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Cognitive Conflict-Based Learning Materials Thermodynamics with Augmented Reality: Is It Practical in Physics Learning?

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ABSTRACT

The problem of low conceptual understanding in physics learning is still often encountered, including in thermodynamics material. The use of technology such as Augmented Reality to support concept formation in physics education is still very limited. One solution that can be offered to overcome this problem is the development of cognitive conflict-based physics teaching materials using Augmented Reality in thermodynamics material. This study aims to analyze the practicality of cognitive conflict-based thermodynamics teaching materials. This study reports the results of a small group evaluation (practicality test) which is part of the Plomp model development stage. The research instrument used was a practicality questionnaire, which was analyzed using a percentage technique. The results of the practicality test showed an average score of 89.90%, which is included in the very practical category. Cognitive conflict-based thermodynamics teaching materials with Augmented Reality have proven to be practical for students to use, both in terms of ease of use, attractiveness, usefulness, and efficiency.

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INTRODUCTION

The revolution in technology and science in the 21st century has triggered a profound transformation in the education system, particularly in learning methodologies. Modern learning can no longer be separated from the need to integrate technology effectively and efficiently. Learning is a reciprocal relationship between students, educators, and the learning environment that encourages the learning process to achieve specific goals (Mufit et al., 2022) . In addition, learning is a series of structured efforts by educators to ensure that the learning process occurs in students (Fitria & Indra, 2021). From these two perspectives, it can be concluded that learning is an interactive process involving the dynamic relationship between students, teachers, and the environment to facilitate the transformation of knowledge and skills.

In physics, learning should ideally engage students actively in the exploration and discovery of concepts aligned with the demands of 21st-century learning (Mufit & Dhanil, 2024). This approach enables students to construct a more comprehensive and meaningful conceptual understanding of physics. According to research by Mufit & Fauzan, (2023), learning models that do not consider students' prior understanding and fail to involve them

in the process of discovering concepts tend to increase the risk of misconceptions, especially since many students carry misconceptions from previous educational levels. Isra & Mufit, (2023) reinforce this argument by revealing that the root of students' misconceptions often stems from their own cognitive constructions, which are then exacerbated by inaccurate information from textbooks, teacher explanations, and unverified digital sources.

The urgency of this research is grounded in the identification of various factors that cause misconceptions in physics learning, particularly in the topic of thermodynamics. Critical factors contributing to misconceptions include students' limited capacity to understand abstract thermodynamic concepts, the lack of access to valid and comprehensive learning resources, and the scarcity of interactive and motivating learning media. Prawiyogi & Syarifudin, (2023) argue that conventional teaching approaches, which still dominate in the field, are insufficient in inspiring students' enthusiasm when dealing with complex concepts. Learning tends to focus on memorizing physics formulas/equations rather than conducting experiments to discover concepts. When learning goals are teacher-centered, students do not truly acquire the material and are only motivated to memorize formulas (Mufit et al., 2020).

Based on the results of observations conducted with two physics teachers at SMAN 5 Pariaman, it is known that misconceptions are still a fairly dominant problem experienced by students in learning. One of the contributing factors is the learning approach that is still centered on the teacher (teacher-centered), where the lecture method is still the main strategy so that students are less actively involved in the knowledge construction process. This is not in accordance with the demands of the independent curriculum and can create the impression of boring learning so that students are reluctant to be actively involved in the learning process. Teachers more often give calculation questions than concept questions. In addition, there are no teaching materials that are specifically designed to help overcome student misconceptions, especially in thermodynamics material which is abstract and complex. This condition can hinder the achievement of a deep understanding of concepts.

The solution to this problem is to develop cognitive conflict teaching materials integrated with Augmented Reality. Based on previous research, an important focus in developing effective and interesting learning media for students is cognitive conflict-based teaching materials integrated with Augmented Reality in thermodynamics material (Agustina & Mufit, 2023). Other studies have also found that the use of Augmented Reality in cognitive conflict models can increase student engagement and their understanding of complex scientific concepts (Mufit & Dhanil, 2024). In addition, the development of physics teaching materials based on cognitive conflict has the potential to reduce misconceptions by providing opportunities for students to repeatedly strengthen their understanding of concepts. This model also encourages active student involvement in the learning process, thus contributing to increasing their learning motivation (Faresta et al., 2020).

Cognitive conflict is a misunderstanding that arises in a person's mind through their perception of an event when attempting to discover the correct concept (Mufit & Fitri, 2022). In order to stimulate students' cognitive system and challenge their initial conceptions, an educational approach referred to as the cognitive conflict-based learning model can be employed. This approach is considered a progressive method, as it attempts to extend conceptual understanding among students while eradicating misconceptions that hamper learning (Zuwita & Mufit, 2023). To support such an argument, Pramono & Mufit (2022) found that the use of the aforementioned model has a significant effect on how students comprehend scientific concepts, therefore reducing prospects of long-standing misconceptions, and as claimed by Mufit & Fauzan (2019), the model passes through four key phases: (1) activation of preconceptions and misconceptions, (2) presentation of cognitive conflict, (3) discovery of concepts and similarities, and (4) reflection.

Augmented Reality is a technology that combines computer-generated digital content with the real world in real time. It can merge virtual 2D or 3D objects into the real world in real time to display those virtual objects (Riyanto & Jollyta, 2023). According to research by Estiawan & Kurniawan, (2025) Augmented Reality as a learning medium for thermodynamics can help teachers deliver complex materials more easily. Moreover, the use of such applications can make teaching and learning activities more effective and efficient. Augmented Reality has three main advantages that make it a popular choice among developers: 1) It can expand users' perception of an object and provide a "user experience" of the displayed 3D object. 2) It allows users to interact in ways that are not possible in the real world. 3)It can be used with a variety of devices, depending on needs and availability (Dedynggego et al., 2015).

The significance of this study lies in advancing the development of thermodynamics teaching materials that integrate Augmented Reality within a cognitive conflict-based framework. These materials, originally created by Agustina & Mufit (2023), were validated by six validators and demonstrated a high level of practicality during one-to-one evaluation, though their effectiveness in a small group evaluation has yet to be determined. Prior findings indicated that the materials achieved a strong validity score of 0.92—classified as valid—based on several criteria, including the quality of content, instructional structure, visual presentation, software integration, and alignment with the cognitive conflict model. Additionally, a practicality score of 91% was recorded, indicating that the materials are highly practical, characterized by ease of use, attractiveness, efficiency, and benefits in the learning process.

To produce high-quality teaching materials, a practicality test through the small group evaluation phase is necessary. According to Nieveen, (2019), a product is considered high quality if it meets three criteria: valid, practical, and effective. Practicality refers to the extent to which a product is easy to use, enjoyable, and capable of optimally supporting the learning process. Therefore, a practicality test is essential to determine the level of ease of use, attractiveness, usefulness, and efficiency of the teaching material from the perspective of students as the main users. The primary objective of this research is to evaluate the level of practicality of thermodynamics instructional materials that have been designed through a cognitive conflict-based approach and enhanced with Augmented Reality technology. To guide this investigation, the study addresses the following research question: "Cognitive Conflict-Based Learning Materials Thermodynamics with Augmented Reality: Is It Practical in Physics Learning?"

METHODS

This research is part of development research that aims to produce physics teaching materials that are not only innovative in content and media, but also practical for use by students and teachers in real learning. Development research was chosen because this approach emphasizes a systematic process in designing, developing, and evaluating learning products based on field needs (Plomp, 2013). In this case, the focus of the research is to examine the practicality of cognitive conflict-based teaching materials integrated with Augmented Reality technology on the topic of thermodynamics. The development model used is the Plomp model which consists of three main phases: (1) preliminary investigation phase, (2) prototype development or design phase (design and realization), and (3) evaluation phase (evaluation) (Plomp, 2013). This research is in the third phase, namely the formative evaluation stage, more specifically the small group evaluation stage, which aims to test the level of practicality of teaching materials before being applied on a wider scale.

The research sample consisted of nine Grade X Phase E students from SMAN 5 Pariaman. The focus of this study was a teaching material product based on cognitive conflict and integrated with Augmented Reality. The selection of participants was carried out with specific considerations, particularly to account for the diverse academic abilities among students. This approach was intended to ensure that the developed open-ended teaching material would be practical and applicable for learners across all achievement levels, including low, medium, and high performers.

The research instrument employed in this study was a practicality test questionnaire. This questionnaire was designed to evaluate the practicality of the teaching material through four key aspects: ease of use, attractiveness, efficiency, and perceived benefits. The analysis of the product's practicality was carried out based on the feedback provided by students from SMAN 5 Pariaman. To determine specific practicality criteria, the teaching material was tested on three distinct groups of students representing high, medium, and low levels of academic ability.

The data obtained were analyzed quantitatively using percentage analysis techniques. Each indicator's percentage was calculated based on the number of positive responses relative to the maximum possible score. These percentages were then categorized into five levels of practicality according to Riduwan (2019), namely: very impractical (0–20%), less practical (21–40%), fairly practical (41–60%), practical (61–80%), and very practical (81–100%). The overall average result was used to determine the general classification of the product's practicality (Riduan, 2019).

RESULTS AND DISCUSSION

Results

The following are the results of the practicality test of cognitive conflict-based thermodynamics teaching materials that have been integrated with Augmented Reality technology. This data is obtained from the calculation of the percentage of each aspect assessed. The practicality test covers four main aspects, namely ease of use, attractiveness, efficiency, and benefits. The assessment was carried out by distributing practicality questionnaires to 9 students who were divided into three small groups (small group evaluation). Each group consists of three students with different levels of ability: high, medium, and low.

The first aspect, ease of use of teaching materials, consists of nine indicators. Six of the nine indicators are in the very practical criteria. The values of the nine indicators are presented in Table 1. From Table 1, it can be seen that the range of values generated for each ease-of-use indicator is in the practical and very practical criteria. The practicality assessment of teaching materials with practical criteria is in indicators d, f and h with a value of 80.56 and indicators with very practical criteria are in indicators a, b, c, e, g, and i which have a value range of 83.33 to 91.67. Judging from the average aspect of ease of use, the open materials produced obtained a score of 85.80 with the criteria of very practical. Thus, the aspect of ease of use of cognitive conflict-based thermodynamics teaching materials integrated with Augmented Reality is included in the very practical criteria.

Table 1. Results of Ease-of-Use Aspect

Indicator	Value (%)	Criteria
a. Instructions for teaching materials are easy to understand*	91.67	Very practical
b. The sequence of materials in the	91,67	Very practical

teaching materials is easy to understand*		
c. The materials presented are easy to understand*	88.89	Very practical
d. The preconception and misconception activation stage are easy to implement*	80.56	Practical
e. The cognitive conflict presentation stage is easy to implement*	88.89	Very practical
f. The concept and equation discovery stage are easy to implement*	80.56	Practical
g. Reflection, has been implemented*	86.11	Very practical
h. Learning activities using Augmented Reality integrated teaching materials are easy to implement*	80.56	Practical
i. 3D images in the Augmented Reality application are easy to understand*	83.33	Very practical
Average	85.80	Very practical

The second aspect is the attractiveness of teaching materials which consists of six indicators. All indicators in this aspect are in the very practical criteria. The values of the six indicators are presented in Table 2. From Table 2, it can be seen that the range of values generated for all indicators of attractiveness starts from 86.11 to 91.67. So, all indicators in the attractiveness aspect have very practical criteria. The average aspect of the attractiveness of teaching materials produced is 89.35 with very practical criteria. Therefore, the criteria for the attractiveness aspect of the cognitive conflict-based teaching material integrated with Augmented Reality on thermodynamics content fall into the category of very practical.

Table 2. Results of the Attractiveness Aspect

Indicator	Value (%)	Criteria
a. Interesting teaching material cover*	88.89	Very practical
b. Interesting teaching material content display*	91.67	Very practical
c. Interesting font type on teaching material*	91.67	Very practical
d. Interesting image illustration*	86.11	Very practical
e. Interesting Augmented Reality application display*	86.11	Very practical
f. Interesting 3D images on Augmented Reality*	91.67	Very practical
Average	89.35	Very practical

The third aspect is the efficiency of teaching materials which consists of five indicators. All indicators in this aspect are very practical. The values of the five indicators are presented in Table 3. From Table 3, it can be seen that the range of scores generated for all efficiency indicators starts from 88.89 to 94.44. So, all indicators of attractiveness are on

very practical criteria. The average efficiency aspect of teaching materials produced is 92.22 with very practical criteria. So that the criteria for the efficiency aspects of Augmented Reality integrated cognitive conflict-based teaching materials on thermodynamic material are on very practical criteria.

Table 3. Results of the Efficiency Aspect

Indicator	Value (%)	Criteria
a. Teaching materials make learning time more efficient*	94.44	Very practical
b. Teaching materials make costs more efficient to own and use*	91.67	Very practical
c. Teaching materials can be used anywhere*	91.67	Very practical
d. Virtual labs are more efficient to use on teaching materials because they already use barcode scanning*	88.89	Very practical
e. Augmented Reality is more efficient to use on teaching materials because there are already markers that are scanned*	94.44	Very practical
Average	92.22	Very practical

The fourth aspect is the benefits of teaching materials which consists of five indicators. All indicators in this aspect are in the very practical criteria. The values of the five indicators are presented in Table 4. From Table 4, it can be seen that the range of values generated for all indicators of attractiveness starts from 88.89 to 97.22. So, all indicators of the benefits of teaching materials are on very practical criteria. The average aspect of the benefits of teaching materials produced is 92.22 with very practical criteria. So that the criteria for the benefit aspects of teaching materials based on Augmented Reality integrated cognitive conflict on thermodynamic material are on very practical criteria.

Table 4. Results of the Benefits Aspect

Indicator	Value (%)	Criteria
a. Teaching materials can be used for independent learning*	88.89	Very practical
b. Teaching materials have the potential to facilitate understanding of concepts*	94.44	Very practical
c. Teaching materials have the potential to improve understanding of concepts*	88.89	Very practical
d. Teaching materials can train cooperation in learning*	91.67	Very practical
e. Augmented Reality has the potential to improve students' understanding of concepts*	97.22	Very practical
Average	92.22	Very practical

Discussion

Based on the results of the research conducted, the practicality test of teaching materials was carried out on three small groups (small group evaluation) consisting of three students in each group. The aspects tested in this teaching material product practicality research consisted of four aspects, namely ease of use, attractiveness, efficiency and benefits. The average for each aspect is 85.80; 89.35; 92.22; and 92.22 with very practical criteria. And the overall average percentage of the overall practicality aspect is 89.90 with very practical criteria.

The first aspect is ease of use, which consists of nine indicators. All of these indicators are included in the practical and very practical criteria, where six indicators are in the very practical category and three others in the practical category. Overall, the average value of the ease-of-use indicator of the developed physics teaching materials reached 85.80, which is classified as very practical. This is in accordance with the opinion of Nieveen (1999) that the practicality aspect of a teaching material product can be measured based on its ease of use (Nieveen, 2019). So overall this aspect has very practical criteria due to the presentation of clear instructions and materials that are easy for students to understand and use. Teaching materials have also been equipped with instructions for use, Augmented Reality features, and other important components such as learning outcomes, learning objectives, and flow of learning objectives, especially for thermodynamic material, which helps students understand the direction of learning more clearly.

Suparman et al. (2020) stated that the preparation of material that is interesting and easy to be understood can improve student learning outcomes. Therefore, this teaching material presents supporting information that is directly related to phenomena close to students. Furthermore, each syntax of the cognitive conflict-based learning model is also easy for students to implement. The first syntax, activation of preconceptions and misconceptions is easy to do because students are directed to answer some basic questions about the concept of thermodynamics. Through these answers, the teacher can immediately see the extent of students' understanding, whether they already understand the concept correctly, have misconceptions, or do not understand at all. The second syntax of cognitive conflict presentation can also be implemented easily because students are guided through questions related to the phenomenon of thermodynamics. This question encourages students to make hypotheses, which are then written in the hypothesis column provided in the teaching materials. Furthermore, at the stage of finding concepts and equations, students also have no difficulty because at this stage students conduct experiments related to thermodynamic phenomena, the work steps have been written in detail. Finally, the reflection syntax is easy to implement because students present the results of their group work in the third syntax. Mufit (2018) explains that it is important to bring up cognitive conflict in the learning process so that students can revise erroneous understanding and obtain the correct concept. In addition, the use of Augmented Reality technology that is easy for students to use also helps them in finding concepts and equations (Mufit, 2018).

The second aspect, attractiveness, consists of six indicators. All indicators of attractiveness show very practical criteria. This can be seen in the cover and appearance of the contents of the teaching materials are attractively designed with student events related to thermodynamic material so that students immediately know what to learn. Inside the contents of the teaching materials are arranged neatly and sequentially, using a clear font type, and equipped with pictures and videos that are fitting and easy to understand. All of this makes students interested in reading and learning. In addition, activities to find concepts and make conclusions are also fun to do because the experiments are simple, and

the tools and materials are easy to find. According to Mufit et al. (2020) teaching materials can be called practical if they look attractive and can help students learn well during the learning process.

Figure 1. (a) Cover of Cognitive Conflict-Based Teaching Materials Integrated with Augmented Reality (b) Augmented Reality Menu Display

As seen in Figure 1(a) and Figure 1(b), the cover of the Integrated Cognitive Conflict-Based Augmented Reality teaching material and the Augmented Reality menu display are made with an attractive and informative appearance. The image design can attract students' attention because it contains illustrations and menus related to everyday life and thermodynamics material. The colors used are harmonious, the fonts are easy to read, and the display is neat so that it is comfortable to look at. In addition, the interactive Augmented Reality menu makes students more enthusiastic about learning because they can see abstract concepts directly in the form of real and easy-to-understand 3D images. Attractive and interactive visual displays in learning materials have been proven to increase students' motivation and understanding of complex material (Hermawan & Hadi, 2024; Rusdi & Taufiq, 2024).

The third aspect is efficiency, which consists of five indicators. All indicators of the efficiency of this teaching material are very practical in terms of efficient learning time, the cost of using teaching materials, access to teaching materials can be anywhere, virtual laboratories supported by barcodes, and Augmented Reality already have markers that can be scanned so that teaching materials are very efficient for students to use in learning. This is also in line with the research of Mufit et al. (2025) with the existence of Augmented Reality provides efficient support in learning without time and place restrictions. In the research of Putri et al. (2025) found that Augmented Reality integrated cognitive conflict-based teaching materials that they developed were also on very practical criteria on the

efficiency aspect.

The last aspect or the fourth aspect is benefits, consisting of five indicators. All indicators in this aspect are categorized as very practical. The benefit indicators in this teaching material are included in the very practical category because this teaching material makes it easier for students to learn independently, has the potential to help understanding and improve mastery of concepts, train cooperation in learning, and Augmented Reality has the ability to build conceptual understanding. In accordance with research conducted by Mufit & Fauzan (2019), to build students' conceptual understanding, a cognitive conflict-based learning model can be used. The discovery of concepts and equations directly by students will be more memorable in their memories. Students conduct real thermodynamic experiments that are visualized through the Augmented Reality application. Integrating technology into teaching materials can be a fun activity for students. Given the many benefits of this teaching material, researchers will continue to the stage of testing the effectiveness of the teaching material.

CONCLUSION

The conclusion of this study is that the average overall practicality of cognitive conflict-based teaching materials integrated Augmented Reality in thermodynamics is 89.90%, categorized as very practical. This study analyzed four aspects: ease of use, attractiveness, efficiency, and benefits, with average scores of 85.80%, 89.35%, 92.22%, and 92.22%, respectively. All of these aspects fall into the very practical criteria. These results indicate that the teaching materials are very practical to use in the classroom. In the next stage, researchers will test the effectiveness of cognitive conflict-based thermodynamics teaching materials integrated with Augmented Reality on students' conceptual understanding.

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