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UTILIZING AUGMENTED REALITY MEDIA IN SCIENCE LABORATORY ACTIVITIES: ENHANCING STUDENTS' COMPETENCE IN EXPLAINING PHENOMENA SCIENTIFICALLY

SAPRUDIN SAPRUDIN[1,*], SALKIN LUTFI[1], FATMA HAMID[1], ALI ISMAIL[2], MUHAMMAD SYAIPUL HAYAT[3], SURYA GUMILAR[4]

[1]Universitas Khairun, Ternate, Indonesia
[2]Universitas Pendidikan Indonesia, Bandung, Indonesia
[3]Universitas PGRI Semarang, Semarang, Indonesia
[4]Institut Pendidikan Indonesia, Garut, Indonesia
*Corresponding Author: saprudin@unkhair.ac.id

Abstract

This research strengthened competence in explaining scientific phenomena (CEPS) through the integration of augmented reality (AR) media in science laboratory activities on temperature and heat. The study followed the development research method using the Analyse, Design, Develop, Implement, and Evaluate (ADDIE) model. Validation was conducted with five media and material experts, and the implementation involved 18 students enrolled in the Basic Physics Practicum 1 course. The results showed that students' CEPS improved significantly after participating in laboratory activities with AR media integration. This improvement occurred because the normalized gain score reached 0.77, placing it in the high category. AR media effectively enhances scientific competence by providing interactive and immersive learning experiences. This research has implications for educators, guiding them in selecting laboratory activities that align with AR integration for more effective science learning.

Keywords: Augmented reality, CEPS, Science laboratory activities, Science phenomena, Temperature and heat.

1. Introduction

The competence to explain scientific phenomena (CEPS) is a crucial aspect of science education that requires strengthening [1]. Scientific phenomena (either natural or human-made) can be observed, measured, and explained using scientific knowledge [2]. However, students' science competence in Indonesia, as reflected in PISA assessments, still needs improvement [3-5]. Teachers play a vital role in enhancing science learning quality [6-8], yet studies indicate that science competence in higher education remains insufficient [9-12].

Technology integration in science laboratory activities is an effective approach to improving science competence [13-17]. Laboratory activities can be real or virtual [18-23]. Augmented reality (AR) technology bridges these two methods, enhancing student learning, motivation, and cognitive processing [24-29]. AR also aids in explaining microscopic phenomena and connecting them to macroscopic concepts [30].

This study enhanced CEPS through the integration of AR in science laboratory activities on temperature and heat. Temperature and heat are fundamental concepts in physics that students must understand thoroughly [31]. We used the Analyse, Design, Develop, Implement, and Evaluate (ADDIE) model, AR media was developed and integrated into laboratory experiments. Few studies explore AR's role in improving CEPS in this context, making this research a novel contribution to the field. Novelties of this study include

(i) Integration of AR in science laboratory activities on temperature and heat. While AR has been widely used in education, its application in laboratory activities related to temperature and heat remains underexplored. This study provides empirical evidence of how AR enhances students' CEPS in this specific context.

(ii) Bridging real and virtual laboratory experiences. Unlike previous studies that focus solely on real or virtual labs, this research integrates both approaches using AR, offering a hybrid learning experience that reinforces conceptual understanding and improves student engagement.

(iii) Empirical validation of AR's role in strengthening CEPS. This study provides quantitative evidence that AR significantly improves CEPS, demonstrated by pre-test and post-test results, filling a gap in research on scientific reasoning and AR applications in physics education.

(iv) Development of an AR-based learning model using the ADDIE framework. The research systematically designs, develops, and implements AR media using the ADDIE model, making it a structured approach for future AR-based educational interventions; and

(v) Innovative use of AR for microscopic-macroscopic conceptual connections. Many physics concepts involve microscopic phenomena that are difficult for students to visualize.

This study leverages AR to bridge the gap between abstract theoretical concepts and real-world applications, improving students' ability to scientifically explain phenomena. Finally, by addressing these gaps, this research contributes to the field of science education, providing a new approach to enhancing scientific competence through technology-driven learning experiences.

2. Theory

Figure 1 illustrates an AR system running on the Android operating system, enabling users to integrate digital objects into the real environment. This system functions through the device's camera and software, which recognizes and processes real-world objects. AR media has significant potential to help students visualize abstract, complex, and microscopic scientific phenomena [30, 32]. It can be applied in both theoretical explanation sessions [33, 34] and science laboratory activities [26, 30, 35-37]. AR in science learning enhances student motivation and academic achievement [34, 38-40].

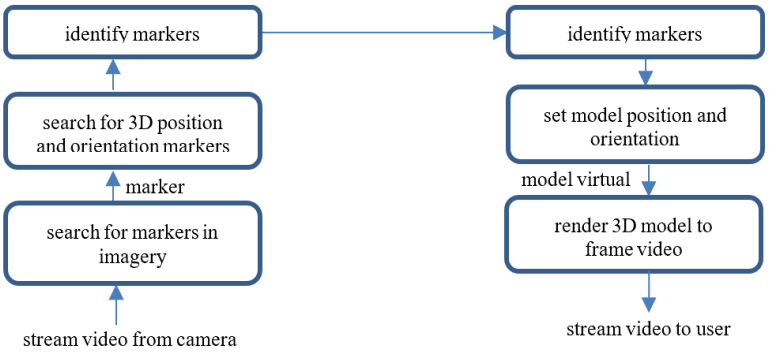

Fig. 1. AR operating system.

One of the difficult subjects is temperature and heat as fundamental concepts in physics that describe energy transfer and molecular motion. Temperature measures the average kinetic energy of particles in a substance, while heat refers to the energy transfer between objects due to a temperature difference. Understanding these concepts is crucial for explaining thermal expansion, phase changes, and heat transfer mechanisms (conduction, convection, and radiation) [31, 41-44]. In real-life applications, they are essential in engineering, meteorology, and energy systems. Misconceptions often arise, such as confusing temperature with heat or assuming coldness is a form of energy. Effective teaching methods, including experiments and AR media, can enhance students' comprehension.

3. Method

This study employed a development research method following the ADDIE model. Validation of AR media involved five experts specializing in media and science content. The AR media was implemented in the Basic Physics Practicum 1 course with 18 students from a university in Ternate City, Indonesia. Data on students' CEPS (Competence to Explain Phenomena Scientifically) was collected using a multiple-choice test and analysed using the normalized gain method to measure the effectiveness of AR media in enhancing scientific explanation skills.

4. Results and Discussion

Figure 2 presents two examples of AR media visualizations depicting particle motion in hot water. Portability testing confirmed that the AR media was successfully installed, executed, and uninstalled on various mobile devices running

Android versions 9 to 14. Validation results from media experts (85%) and science material experts (85%) indicate that the AR media is highly suitable for laboratory activities on temperature and heat.

(a) (b)

Fig. 2. AR media display: Visualization of particle motion in hot water and (b) Visualization of particle movement during the water heating process.

Table 1 shows an overall improvement in students' CEPS across all indicators. Most improvements fall into the high category, except for the ability to recognize and develop explanatory hypotheses, which is categorized as moderate. AR media helps contextualize real-world problems by visualizing scientific phenomena, making it easier for students to recall and apply scientific knowledge [40]. Microscopic visualizations, such as particle motion in liquids at different temperatures, enhance students' conceptual understanding and ability to interpret multiple representations [30].

The use of AR media in laboratory activities allows students to interact spontaneously with observed objects [45], promoting model identification, construction, and evaluation. Additionally, AR can visualize heat transfer in modern technological applications, such as convection flow in deep fryers and air fryers, reinforcing the real-world relevance of science concepts. This study adds new information regarding the use of technology for explaining physics, as reported elsewhere [46-48].

Table 1. Improvement of students' CEPS.

No.	CEPS Indicator	$\langle g \rangle$
1	Recall and apply appropriate scientific knowledge	0.88
2	Use different forms of representations and translate between these forms	0.79
3	Make and justify appropriate scientific predictions and solutions	0.86
4	Identify, construct, and evaluate models	0.75
5	Recognize and develop explanatory hypotheses of phenomena in the material world	0.56
6	Explain the potential implications of scientific knowledge for society	0.79
	Average	0.77

5. Conclusion

This study confirms that AR media enhances students' CEPS in temperature and heat laboratory activities. Validation results from media and science experts indicate high suitability and student assessments show significant improvement, particularly in visualizing and explaining microscopic phenomena. AR media helps contextualize scientific concepts, making learning more interactive and engaging. By bridging real and virtual laboratory experiences, AR fosters better conceptual understanding and scientific reasoning. These findings highlight AR's potential as an innovative learning tool, providing a scalable approach to improving science education through technology-enhanced laboratory activities.

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