Readiness of Indonesian physics teachers to implement augmented reality-based learning

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Article Info

Article history:

Received Jan 19, 2024
Revised Nov 30, 2024
Accepted Dec 21, 2024

Keywords:

Augmented reality
AR-based learning
Learning media
Physics teacher
Teacher readiness

ABSTRACT

In the 21st century, technological development has entered all aspects of life, including education. With its global potential, technology digitizes education, requiring teachers to use technology through media such as augmented reality (AR). This study aims to determine the readiness of physics teachers in Indonesia to implement AR-based learning. More specifically, this research explores the extent to which physics teachers are prepared based on aspects of alignment, capability, and engagement (ACE) in implementing AR-based learning. This exploratory research is conducted by distributing questionnaires with ACE aspects. This study involved several junior and senior high school physics teachers. Data analysis techniques use KH Coder and quantitative descriptive. The results show that teachers already know the definition, features, and benefits of AR in learning (alignment aspect). Still, only a minority of teachers have implemented AR-based learning (capability aspect). In the engagement aspect, it is known that teachers want to learn more about how to create AR and implement AR effectively. The implications of this research are recommendations to stakeholders to encourage and facilitate teachers, especially physics teachers.

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1. INTRODUCTION

In the 21st century, technological development enters all aspects of life, including educational aspects [1]. Almost everyone uses information and communication technologies (ICT) feature. Technology works in conjunction with other technological advancements to give rise to novel frameworks, including artificial intelligence, machine learning, deep learning, and federated learning [2]–[6]. The use of technology has the potential to influence the quality of education globally.

Implementing learning within the technological, pedagogical, and content knowledge (TPACK) framework is increasingly necessary to adapt to technological developments [7]. Technology integration in learning is a form of innovation expected to shape the digitalization of education as a modern education system [8]. Technology allows educators to improve their pedagogical practices through media they use [9]. Technology is essential to building an environment in the classroom, as proven by many studies [10]–[13].

One technology that can be integrated into learning and is currently trending is augmented reality (AR) [14]. AR is an immersive technology that collaborates with 3D objects in the natural environment [15]. AR is usually used as multimedia for learning, and many platforms can be used to develop AR, for example, Assembler [16]. Transforming science learning into a fun activity marks a significant benefit of AR integration in learning [17].

Furthermore, using AR in learning can help students understand the content, particularly physics subjects [18], [19]. Most physics consists of abstract material that cannot be touched or seen by the naked eye, and it is hard to find simple real-life examples, such as magnetic fields or electricity [20]. AR technology as a learning medium with its advantages can make it possible to show students objects that are impossible to bring into the classroom because, with AR, 2D objects can be developed into 3D [21]. The conduct of AR-based learning is considered necessary not only to gain students' understanding but also for students' technology literacy. In other words, AR-based learning is crucial to examining how IT application affects education. However, the use of AR in learning is still not commonly practiced [22].

One factor that can influence the success of the teacher's implementation of learning is the teacher's readiness to implement it [23]. Thus, teachers' readiness is one of the crucial factors in conducting AR in class or AR-based learning. Before implementing AR in learning, teachers must be ready first; teacher readiness can be identified by exploring their related knowledge about the definition, advantages, disadvantages, and how to use AR. Teachers' knowledge of the appropriate use of technology is also a teacher's pedagogical readiness [24].

Several studies exploring teacher readiness in teaching using technology, including research by Marques and Pombo [10], which explores teachers' readiness to adapt game-based AR. In addition, Tezer and Beyoğlu [25] analyzed teacher readiness's influence on their acceptance of the mobile learning technology system. A study by Bachtiar *et al*. [24] and Jamrus [26] investigated teacher readiness to integrate technology into English language learning. The motivational readiness of prospective teachers to use AR related to Ukrainian language and literature lessons was researched by Petrovych *et al*. [8]. Other studies [1], [27] are related to teacher readiness in integrating technology into learning or in implementing the TPACK framework [28]. Research related to teachers' readiness to integrate technology into learning is essential research to be carried out in the 21st century as a form of adaptation to technological developments. However, no research has specifically explored teachers' readiness to implement AR-based learning, especially for physics teachers. Therefore, this research explores physics teachers' readiness to implement AR-based learning. Teacher readiness in teaching can also be explored through the alignment, capabilities, and engagement (ACE) aspect [23]. Thus, the following research questions are:

i) To what extent are physics teachers aligned with AR-based learning?
ii) To what extent do physics teachers' capabilities enable AR-based learning?
iii) To what extent are physics teachers engaged with AR-based learning?

2. METHOD

Exploratory research is used in this study to explore physics teachers' readiness for AR-based learning. Data on teachers' preparedness was collected using a questionnaire instrument consisting of several open and closed questions. The questions regarding the readiness of future physics teachers presented in the questionnaire consist of ACE. There are three questions on the alignment aspect, four on the capability aspect, and three on the involvement aspect. The question items are seen in Table 1.

Table 1. The questions about each aspect

No	Aspect	Question
1	Alignment	Have you ever heard the term AR?
2		Please write down what you know about AR-based learning (if there is, yet; If not, please add only "-")
3		Are you interested in implementing AR-based learning for teaching Physics? And why? a. Very interested; b. Interested; c. Moderately interested; d. Not interested; e. Very not interested
4	Capabilities	Which stage and class will you choose if you want to apply physics AR-based learning? And why? a. 1st grade junior high school; b. 2nd grade junior high school; c. 3rd grade junior high school; d. 1st grade senior high school; e. 2nd grade senior high school; f. 3rd grade senior high school
5		What topic will you choose if you want to apply physics AR-based learning? And why?
6		Have you ever implemented physics AR-based learning?
7		According to your knowledge and understanding, what model learning is appropriate for implementing physics AR-based learning if it is implemented? And why?
8	Engagement	If physics AR-based learning is implemented, what are the advantages?
9		If physics AR-based learning is implemented, what are the disadvantages?
10		What do you want to know more about physics AR-based learning?

The instrument was adapted from Sulaeman *et al.* [23], which explored teacher readiness based on ACE aspects and was declared valid based on expert judgment. The questionnaire adaptation process was carried out through focus group discussions (FGDs), which were held in three meetings, each consisting of 1 hour and 30 minutes face-to-face. The FGD activity was attended by one learning expert and two media experts. The first FGD meeting discussed the instruments that would be used to explore physics teachers' readiness for AR-based learning. The second FGD meeting agreed on the adapted reference instrument, and the third meeting discussed finalizing the questions in the questionnaire. From the results of the FGD, it was decided to add several question items, namely items 1, 3, 7, 8, and 9 (Table 1), to dig deeper into the readiness of physics teachers. Data collection took three months. The sampling technique used was random sampling, by distributing the questionnaire via Google Forms through the physics teacher deliberation groups in various provinces in Indonesia.

There are 67 teachers (junior high school science and high school physics teachers) with a Bachelor's degree in Physics Education who are willing to fill in. This sample size can be said to be sufficient. The median sample size required in educational research is at least 30 [29]. The amount we take is adequate for our needs without considering the population size. The result is shown as a descriptive quantitative and co-occurrence network of words by KH Coder, software that can present tendencies in participants' answers to open-ended questions. It has been reviewed compared to WordStat and Deepdive [30]. The descriptive participants can be seen in Table 2.

Table 2. Participant descriptive

Gender	High school teacher		Middle school teacher	
	Number	Percentage	Number	Percentage
Male	15	66%	4	17%
Female	29	34%	19	83%
Total	44	100%	23	100%

3. RESULTS AND DISCUSSION

3.1. RQ1: To what extent are physics teachers’ goals in alignment with AR-based learning?

Overall, the result analysis of the percentage of teachers based on questionnaire number 1 shows that most teachers have heard the term or know about AR. In more detail, around 72% of teachers said they already knew about AR, and the rest said they had never heard of AR. The results of further analysis using KH Coder, relating to the definition of AR-based learning from the physics teacher’s perspective, are presented in Figure 1.

Figure 1 shows that based on physics teachers' perspectives, AR is a technology learning media that can be used to virtualize objects for students. However, no one has specifically explained how AR helps visualize objects more realistically through 3D features. This 3D feature is the main feature of AR, which makes this media superior compared to conventional technology-based learning media. Teachers' knowledge about 3D features in AR and how to develop them should be mastered so that AR technology can be maximized to improve the quality of learning. AR can combine 3D objects with the natural world in learning [31]. 3D features are loaded for the user to get the experience of viewing virtual objects as if they were in a real environment [32].

In addition, most teachers are intensely interested in implementing AR in their learning. The percentage of teachers' interest in implementation AR is 58% very interested, 33% interested, 9% quite interested, and 0% who chose not interested. The teachers' interest in the application of AR was stated, for instance, by T23 as:

> “*Because AR technology combines virtual objects (text, images, and animation) in the real world, it can make students feel as if they are faced with natural objects being studied. Also, it impacts the teaching and learning process by making it more fun and easier to understand the subject matter*.” (T23)

This result shows that teachers' interest in implementing AR in learning is because teachers know the uses, functions, and some benefits of using AR and think that this media can potentially increase the quality of the learning process. The effectiveness of the learning process can also be supported through a strategy of integrating technology in learning [33], for example, through AR [34]. AR is used to assist in student understanding, especially in students' spatial knowledge in the learning process, and this technology involves students in learning [35], [36]. Thus, based on the results described, teachers have quite strong alignment aspects of readiness in AR-based learning, where teachers know the meaning of AR, the uses of AR-based learning, and the main features of AR.

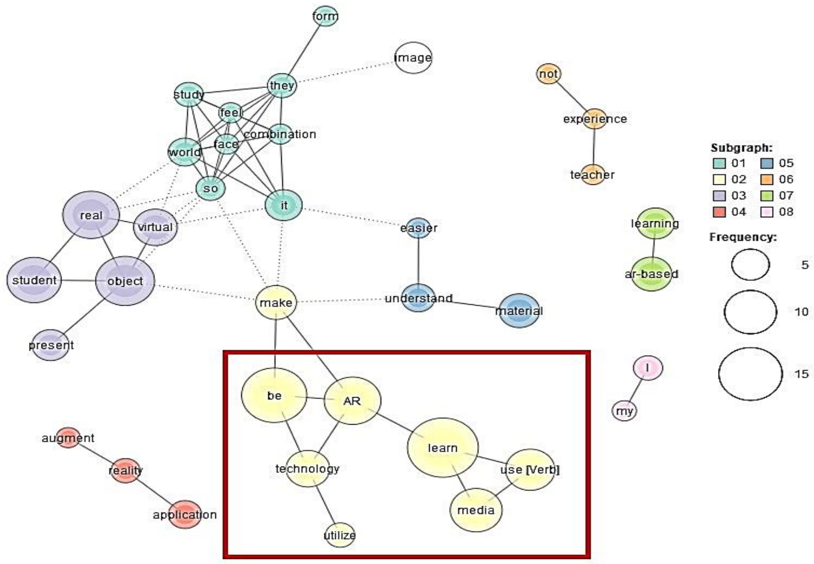

Figure 1. Teachers' knowledge of AR

3.2. RQ2: To what extent do physics teachers' capabilities enable AR-based learning?

In the capability aspect, to explore teachers' readiness to implement AR-based learning, one question was related to the choice of grade level at which AR-based learning can be implemented. This question is contained in question number 4. The results of the analysis of the teacher's answer to question number 4 are shown in Figure 2.

Figure 2 shows that most teachers choose to implement AR at the high school level compared to the junior high school level, especially at grade 1 at senior high school. Based on Indonesia's curriculum, although students have begun to be trained in abstract thinking at the junior high school level [37], there are more abstract concepts at senior high school than at junior high school. Teachers need media that can help them explain abstract concepts [33]. However, the choice of teachers in high school decreases as the class level increases; more teachers choose to apply AR in grade X (grade 1 for senior high school) compared to grade XII (grade 3 for senior high school), even though class XII contains more abstract concepts than other classes. This result is thought to be because most of the participant teachers teach in grade X, so the selection of teachers is based on the level at which they teach, not on which level has more abstract concepts.

Apart from choosing the class level, teachers are also asked to provide their choices regarding topics that can or are suitable to be taught using AR-based learning. This question is contained in question number 5. The choice of issues that can be conducted using AR media based on teacher perceptions is presented in Figure 3.

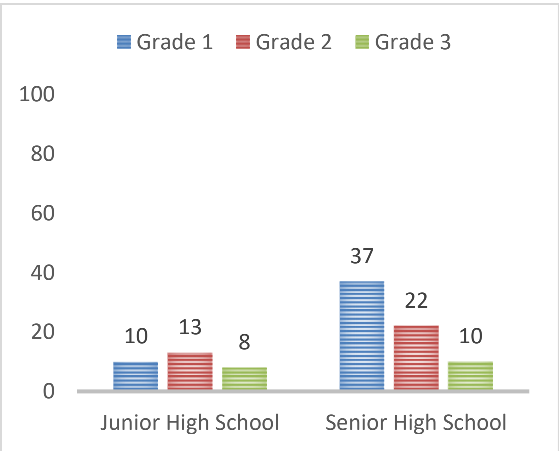

Figure 2. Teachers' preferred grade levels for implementing AR

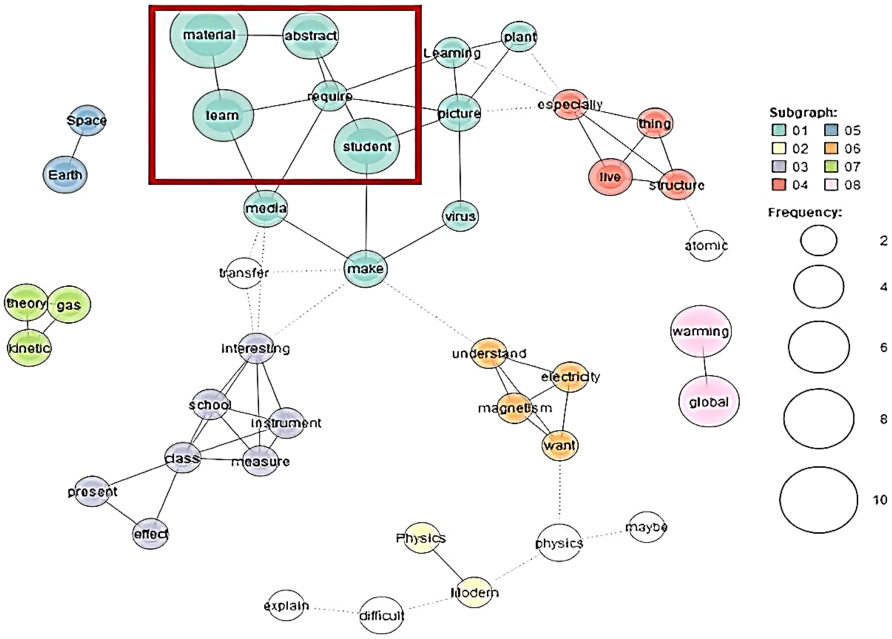

Figure 3. The choice of topics for implementing AR

Based on Figure 3, teachers already understand that AR suits abstract topics (subgraph 01). Specifically, the topics chosen by teachers that are appropriate or need to be taught using AR media include, among others, global warming (subgraph 08), kinetic gas theory (subgraph 07), electricity and magnetism (subgraph 06), earth and space (subgraph 05), and modern physics (subgraph 02). These materials are topics that require effort to understand, which requires AR [38], [39]; for example, the results of research showed that students need AR media to understand abstract concepts in global warming learning more efficiently [40]. Another study, for example, by Donhauser *et al*. [41], attempts to visualize the relationship between magnetic fields, electric currents, and Lorentz forces with the help of AR. Teachers already know that these topics contain some abstract concepts, and media or technology is needed to make it easier for students to understand them.

Augmented reality can be used as a new strategy to learn physics interactively [42], and with easy access, AR can be used to overcome the challenges experienced by teachers in teaching conceptual topics, which usually require media that is quite expensive and not easily accessible to students [43]. Unfortunately, based on research data analysis, only 10% of teachers have implemented AR-based learning. Currently, AR-based learning is still rarely applied [44], [45] and is relatively new to being used as a learning medium in the world of education [40].

AR-based learning is implemented by utilizing AR as a learning medium. AR learning can also be integrated with specific learning approaches or models. In this research, teachers were asked to choose the learning model suitable for integrating AR media. The results of the data analysis related to teachers' perceptions of what learning models are appropriate to be combined with AR-based learning are presented in Figure 4.

Figure 4 shows that most teachers choose project-based learning (PjBL) and problem-based learning (PBL) as learning models suitable for integration with AR Media. However, several teachers still don't know the appropriate learning model. AR in learning has been proven to improve the performance of scientific projects produced [46]. Students' positive emotions in the PBL process can be increased through AR technology [47]. The need for more innovative learning in its implementation can guide students to interact with the object [48].

Thus, these results show that teachers' readiness in the capabilities aspect is still lacking. Even though most teachers claim to know about AR-based learning, most teachers have never implemented AR in learning. On the other hand, teachers can determine appropriate class levels, topics, and models to be integrated with the PBL model and require attention from stakeholders to encourage teachers to realize the application of AR at the chosen class level, topic, and model.

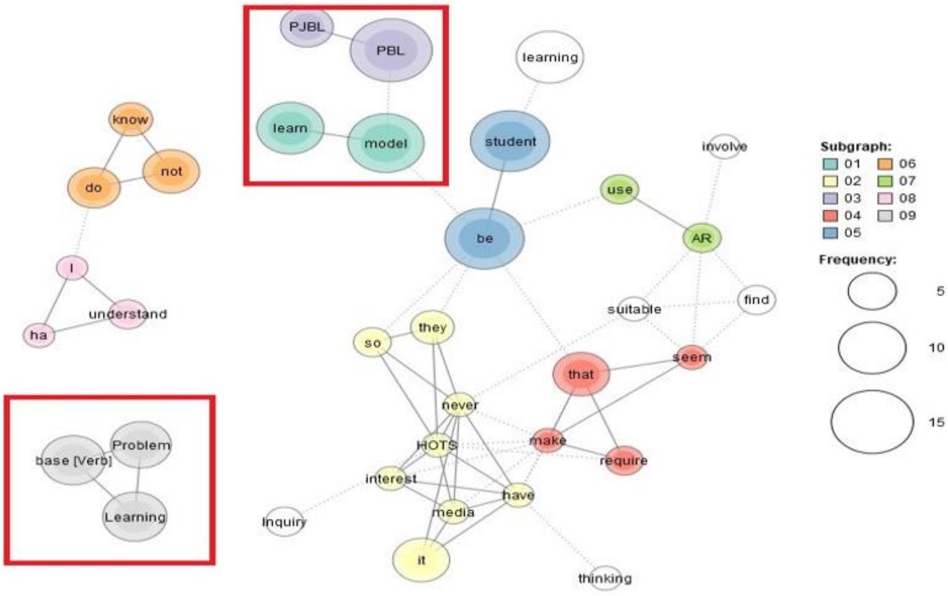

Figure 4. The choice of learning models for implementing AR

3.3. RQ3: To what extent are physics teachers engaged with AR-based learning?

After exploring the knowledge of AR in the alignment and capabilities aspect, the readiness of teachers to engage in AR-based learning is explored. The result of the data analysis found that from teachers' perspectives, the benefits of using AR in learning are it can facilitate fun learning and attract students' knowledge. Moreover, using AR can make students understand abstract concepts more efficiently, support creativity growth, and increase new experiences. The use of AR by teachers can also arouse students' enthusiasm to be actively involved in learning [32], so it can support student-centered learning implementation [27]. Apart from that, its easy use with high mobility, such as using it via a smartphone, is also an advantage of AR [49]. Integrating technology in learning brings many benefits to improving the quality of education, especially in meeting the needs of 21st-century students [50]. Therefore, its implementation needs to be adequately supported and facilitated. Meanwhile, the disadvantage of AR-based learning is the need for an internet network. This result needs to be the concern of the stakeholders. Whereas what the teachers still want to learn more about AR-based learning is shown in Table 3.

Table 3. Statement from participant

Teacher	Statement
T2, T4, T5, T11, T14, T25	Making/creating AR-based learning media
T9, 14, T16, T17, T26	How to implement AR-based learning effectively
T53	The growing interest in student learning with AR

These results align with the research by Marquez and Pombo [10], showing that getting access to making AR and being experts in making AR are things that want to deepen learning related to AR technology. Many teachers are not ready to integrate technology into learning due to inadequate preparation and related training activities [51]; this condition is because most teachers often use conventional media only [52]. Teachers must improve their digitalization competence [53]. Based on the results, we can say that the engagement aspect of teacher readiness is sufficient because teachers already know the advantages and disadvantages of AR-based learning implementation and what they should learn more about.

The results showed that the teachers generally have a strong readiness in the alignment aspect, while for capabilities, they have less readiness and sufficient readiness in the engagement aspect. Teachers already know the definition, features, and benefits of AR in learning (alignment aspect). Still, only a minority of teachers have implemented AR-based learning (capability aspect). In the engagement aspect, it is known that teachers want to learn more about how to create AR and implement AR effectively. The implications of this research are recommendations to stakeholders to encourage and facilitate teachers, especially physics teachers.

The reason why most physics teachers have never implemented AR-based learning is thought to be because teachers do not yet have the knowledge and skills to create and enforce AR-based learning.

Therefore, practically, these results can be a basis and recommendation for stakeholders in bridging teachers to have the knowledge and skills to create and apply AR so that, in the end, more teachers can implement AR-based learning. Theoretically, it is necessary to provide in-depth training for teachers to develop and implement AR-based learning, especially on abstract topics chosen by the teacher, such as global warming, kinetic theory of gas, electricity, and magnetism.

The limited number of participants in this research, only 67 physics teachers in Indonesia, can also be a recommendation for further research to expand the number of participants. Increasing the number of participants is needed to obtain a more representative picture of the readiness of physics teachers in Indonesia to implement AR-based learning. Future research also needs to explore why many teachers still have not implemented AR-based learning even though they are interested in implementing it.

4. CONCLUSION

Indonesian physics teachers' readiness to implement AR-based learning can be obtained based on alignment, capabilities, and engagement. From the alignment aspect, teachers show strong alignment with AR-based learning; they already know the definition, main features, and benefits of using AR in learning. From the capabilities aspect, teacher readiness is still lacking because a minority of teachers have implemented AR-based learning. Last, the engagement aspect is sufficient because teachers already know the advantages and disadvantages of AR-based learning implementation and what they should learn more about.

Teachers want to learn more about how to create AR and how to implement AR effectively. Holding in-depth training for teachers to develop and implement AR-based learning, especially on abstract topics chosen by teachers, such as global warming, kinetic theory of gases, electricity, and magnetism, is needed. The implications of this research are recommendations to stakeholders to encourage and facilitate teachers, especially physics teachers, to teach by integrating technological knowledge and skills. One way that can be done by universities of education or the teaching profession is, for example, by increasing the quantity and improving the quality of training related to the application of AR-based learning. In educational institutions for prospective teachers, there also needs to be curriculum integration with several technological literacies to prepare future teachers so that when they become teachers, they can adapt teaching to ongoing technological developments.

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