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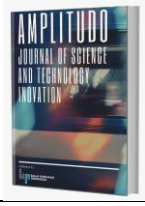

# Thermodynamics-Augmented Reality as a Visual Learning Media to Improve Student Creativity

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**Abstract:** In the digital era, integrating technology in education provides a great opportunity to improve the quality of learning. Using smart devices and educational applications creates an interactive learning experience, expands access to global resources, and facilitates collaboration-based learning. In this context, smartphone-based mobile learning (M-learning), especially Android, has become a popular learning medium among teenagers. This technology offers great potential in increasing the effectiveness of the teaching and learning process, especially in materials that require complex visualization, such as thermodynamics in physics. The abstract concept of thermodynamics is often difficult for students to understand without adequate visualization, leading to misconceptions. To overcome this problem, Augmented Reality (AR) technology can be used as a learning medium to combine the real world with digital content in real time, allowing for clearer and more concrete visualizations. The development of AR-based learning media on thermodynamics materials, such as Thermodynamics-Augmented Reality, is expected to reduce misconceptions, increase creativity, and facilitate students' deeper understanding of complex concepts.

**Keywords:** Augmented Reality; Creativity; Thermodynamics.

## Introduction

Education and technology are closely intertwined in addressing the challenges of the 21st century. The integration of technology in education provides opportunities to create more interactive learning experiences, offer access to global educational resources, and facilitate collaborative learning. The utilization of online learning platforms, educational applications, and smart devices can enhance the efficiency and effectiveness of the teaching and learning process. In this context, Asmawi et al. (2019) argue that education and technology complement each other, with technology serving as a tool to facilitate the development of various intelligences in learners. Therefore, the integration of technology in education not only supports the development of digital skills but also stimulates critical thinking, creativity, and collaboration among today's generation of students.

As information and communication technology (ICT) advances, learning media also evolves. One such technology-based medium is mobile learning (M-learning), which emerged due to the growth of communication technologies, particularly smartphones. Android is currently one of the most popular smartphone operating systems. Smartphones have become highly useful because their internet connectivity provides a gateway to the world for exchanging information. This has led to an increase in smartphone users year by year. Among the many users, those aged 15-19 make up the largest percentage compared to other age groups, indicating that the majority of smartphone users are middle and high school students (Ardiyansah et al., 2020).

The widespread development of technology, especially smartphones, must be approached wisely. Technology is no longer the domain of a select few, but rather, it is available to all. The benefits of technology should be continuously explored to improve human life. The high number of smartphone users presents both

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challenges and opportunities in the field of education. The challenge lies in the potential for misuse, such as for negative purposes. However, smartphones also present a great opportunity to develop technology that is beneficial in education. One of the key advantages of smartphones is their potential to serve as an effective, creative, and educational learning medium (Diski, 2021).

The development of technology should also be incorporated into physics education. One subject that particularly benefits from technological assistance is thermodynamics. This subject involves several systems and concepts that require visual representation. Without such visualization, misconceptions among learners may arise. According to Nisrina et al. (2020), abstract concepts in physics are some of the most difficult for students to understand, necessitating virtual assistance to illustrate each concept. Therefore, there is a need for a learning process that incorporates media or technology to aid understanding.

Many educational media models still rely on media that do not visualize the material being taught, which can make it difficult for students to fully grasp what they are learning. For this reason, it is essential to have learning media that can provide visual representations to help students understand and become more competent in the subject. An important challenge is the lack of awareness or understanding among students about the visual representation of material presented by the teacher, especially in the absence of teaching aids or demonstration objects (Destra, 2022). Thus, the use of media is strongly recommended to develop learning, particularly in physics education. One such medium is Augmented Reality (AR) technology, which is expected to help students understand the material they are learning better. While AR may still be unfamiliar to some, it is traditionally developed for PC desktop applications. However, with technological advancements, many applications have now adopted AR technology into smartphone applications (Murfi et al., 2020).

Augmented Reality (AR) is a synthesis of real and virtual representations. AR aims to develop technology that allows real-time integration of computer-generated digital content with the real world. One area of physics that benefits from AR technology is thermodynamics, as many of its systems require visual representation. Visualization is achieved through the use of AR (Mukti, 2019).

Based on the above explanation, to reduce misconceptions in thermodynamics and comprehensively visualize each concept, Thermodynamics-Augmented Reality (TAR) was developed as a visual learning medium to enhance students' creativity.

## Method

This study is quasi-experimental research with a pre-test and post-test one-group design involving two groups: the experimental group and the control group. The subjects of the study consisted of 24 students from class XI IPA II at MAN 1 Mataram, divided into two groups: the control group and the experimental group. The experimental group used AR-based learning media to understand thermodynamics concepts, while the control group used conventional learning methods. Data were collected through creativity tests administered before and after the intervention, as well as through observation of students' activities during the learning process.

The steps in this research include: (1) The initial stage, which involves observation at the school being investigated, obtaining permission for the study, conducting a survey, and preparing assessment tools such as instruments, (2) Development of AR-based learning media focusing on fundamental thermodynamics concepts such as the laws of thermodynamics and the Carnot cycle, (3) Validation of the creativity test instrument by a supervising lecturer, (4) Implementation of learning activities for one day, with the experimental group using AR media and the control group following regular lessons, and (5) Data analysis using statistical tests to examine the differences in pre-test and post-test scores between the two groups.

The data collection technique used consists of a set of five creative questions. Information was obtained in the form of quantitative data, with the questions being administered to the entire sample. Data analysis for this study was conducted using formal descriptive statistical analysis.

## Result and Discussion

*Result*

The subjects of this study were 24 students from class XI IPA 2. The researcher conducted observations of the ongoing learning activities. Afterward, the students were given a pre-test on creativity related to the study of the Carnot cycle. The results of the pre-test were then grouped to assess the overall profile of students' creative thinking abilities.

The findings of this study indicate that the use of Thermodynamics-Augmented Reality (TAR) as a visual learning medium has a positive impact on increasing students' creativity. Based on statistical test results, it was found that students using TAR media experienced a 20% increase in creativity scores according to the Work Sheets provided. In contrast, the control group, which used conventional methods, only showed a 5% increase.

Additionally, class discussions revealed that students in the experimental group found it easier to understand abstract concepts in thermodynamics, such as the laws of thermodynamics and the Carnot cycle. They stated that the visualizations presented by the TAR media helped them comprehend the material in greater depth compared to the conventional learning method, which heavily relied on text and verbal explanations.

Furthermore, the data presented in Figure 1, which compares pretest and posttest results, shows that the experimental group using TAR had a significantly greater increase in scores compared to the control group. For instance, the pretest scores of the experimental group ranged from 65 to 89, with a notable increase in posttest scores, the highest of which reached 96. In contrast, the control group demonstrated a much smaller improvement, with posttest scores peaking at only 37 to 35.

These results suggest that TAR technology not only enhances students' creativity but also facilitates a deeper understanding of complex scientific concepts such as thermodynamics, highlighting its potential as an effective educational tool.

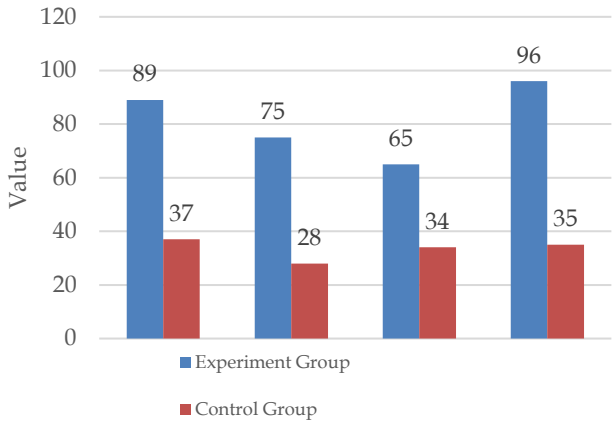


**Figure 1.** Comparison of Control and Experimental Classes

From these results, it can be concluded that the use of augmented reality-based learning media in thermodynamics concepts effectively enhances both students' understanding and creativity compared to conventional teaching methods. Therefore, the application of augmented reality technology in science education can serve as an innovation that supports the improvement of teaching quality, particularly in understanding abstract concepts that are difficult to explain through traditional methods. By providing visual and interactive representations of complex phenomena, augmented reality allows students to engage with and better grasp difficult concepts, fostering a more effective and engaging learning experience. This suggests that augmented reality has significant potential in transforming how students learn and understand scientific principles, ultimately contributing to more meaningful and impactful educational outcomes.

*Discussion*

The use of Thermodynamics-Augmented Reality (TAR) in science education, particularly in thermodynamics, has proven to significantly enhance students' creativity. This improvement is primarily influenced by TAR's ability to visualize abstract concepts, increase interactivity in learning, and foster collaboration among students. In traditional learning, concepts such as heat transfer, energy changes, and thermodynamic cycles are often difficult to understand due to their abstract nature, requiring high spatial imagination. With the advent of augmented reality (AR) technology, these concepts can be visualized as more concrete three-dimensional models, making it easier for students to grasp the fundamental principles of thermodynamics in a more intuitive way (Sriadhi et al., 2022; Bakrania, 2020).

In addition to more concrete visualization, AR also encourages higher interactivity in learning. Unlike traditional methods, which tend to be passive, where students only receive information from books or the teacher's explanations, AR allows students to interact directly with the available simulations and models. In the context of thermodynamics, students can see how the laws of thermodynamics work in real-time, such as how changes in pressure and volume affect the temperature in a closed system. This interactivity not only increases students' engagement in the learning process but also helps them develop creative solutions in solving problems they encounter during the virtual experiments they conduct (Sriadhi et al., 2022; Wittayakhom & Piriyasurawong, 2020).

Furthermore, the use of TAR in the classroom also enhances collaboration among students. In AR-based learning environments, students often work in groups to analyze data, interpret simulation results, and discuss their findings. This collaboration allows them to exchange ideas and develop various strategies to solve the tasks or projects assigned to them. For example, when analyzing the Carnot cycle in AR, students can discuss the factors that affect the efficiency of thermodynamic engines and compare their predictions with the results of the simulations they run. This interaction not only strengthens their understanding of the concepts being taught but also enhances their critical thinking skills and communication abilities (Chen et al., 2020; Wittayakhom & Piriyasurawong, 2020).

In terms of learning outcomes, the comparison of pretest and posttest scores shows a greater improvement in the group using TAR compared to the control group

that still employed conventional methods. This study's results indicate that TAR provides a more effective learning experience than traditional methods. In terms of creativity, students using TAR experienced a significant increase, while the control group showed only a slight improvement. These findings support the assumption that the use of interactive technologies such as AR can assist students in developing a deeper conceptual understanding while enhancing critical thinking skills that are essential in science education (Sriadhi et al., 2022; Yu-peng & Yu, 2023).

Overall, this research confirms that the integration of augmented reality in science education, particularly in the concept of thermodynamics, can provide significant benefits. By utilizing interactive visualization, increasing student engagement, and encouraging collaboration in the learning process, TAR has proven to be an effective tool for enhancing student creativity. Therefore, the application of AR technology in science education should continue to be developed and widely implemented as part of modern educational innovations. Additionally, further research could be conducted to explore how this technology can be optimized for other subjects to improve the effectiveness of learning at various educational levels (Lampropoulos, 2024).

## Conclusion

Based on the research findings, it can be concluded that Augmented Reality-based learning media for thermodynamics is effective in enhancing students' creativity. AR not only facilitates the understanding of abstract concepts but also encourages students to think more creatively and seek solutions. However, it is important to ensure proper preparation in terms of equipment and teacher training to ensure the optimal implementation of AR in the learning process. Effective integration of AR requires teachers to be well-trained in utilizing this technology, as well as the availability of adequate devices to support interactive learning. With such preparations, the use of AR can significantly improve the quality of education by providing students with an engaging and immersive learning experience that enhances both their understanding and creative problem-solving skills.

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**Author Contributions**
Conceptualization, First Author and Second Author; methodology, First Author; validation, First Author and Second Author; formal analysis, First Author; investigation, First Author, Second Author, and Third Author; resources, Bayero University, Kano; data curation, First Author and Second Author; writing—original draft preparation, First Author; writing—review and editing, Second Author, Third Author, and Third Author; visualization, Third Author and Third Author.

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**Conflicts of Interest**
The authors declare no conflict of interest.

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