromagnetic Induction with 30.5% and Alternating Current Circuits with 24.4%. These results were obtained from the Google Form question: "Which topic in high school physics learning do you think is the most difficult?"

Table 2. Topics that are Difficult for High School Students.

Topic	Percentage (%)
Mechanics	21.4
Vibrations and Waves	20.6
Thermodynamics	19.1
Direct Current Electrical Circuits	22.9
Static electricity	20.6
Magnetic Field	33.6
Electromagnetic Induction	30.5
Alternating Current Circuit	24.4

In the questionnaire given to teachers, the question was asked: "In your experience, which topic is the most difficult and least interesting for students?" Physics teachers also identified "Magnetic Field" as the most common topic, with a higher percentage of 65.4%, followed by "Electromagnetic Induction" with 38.5%, as shown in Table 3. This shows the consistency between students' perceptions and teachers' difficulty understanding the topic of magnetic fields.

Table 3. Difficult Topics for High School Students Based on The Views of Physics Teachers.

Topic	Percentage (%)
Mechanics	21.4
Vibrations and Waves	20.6
Thermodynamics	19.1
Direct Current Electrical Circuits	22.9
Static electricity	20.6
Magnetic Field	33.6
Electromagnetic Induction	30.5
Alternating Current Circuit	24.4

The results of the study showed that magnetic fields are one of the most difficult physics topics for high school students to understand. Based on students' views, 33.6% of them thought that magnetic fields were difficult to understand, while 65.4% of physics teachers agreed that this topic was one of the most challenging for students. This difficulty is consistent with findings showing that magnetic fields are often difficult to understand and difficult to visualize due to their abstract nature (Chasteen & Pollock, 2009; Li & Singh, 2017; Neset Demirci, 2006). This highlights the importance of developing learning modules that can facilitate student understanding through a more visual and interactive approach.

To understand the reasons why students find the topic of magnetic fields difficult, the teacher was asked the question: "Why do you think students find it difficult and have no interest in learning the topic? (More than one answer is permitted)". Physics teachers identified several factors that caused students difficulty in understanding this topic. Based on Table 4, the main factors cited were abstract concepts that were difficult to visualize (65.4%) and the large number of concepts that students needed to master (61.5%). Other factors that also had an influence were the lack of experiments or demonstrations that helped explain the topic (46.2%) and less exciting teaching materials (30.8%).

Table 4. Factors that Contribute to Physics Topics Being Viewed by Students.

Factors	Percentage (%)
Many definitions and terms are not understood.	19.2
There are many concepts that students must master.	61.5
Many problems need to be solved.	26.9
Abstract concepts cannot be visualized.	65.4
There are no experiments/demonstrations to explain the topic.	46.2
Uninteresting teaching materials	30.8
Other	7.7

From the available data, it is known that the main difficulty in understanding the magnetic field is that the concepts are abstract and difficult to visualize (65.4%). In addition, the number of concepts that students must master is also a significant factor (61.5%). This result is consistent with previous studies showing that abstract concepts in physics require teaching methods that enable better visualization (Gilbert, 2008; Li & Singh, 2017). As a result, this difficulty can be addressed by learning modules that integrate visual technologies like augmented reality (AR).

3.3 Elements to be included in learning modules.

Teachers and students expressed their views on the elements that should be included in the learning modules, as shown in Table 5 and Table 6. The question asked was: "Whether there is teaching material in physics lessons in the form of a module, what content must be included in the module? (You can choose more than one)". Teachers emphasized the importance of visualizing abstract concepts (96.2%), example questions and their solutions (88.5%), and practical activities (88.5%). On the other hand, students also supported the visualization of abstract concepts (72.5%) and example questions (68.7%), but gave less weight to practical activities (48.1%).

Table 5. Elements to be Included in the Learning Modules from the Teacher's Perspective.

Elements	Percentage (%)
Explanation of concepts	84.6
Example questions and solutions	88.5
Practical Activities	88.5
Abstract Concept Visualization	96.2
Assessment (Evaluation)	80.8

Table 6. Elements that Students Consider to be Included in the Learning Modules.

Elements	Percentage (%)
Explanation of concepts	66.4
Example questions and solutions	68.7
Practical Activities	48.1
Abstract Concept Visualization	72.5
Assessment (Evaluation)	48.9

Teachers and students emphasize the importance of abstract concept visualization elements, example problems and solutions, and clear explanations of the material in the learning module. Concept visualization using augmented reality (AR) technology has been shown to be effective in improving students' understanding of difficult concepts such as magnetic fields (Dünser et al., 2012; Liu et al., 2021; Radu & Schneider, 2019). This technology allows students to interact with three-dimensional models that represent physical concepts, making it easier for them to understand the material better.

3.4 Types of Teaching Materials that Students Like and Need.

Students were also asked questions about the types of teaching materials they liked and needed to learn physics. The results of the respondents' answers are shown in Figure 1. Most respondents chose teaching materials in the form of interactive modules with abstract concept visualizations (61.10%), practical modules (55.70%), simulations (40.50%) and GameEdu (35.90%). Based on these results, it can be seen that students need teaching materials that are able to visualize abstract concepts, such as the subject of magnetic fields. In addition, these results also show that students like and need teaching materials in the form of experiments, simulations and GameEdu.

Figure 1. Types of Teaching Materials that Students Like and Need.

3.5 Technology Usage in Learning.

Some physics teachers have begun to integrate technology into their teaching, as shown in Figure 2. Based on the data, 23% of teachers have integrated instructional materials with technology, while 77% have not. Figure 3 shows that the most commonly used technology types by teachers are YouTube links with problem-solving videos (32%), YouTube links with animated learning videos (30%), and PhET simulations (28%). However, no teachers have integrated physics teaching materials with augmented reality (AR) technology. These results are consistent with the data in Figure 4, which shows that teachers' knowledge of augmented reality (AR) technology is still limited.

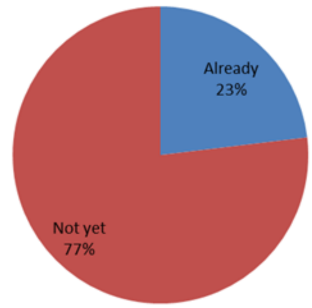

Figure 2. Teachers Who Integrated Instructional Materials with Technology.

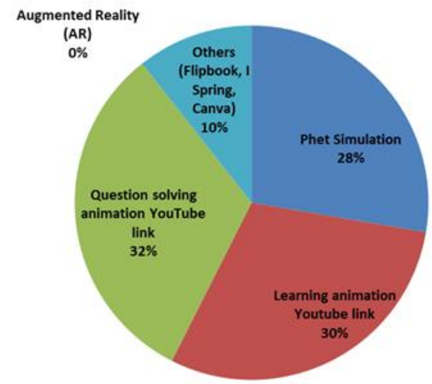

Figure 3. Types of Technologies Integrated into Teaching Materials.

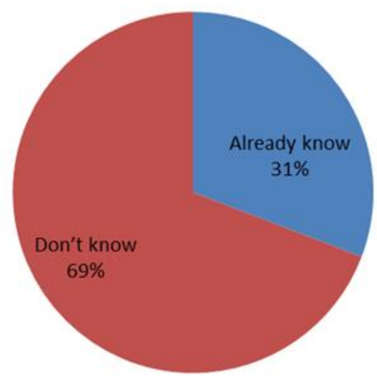

Figure 4. Teacher Knowledge about Augmented Reality (AR).

Although technology is beginning to be integrated into physics learning, the use of AR is still relatively new and has not yet been fully utilized. Research shows that AR can provide a more interactive and immersive learning experience, which is crucial for students to understand abstract concepts (Abdusselam & Karal, 2020; Faridi et al., 2021; Ibáñez & Delgado-Kloos, 2018). By integrating AR, students can see a visual representation of the magnetic field in three dimensions and thus better understand its properties.

3.6 Teachers' Perception of the Need to Develop AR-Integrated Physics Learning Modules.

Based on the questionnaire results shown in Figure 5, there is a recognized need for the development of physics modules that integrate AR, particularly to visualize abstract concepts that are difficult for students to understand. As shown in Figure 5, 65% of respondents indicated that the development of AR-integrated physics learning modules was necessary. None of the respondents said that such a development was not necessary.

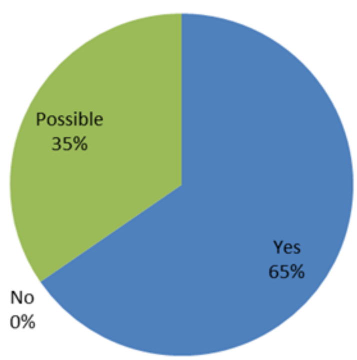

Figure 5. Teachers' Perception of the Need to Develop AR-Integrated Physics Learning Modules.

Physics teachers strongly support the development of learning modules that integrate AR, especially for abstract topics such as magnetic fields. Research shows that using AR in education can increase student engagement and motivation and help them understand complex materials (Billinghurst & Dünser, 2012; Erbas & Demirer, 2019; Lai et al., 2019; Rizki et al., 2023; Sun et al., 2023; Ziden et al., 2022). Learning modules designed with AR integration should be able to overcome students' difficulties in learning magnetic fields and significantly improve their learning outcomes.

4. CONCLUSION

This study provides valuable empirical data for researchers on the content and technologies that need to be integrated into the physics learning module to be developed. These findings serve as a guide for the design and development of modules in the next phase. Based on data analysis, magnetic fields were identified as one of the most difficult physics topics for students to understand, primarily due to their abstract nature and difficulty in imagining them. Developing a module that integrates AR is a promising solution to improve student understanding. AR enables the visualization of abstract concepts in interactive three-dimensional forms, making it easier for students to understand and master the subject matter.

In addition, this module is expected to provide clear explanations of concepts, example problems and their solutions, simulations and relevant practical activities all elements considered necessary by teachers and students. Therefore, the development of an AR-based module on the topic of magnetic fields is not only relevant but also necessary to improve the quality of physics teaching in high schools. The implementation of this technology has the potential to not only improve students' learning outcomes, but also increase their interest in studying physics as a whole.

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