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Impacts of Cognitive Conflict-Integrated Teaching Material on Student's Conceptual Understanding and Learning Motivation in Light Wave Learning

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ABSTRACT (10 PT)

Physics learning on the topic of light waves continues to face several challenges, including low conceptual understanding, persistent misconceptions, and insufficient student learning motivation. This study investigated the effectiveness of cognitive conflict-based teaching materials integrated with Augmented Reality (AR) in improving students' conceptual understanding and learning motivation. A quantitative quasi-experimental approach with a nonequivalent pretest–posttest control group design was employed. Data were collected using a four-tier multiple-choice test and an ARCS-based learning motivation questionnaire and analyzed using descriptive statistics and the Mann–Whitney U test. The results showed that students in the experimental group achieved a higher level of conceptual understanding (80.5%) than those in the control group (48.0%), accompanied by a greater reduction in misconceptions. Significant differences were also found in both conceptual understanding and learning motivation between the two groups ($p < 0.05$). These findings suggest that cognitive conflict-based teaching materials integrated with AR are effective in improving conceptual understanding and learning motivation and can serve as an innovative alternative for physics learning.

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INTRODUCTION

In physics education, conceptual understanding and learning motivation are important factors influencing learning success. Motivated students tend to participate more actively and develop a deeper understanding of scientific concepts. Physics education aims to help students understand natural phenomena through scientific concepts, principles, and laws. Conceptual understanding is essential in physics learning, as students are expected not only to memorize formulas but also to explain physical phenomena scientifically and apply concepts in various contexts. Learning motivation also supports students' engagement and achievement during the learning process. According to Keller (2010), learning motivation consists of four components: attention, relevance, confidence, and satisfaction, which contribute to better learning outcomes. Previous studies have shown that conceptual understanding and learning motivation are positively associated with students' achievement and engagement in science learning (Song & Kao, 2023).

Despite the importance of conceptual understanding and learning motivation, numerous studies have reported that students' conceptual understanding of physics remains relatively low and is often accompanied by misconceptions, which can hinder the development of accurate scientific knowledge (Rizkita & Mufit, 2022). Learning motivation is another crucial factor influencing learning success because it determines the extent of students' engagement in learning activities. Learning motivation has also been shown to have a positive relationship with students' conceptual understanding of physics (Shidik, 2020). In addition, the implementation of cognitive conflict can improve conceptual understanding and reduce misconceptions by encouraging students to reconstruct their prior knowledge and develop scientifically accepted concepts (Mufit et al., 2020). Therefore, efforts to improve conceptual understanding should be accompanied by instructional approaches that foster students' learning motivation, particularly in learning abstract physics concepts.

Light waves are abstract physics topics because their concepts cannot be directly observed, making them difficult for students to understand and increasing the risk of misconceptions. Previous studies have reported misconceptions in light dispersion, interference, image formation, and the nature and propagation of light (Irianti, 2021; Lutfia & Putra, 2020). Unaddressed misconceptions can hinder knowledge construction and cause students to retain incorrect conceptions, which may affect subsequent learning. As a result, students may struggle to interpret physical phenomena and apply concepts in problem-solving. Therefore, instructional approaches are needed to improve conceptual understanding and reduce misconceptions.

A preliminary study was conducted at SMAN 13 Padang to identify students' conceptual understanding of light-wave concepts. The findings indicated that students' understanding remained relatively low and misconceptions were still prevalent. These conditions suggest that many students experience difficulties in constructing scientifically accurate concepts. Therefore, instructional innovations are needed to facilitate conceptual change and improve students' conceptual understanding. The findings of the conceptual understanding analysis are presented in Table 1.

Table 1. Conceptual Comprehension Test Results

Categories of Comprehension	Percentage (%)
Conceptual Understanding (CU)	20.3
Misconception (M)	48.1
Not Understanding the Concept (NU)	31.3

As shown in Table 1, the majority of students were categorized as having misconceptions (48.1%) or lacking conceptual understanding (31.3%), while only 20.3% demonstrated a proper understanding of the concepts. These findings indicate that students' conceptual understanding of light-wave topics remains relatively low. The high percentage of misconceptions suggests that many students continue to hold prior conceptions that are inconsistent with scientific explanations. As a result, students may experience difficulties in understanding more advanced concepts related to light waves. Therefore, instructional strategies are needed to facilitate conceptual change and support the development of a deeper understanding of light-wave concepts.

In addition to conceptual understanding, the preliminary study examined students' learning motivation toward light-wave learning based on the ARCS model, which includes attention, relevance, confidence, and satisfaction. The results indicated that students' motivation was low across all four dimensions. This condition may contribute to difficulties in achieving optimal learning outcomes. Therefore, instructional strategies are needed to enhance motivation and encourage active involvement in learning activities. The findings of the learning motivation analysis are presented in Table 2.

Table 2. Student Motivation Questionnaire Results

Criteria	Material Indicators			
	Attention	Relevance	Confidence	Satisfaction
	n (%)	n (%)	n (%)	n (%)
Low	21 (67.7)	16 (51.6)	19 (61.3)	20 (64.5)
Medium	10 (32.3)	14 (45.2)	10 (32.3)	10 (32.2)
Height	0 (0)	1 (3.2)	2 (6.5)	1 (3.2)

Note. n = number of students; values in parentheses indicate percentages.

As presented in Table 2, students' learning motivation was predominantly categorized as low across nearly all indicators. The highest percentage of students in the low category was found in the attention dimension (67.7%), followed by satisfaction (64.5%), confidence (61.3%), and relevance (51.6%). These findings indicate that students' attention, confidence, perceived relevance, and satisfaction in physics learning have not yet developed optimally. Such conditions may reduce students' engagement in the learning process and contribute to their low level of conceptual understanding. Therefore, instructional innovations are needed to create a more engaging learning environment and support the development of students' learning motivation.

To further support these findings, an interview was conducted with a physics teacher at SMAN 13 Padang. The interview revealed that learning activities still relied mainly on printed textbooks and provided limited opportunities for identifying misconceptions, drawing conceptual conclusions, and engaging students actively in the learning process. In addition, the teaching materials lacked visualizations that could support the understanding of abstract physics concepts. As a result, learning tended to be teacher-centered and less effective in providing meaningful learning experiences, which is consistent with the findings of Entino et al. (2022). These conditions highlight the need for more innovative teaching materials to support students' conceptual understanding and motivation.

Based on these issues, teaching materials are needed that not only facilitate misconception remediation but also enhance students' learning motivation. One potential solution is the integration of the Cognitive Conflict-Based Learning (CCBL) model with AR technology. The CCBL model promotes conceptual change through stages of activating students' preconceptions, presenting cognitive conflict, concept discovery, and reflection (Mufit, 2019). Through this process, students are encouraged to evaluate and reconstruct their understanding in accordance with scientific concepts. Previous studies have shown that cognitive conflict-based instruction is effective in reducing misconceptions and improving conceptual understanding (Saomi & Kade, 2021). Therefore, CCBL has considerable potential to support meaningful learning and strengthen students' understanding of physics concepts. This approach is particularly relevant for learning light-wave concepts, where students often hold initial conceptions that differ from scientific explanations. By confronting these misconceptions, students can be guided toward a more accurate scientific understanding.

The implementation of cognitive conflict can be further strengthened through AR, which provides interactive visualizations of abstract concepts and supports knowledge construction. Salsabillah et al. (2025) reported that AR facilitates the visualization of abstract physics concepts and increases students' engagement in learning activities. Likewise, Sidik et al. (2024) found that AR-based learning media can enhance students' learning motivation, while Safitri et al. (2025) demonstrated that AR improves conceptual understanding through visual representations of physical phenomena. Therefore, integrating CCBL and AR into teaching materials has the potential to improve both conceptual understanding and learning motivation in light-wave learning. This integration enables students to directly observe representations of phenomena that are otherwise difficult to visualize in conventional instruction. As a result, students can more easily connect prior knowledge with scientific explanations and develop deeper conceptual understanding.

Numerous studies have demonstrated the effectiveness of cognitive conflict approaches in improving physics learning outcomes. Puspita et al. (2022) reported that a cognitive conflict-based e-book integrated with experimental video analysis improved students' understanding of kinematics concepts. Fitri and Mufit (2022) also found that cognitive conflict-based teaching materials enhanced students' conceptual understanding of momentum and impulse, while Rizkita and Mufit (2022) showed that cognitive conflict contributes to reducing misconceptions through conceptual change. Although the effectiveness of cognitive conflict and AR in physics learning has been widely reported, studies integrating both approaches within teaching materials while examining their effects on conceptual understanding and learning motivation in light-wave learning remain limited. Therefore, this study investigates the effectiveness of cognitive conflict-based teaching materials integrated with AR in improving students' conceptual understanding and learning motivation, particularly in abstract physics topics.

The novelty of this study lies in the integration of cognitive conflict and AR technology within teaching materials for the topic of light waves. These materials are designed to help students identify and overcome misconceptions while providing interactive visualizations that facilitate the understanding of abstract concepts. Through cognitive conflict activities, students are encouraged to evaluate discrepancies between their prior conceptions and scientific explanations, leading to conceptual change and knowledge reconstruction. At the same time, AR supports this process by presenting visual representations of phenomena that are difficult to observe directly, making learning more meaningful and engaging. Furthermore, this study examines the effectiveness of the developed teaching materials in improving both students' conceptual understanding and learning motivation.

Based on the issues described above, this study aims to analyze the effectiveness of cognitive conflict-based teaching materials integrated with AR in improving students conceptual understanding and learning motivation on the topic of light waves. The findings are expected to contribute to the development of instructional materials that support more meaningful physics learning. In addition to minimizing misconceptions, the developed materials are expected to enhance students conceptual understanding. Therefore, the objective of this study is to analyze the impact of cognitive conflict-based teaching materials integrated with AR on students' conceptual understanding and learning motivation in learning light waves.

METHODS

A quantitative quasi-experimental design with a nonequivalent pretest–posttest control group structure was employed in this study. The effectiveness of teaching materials that integrate cognitive conflict with Augmented Reality was examined in relation to students conceptual understanding and learning motivation. The teaching materials had been produced and validated in an earlier development study before being implemented in the present research. The study took place at SMAN 13 Padang in the second semester of the 2025/2026 academic year.

The population of this study consisted of eleventh-grade students in the physics specialization program. The study employed purposive sampling, where the sample was chosen according to particular criteria in accordance with the research purpose (Sugiyono, 2013). Prior to sample selection, normality, homogeneity, and mean equivalence tests were conducted on students initial ability data to ensure that the selected classes had comparable baseline abilities. The results indicated that classes XI F3 and XI F2 possessed equivalent initial abilities. Accordingly, class XI F3 was assigned as the experimental group, which received cognitive conflict-based teaching materials integrated with AR, while class XI F2 served as the control group and was taught using conventional instructional materials. The research design is presented in Table 3.

Table 3. Research Design

Classes	Pretest	Treat	Postest	Motivation Questionnaire
Eksperiment	O_1	X	O_2	M_1
Control	O_3	-	O_4	M_2

Description

O_1 : Experimental class pretest

O_2 : Postest experimental class

O_3 : Control class pretest

O_4 : Postest control class

M_1: Motivation for the experimental class

M_2: Motivation for the control class

X : The use of AR-integrated cognitive conflict-based teaching materials

Two instruments were utilized in this study, namely a conceptual understanding test and a learning motivation questionnaire. Students conceptual understanding was assessed through a four-tier multiple-choice diagnostic test designed to identify different levels of understanding. Learning motivation data were gathered using a questionnaire adapted from Keller's ARCS model. The questionnaire measured four aspects of motivation including attention, relevance, confidence, and satisfaction. These instruments provided the data required to evaluate the effectiveness of the instructional materials.

The collected data were processed using descriptive and inferential statistical techniques. Descriptive analysis was employed to summarize the distribution of the data through the mean, standard deviation, minimum score, and maximum score (Aslam, 2024). Before testing the hypotheses, the data were examined for normality and homogeneity using the Shapiro–Wilk test and homogeneity of variance test, respectively (Ahadi et al., 2023). The choice of statistical test was determined by the distribution of the data. The Independent Samples t-test was used for normally distributed data, whereas the Mann–Whitney U test was applied when the normality assumption was not satisfied (Emerson, 2023). All analyses were conducted using IBM SPSS Statistics version 25.

RESULTS AND DISCUSSION

Results

Analysis Result of Conceptual Understanding

A diagnostic assessment was administered to determine students' levels of conceptual understanding, which were classified into Conceptual Understanding (CU), Not Understanding the Concept (NU), and Misconception (M). The analysis focused on identifying students' conceptual status before the intervention and examining changes in understanding following the implementation of AR-supported cognitive conflict-based teaching materials. This classification enabled a more detailed evaluation of students' conceptual changes throughout the learning process. The pretest results were used to identify students' initial understanding of light-wave concepts and the extent of misconceptions prior to the intervention. The pretest analysis indicated that many students in both groups had not yet achieved adequate conceptual understanding, with a considerable proportion categorized as NU and M. This suggests that students entered the learning process with incomplete or inaccurate conceptions of light-wave concepts. These findings highlight the importance of instructional interventions designed to promote conceptual change and reduce misconceptions. The distribution of students' conceptual understanding before the intervention is presented in Table 4.

Table 4. Percentage of Students Conceptual Understanding in the Pretest

Category	Experiment (%)	Control (%)
Conceptual Understanding (CU)	31.4	27.4
Not Understanding the Concept (NU)	20.5	42.0
Misconception (M)	47.7	26.0

Based on the pretest results presented in Table 4, students in both the experimental and control groups demonstrated low initial understanding of light-wave concepts prior to the learning intervention. The proportion of students categorized as Conceptual Understanding (CU) was only 31.4% in the experimental group and 27.4% in the control group. In the control group, the percentage of students categorized as Not Understanding the Concept (NU) reached 42.0%, indicating difficulties in understanding the material. Overall, these findings suggest that students entered the learning process with weak conceptual foundations and substantial misunderstanding of light-wave concepts. Therefore, instructional intervention was necessary to facilitate conceptual change and improve conceptual understanding.

Following the implementation of the learning intervention, a posttest was conducted to evaluate students' conceptual understanding of light-wave concepts. The posttest results provide information regarding the extent to which students' conceptual status changed after the learning process. Changes in the proportions of Conceptual Understanding (CU), Not Understanding the Concept (NU), and Misconception (M) categories were analyzed to determine the effectiveness of the instructional treatment. The distribution of posttest results for both groups is presented in Table 5.

Table 5. Percentage of Students Conceptual Understanding in Posttest

Category	Eksperiment (%)	Control (%)
Conceptual Understanding (CU)	80.5	48.0
Not Understanding the Concept (NU)	6.3	24.0
Misconception (M)	13.0	26.0

Based on the posttest results presented in Table 5, the experimental group showed a clear improvement in conceptual understanding compared to the control group. The proportion of students classified as Conceptual Understanding (CU) in the experimental class reached 80.5%, which was substantially higher than that of the control class at 48.0%. This result indicates that the instructional materials helped students reconstruct their prior conceptions toward scientifically accepted understanding. In addition, the percentage of students categorized as Not Understanding the Concept (NU) in the experimental group was only 6.3%, considerably lower than the control group at 24.0%. Likewise, the percentage of students experiencing misconceptions (M) in the experimental group decreased to 13.0%, compared with 26.0% in the control group. These differences indicate that the intervention not only improved conceptual understanding but also reduced conceptual uncertainty and misconceptions more effectively than conventional instruction. Furthermore, the use of Augmented Reality visualization helped students grasp abstract concepts of light waves more effectively, leading to stronger conceptual development.

Although the descriptive analysis indicated differences between the experimental and control groups, statistical testing was required to determine whether these differences were significant. A normality test was conducted on the posttest data, and the Shapiro–Wilk test revealed that the data did not satisfy the assumption of normality. As a result, hypothesis testing was performed using the nonparametric Mann–Whitney U test. The results of the Mann–Whitney analysis are presented in Table 6.

Table 6. Postetst CU, NU, and M Postetst U Test Results

No	Aspects	Value		
		CU	NU	M
1	Mann-Whitney U	89.000	152.500	292.500
2	Wilcoxon W	719.000	782.500	922.500
3	Z	-6.229	-5.559	-3.850
4	Sig. Asim. (2-tailed)	0.000	0.000	0.000

The Mann–Whitney U test results presented in Table 6 show that the significance value (Asymp. Sig. 2-tailed) for all categories, namely Conceptual Understanding (CU), Not Understanding the Concept (NU), and Misconception (M), was 0.000. Since all significance values were lower than 0.05, H_0 was rejected and H_1 was accepted. These results indicate statistically significant differences between the experimental and control groups in all three categories. The experimental group demonstrated a higher level of conceptual understanding and lower levels of not understanding and misconceptions than the control group. Therefore, cognitive conflict-based teaching materials integrated with Augmented Reality had a significant effect on students' conceptual understanding of light-wave concepts.

Analysis Results of Student Motivation

Students' learning motivation was measured using an ARCS-based questionnaire covering four motivational dimensions: attention, relevance, confidence, and satisfaction. Motivation was analyzed across these dimensions to provide a comprehensive description of students' motivational development following the learning intervention in both groups. This analysis was conducted to evaluate students' levels of learning motivation after participating in the learning process. The motivational profiles of students in the experimental and control groups are presented in Table 7.

Table 7. Distribution of Student Learning Motivation in Experimental Classes

Criteria	Material Indicators			
	Attention	Relevance	Confidence	Satisfaction
	n (%)	n (%)	n (%)	n (%)
Low	0 (0)	3 (9.7)	0 (0)	3 (9.7)
Medium	8 (25.8)	6 (19.4)	9 (29.0)	4 (12.9)
Height	27 (87.1)	26 (83.9)	26 (83.9)	28 (90.3)

Note. n = number of students; values in parentheses indicate percentages.

Table 7 indicates that most students in the experimental class achieved high motivation scores in all four ARCS components. The high score in the attention dimension indicates that the integration of AR and interactive learning activities effectively captured students' interest throughout the learning process. In terms of relevance, the students were able to relate the concepts learned to the phenomena observed through AR visualizations, making the learning experience more meaningful. This result aligns with Keller's ARCS framework, which identifies attention, relevance, confidence, and satisfaction as essential elements influencing learning motivation (Keller, 2010). Therefore, the integration of cognitive conflict-based teaching materials and AR was able to create a more engaging learning environment and encourage active participation in physics learning.

In contrast to the experimental group, a different pattern was observed in the control group. Students in this group participated in learning activities using conventional teaching materials without the support of cognitive conflict-based instruction and Augmented Reality. As a result, the level of learning motivation demonstrated by the students tended to vary across the ARCS dimensions. The distribution of students learning motivation in the control class is presented in Table 8.

Table 8. Distribution of Student Learning Motivation Control Class

Criteria	Material Indicators			
	Attention	Relevance	Confidence	Satisfaction
	n (%)	n (%)	n (%)	n (%)
Low	10 (32.3)	8 (25.8)	9 (29.0)	8 (25.8)
Medium	22 (71.0)	19 (61.3)	21 (67.7)	18 (58.1)
Height	3 (9.7)	8 (25.8)	5 (16.1)	9 (29.0)

Note. n = number of students; values in parentheses indicate percentages.

As presented in Table 8, learning motivation in the control group was predominantly categorized as moderate across all ARCS dimensions. This finding suggests that instruction relying primarily on printed textbooks did not provide sufficient learning experiences to optimally enhance student attention, confidence, and satisfaction. A relatively small proportion of students demonstrated high attention and confidence, suggesting that learning activities did not fully promote active engagement, causing students to assume a more passive role throughout the instructional process. Consequently, student engagement in classroom activities was lower than that observed in the experimental group, which utilized cognitive conflict-based teaching materials integrated with AR.

To determine whether differences in learning motivation existed between the experimental and control groups, statistical analysis was conducted on the total motivation scores. Prior to hypothesis testing, the data were subjected to a normality test using the Shapiro–Wilk procedure. The results indicated that the motivation data did not meet the assumption of normality, as the significance value for the experimental group was 0.002 (< 0.05), whereas the significance value for the control group was 0.455 (> 0.05). Therefore, the analysis proceeded using the non-parametric Mann–Whitney U test. The results of the Mann–Whitney analysis are presented in Table 9.

Table 9. Student Motivation U-Test Results

No	Aspects	Value
1	Mann-Whitney U	152.500
2	Wilcoxon W	782.500
3	Z	-5.404
4	Asymp.Sig. (2-tailed)	0.000

As presented in Table 9, the Mann–Whitney U test yielded an Asymp. Sig. (2-tailed) value of 0.000, indicating a significant difference in learning motivation between the experimental and control groups. This result demonstrates that the use of augmented reality-supported cognitive conflict teaching materials positively influenced students' learning motivation. Students in the experimental group showed higher levels of motivation, suggesting that the teaching materials were effective in promoting active engagement and interest in the learning process. Therefore, cognitive conflict-based teaching materials integrated with AR have the potential to enhance students' learning motivation in physics learning. This significant difference suggests that the intervention created a more engaging and supportive learning environment compared to conventional instruction. The combination of interactive visualization and cognitive conflict encouraged students to participate more actively and remain focused during the learning process.

Discussion

The findings of this study indicate that cognitive conflict-based teaching materials integrated with AR had a positive effect on students' conceptual understanding of light-wave concepts. This was evidenced by the increase in students categorized as Conceptual Understanding (CU) and the decrease in misconceptions in the experimental group compared with the control group. These results suggest that the teaching materials facilitated conceptual change by encouraging students to evaluate and reconstruct their prior conceptions through the cognitive conflict phase of CCBL (Mufit et al., 2023). The findings are consistent with Mufit et al. (2020), who reported that cognitive conflict positively influences conceptual understanding and reduces misconceptions in physics learning. Similar results were reported by Makhrus and Busyairi (2022), who found that cognitive conflict-based instruction helps students develop more accurate scientific understanding. This improvement may occur because cognitive conflict encourages students to recognize inconsistencies between their initial conceptions and scientific explanations, leading them to construct more scientifically accurate concepts.

The enhancement of students' conceptual understanding in the experimental class can be attributed to the incorporation of AR features into the teaching materials. Through interactive visualizations, AR helped students understand abstract physical phenomena more concretely, facilitating scientific concept construction. According to Atiqah and Mufit (2024), this function of AR is particularly relevant during the concept discovery phase of the CCBL model. The present findings are consistent with Devana et al. (2025), who reported that integrating AR into cognitive conflict-based teaching materials improves students' understanding of abstract physics concepts. Similarly, Sianipar et al. (2025) concluded that AR enhances conceptual understanding and learning engagement through more interactive learning experiences. In light-wave learning, AR helped students connect theoretical concepts with observable representations and apply them in solving conceptual problems.

The results of the statistical test indicated significant differences in conceptual understanding between the experimental and control groups. This finding shows that cognitive conflict-based teaching materials integrated with AR had a significant impact on students' conceptual understanding. The combination of cognitive conflict and AR created a learning environment that supported conceptual change more effectively than conventional teaching materials. These findings are consistent with Fitri and Mufit (2022), who found that cognitive conflict-based teaching materials improve students' mastery of physics concepts. Similar results were reported by Puspita et al. (2022), who concluded that such materials enhance conceptual understanding by creating discrepancies between students' prior conceptions and scientific explanations. This suggests that integrating cognitive conflict with AR is an effective strategy for improving students' understanding of abstract physics concepts. It also indicates that the intervention helped students reconstruct their understanding toward scientifically accurate concepts.

In addition to improving conceptual understanding, the implementation of cognitive conflict-based teaching materials integrated with AR also had a positive effect on learning motivation. The motivation data showed that most students in the experimental group demonstrated high motivation across all ARCS components, whereas students in the control group were predominantly categorized as having moderate motivation. These findings indicate that AR functioned not only as a visualization tool but also as a medium capable of increasing students' attention and interest in learning (Amores et al., 2023). Through more interactive and meaningful learning experiences, students became more confident in understanding the material and more satisfied with the learning process. This suggests that the integration of AR and cognitive conflict successfully supported the four dimensions of the ARCS model, particularly attention and confidence. As students became more actively involved in the learning process, their motivation to engage with physics concepts also increased. Higher motivation also encouraged students to participate more actively in discussions, ask questions, and explore concepts more deeply during classroom activities. This increased engagement may also help students maintain learning persistence when facing challenging physics concepts. Consequently, students became more willing to invest effort in understanding complex material.

These findings are supported by Putri et al. (2025), who reported that cognitive conflict-based teaching materials integrated with AR enhance learning motivation by providing more interactive and engaging learning experiences. Similar results were reported by Mufit et al. (2025), who found that cognitive conflict-based learning integrated with AR improves learning motivation and student engagement throughout the learning process. Furthermore, Azlin et al. (2021) demonstrated that AR-based instructional materials significantly improve learning motivation across the four ARCS dimensions: attention, relevance, confidence, and satisfaction. Through interactive visualizations and meaningful learning experiences, the integration of AR and cognitive conflict can increase students' interest, confidence, and active participation in physics learning.

A distinctive contribution of this study lies in the integration of augmented reality and cognitive conflict-based teaching materials to support the learning of light-wave concepts. Most previous studies have focused primarily on either conceptual understanding or learning motivation separately. In contrast, the present study demonstrates that the integration of cognitive conflict and AR can simultaneously improve both conceptual understanding and learning motivation. Through interactive visualizations, AR helps students understand abstract light-wave phenomena, while cognitive conflict encourages the reconstruction of scientifically accurate conceptions. These findings suggest that cognitive conflict-based teaching materials integrated with AR represent an effective alternative for addressing misconceptions and enhancing motivation in learning abstract physics concepts. Furthermore, this approach has the potential to be applied to other physics topics that involve abstract concepts and high levels of misconceptions. Therefore, the integration of cognitive conflict and AR may serve as a promising innovation for improving the quality of physics instruction in broader educational contexts.

CONCLUSION

The findings of this study demonstrate that instructional materials supported by AR and developed within a cognitive conflict framework effectively enhance students' conceptual understanding and learning motivation on light-wave concepts. The implementation of these teaching materials enabled students to reconstruct inaccurate prior conceptions, leading to an increase in the proportion of students who correctly understood the concepts and a reduction in misconceptions. The interactive visualizations provided through AR also facilitated the comprehension of abstract concepts, making the learning process more meaningful. The results revealed improvements in students' learning motivation across all ARCS dimensions, namely attention, relevance, confidence, and satisfaction. The integration of cognitive conflict and interactive visualizations created a more engaging, challenging, and learning environment centered on students that encouraged active participation throughout the learning process. Therefore, teaching materials based on cognitive conflict and integrated with AR can be considered an innovative and effective alternative for physics instruction, particularly in addressing misconceptions, strengthening conceptual understanding, and enhancing students' learning motivation on abstract topics such as light waves.

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