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Need Analysis for the Design of an Online Module Based on Cognitive Conflict and the Deep Learning Approach to Correct Students' Misconceptions About Light Waves

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Abstract. Students' conceptual understanding of light waves remains relatively low, while the instructional materials currently in use have not been able to optimally facilitate the remediation of misconceptions. This study aims to analyze the need to develop a cognitive conflict-based e-module integrated with the deep learning approach—an approach that emphasizes meaningful, reflective, and enjoyable conceptual understanding through the components of meaningful learning, mindful learning, and joyful learning. The integration of cognitive conflict with the deep learning approach in the topic of light waves represents a novelty in this research, given that previous studies generally focused only on one of these approaches or combined cognitive conflict with Augmented Reality technology. This study is a preliminary investigation within Plomp's preliminary research model for instructional design, with data collected through interviews with 2 physics teachers and 3 students, as well as a four-tier multiple-choice diagnostic test administered to 31 twelfth-grade students in Phase F at MAN 3 in Padang. The analysis results indicate that 69.7% of students held misconceptions, while the instructional materials used were still dominated by printed textbooks and worksheets and did not support concept visualization or the remediation of misconceptions. These findings underscore the need to develop e-modules based on cognitive conflict and a deep learning approach that align with the needs of teachers and students, while also contributing to the development of digital physics instructional materials capable of visualizing abstract concepts and supporting the remediation of misconceptions more effectively.

Kata Kunci: E-module, Cognitive Conflict, Deep Learning, Misconception, Light Waves.

1. Introduction

Physics education in the 21st century is no longer sufficient if it is directed solely at mastering formulas and solving problems; rather, it must build students' ability to understand concepts, reason about phenomena, and apply knowledge appropriately in various situations. This direction aligns with the implementation of the Merdeka Curriculum, which emphasizes flexible, adaptive, and student-centered learning (Khoirurrijal et al., 2022). Therefore, physics instruction must be designed so that students not only receive information but also actively construct understanding through observation, exploration, and scientific reasoning.

Conceptual understanding is a fundamental aspect of physics learning because it relates to students' ability to grasp the meaning of a concept, rephrase it in their own words, and connect that concept to other relevant concepts (Hanna, 2016). However, the abstract nature of many concepts in physics often causes students to struggle in developing an understanding that aligns with scientific concepts. Initial understandings formed based on experience or intuition may differ from actual scientific concepts, leading to misconceptions (Zulaika et al., 2022). Persistent misconceptions can hinder the process of forming new knowledge because students rely on these initial concepts when interpreting subsequent phenomena.

One of the most complex topics in physics is light waves. This topic covers the concepts of interference, diffraction, polarization, and the electromagnetic spectrum, which require students to be able to connect various representations such as verbal, visual, mathematical, and physical. Because light wave phenomena cannot always be observed directly, students often struggle to connect theoretical models with real-world phenomena. Difficulty in connecting various conceptual representations can lead students to develop a partial understanding because they are not yet able to integrate physical phenomena with the scientific models used to explain these concepts (Setiaji & Ermawati, 2022). Therefore, learning strategies are needed that can help students establish connections between phenomena, representations, and scientific concepts.

The issue of conceptual understanding in light wave material is also related to the limitations of the instructional materials used in learning. Textbooks and student worksheets remain the most used learning resources, but their presentation tends to be dominated by text and mathematical equations, making them less than optimal for visualizing abstract concepts. Furthermore, the available instructional materials do not fully provide students with opportunities to express their prior conceptions, evaluate their understanding, and correct misconceptions that do not align with scientific concepts. These conditions indicate a need for instructional materials that not only convey information but also support students' conceptual change processes.

One type of instructional material that can be developed to meet these needs is an e-module. An e-module is a systematically organized electronic instructional material that can integrate various multimedia components such as text, images, animations, videos, exercises, and interactive navigation (Seruni et al., 2019). The use of e-modules provides learning flexibility because students can study the material according to their needs and learning pace. They contain useful guidelines for independent and individual learning (Chandra et al., 2025). In addition, the exercises and assessments available in e-modules can help students independently check their understanding (Herawati & Muhtadi, 2018). . However, the use of e-modules does not automatically resolve misconceptions if the learning activities within them are not designed to support the process of conceptual change.

The cognitive conflict model guides students to confront situations or phenomena that do not align with their initial conceptions, thereby encouraging them to recognize discrepancies in their understanding and engage in the process of conceptual change through the formation of concepts that are more consistent with scientific concepts. The stages of cognitive conflict—which include the activation of preconceptions and misconceptions, the presentation of cognitive conflict, concept discovery, and reflection—provide students with the opportunity to recognize the inconsistencies in their initial understanding and construct concepts that are more in line with scientific concepts (Mufit & Fauzan, 2019).

Previous research indicates that cognitive conflict contributes to supporting conceptual change in physics learning. The application of the cognitive conflict model in physics learning shows that presenting a conflict between initial conceptions and scientific concepts can help students recognize discrepancies in their understanding and promote the process of conceptual change (Fadllan, 2011). The development of experiment-based cognitive conflict strategies indicates that the process of comparing initial predictions with observational results can strengthen the evaluation of students' understanding (Pulu & Widia, 2022). Furthermore, research on the topics of work and energy, as well as studies on conceptual change using the cognitive conflict approach, suggest that this approach has the potential to support the remediation of physics misconceptions.

Nevertheless, previous research still has limitations. Most studies have focused more on how cognitive conflict can raise students' awareness of inconsistencies in their initial concepts, while the processes following the conflict have not been extensively explored. Subsequent stages such as linking new concepts to prior knowledge, reflecting on changes in understanding, and reinforcing concepts so they can be applied in different contexts remain aspects that require attention. Furthermore, previous applications of the cognitive conflict approach have primarily focused on topics such as mechanics, static fluids, and work and energy, whereas the topic of light waves has distinct characteristics because it requires the integration of various more complex scientific representations.

The development of cognitive conflict through technology and digital instructional materials offers opportunities to strengthen the learning process. The integration of Augmented Reality into cognitive conflict-based learning provides visualization support for abstract physics concepts, thereby helping students understand the relationship between visual representations and scientific concepts (Atiqah & Mufit, 2024). The development of cognitive conflict-based e-modules offers an alternative form of digital instructional material that integrates the stages of conceptual change into learning activities (Pratama et al., 2021). Meanwhile, the VAK-based approach to presenting material offers varied learning experiences in understanding sound and light waves (Permatasari et al., 2022). However, this approach still focuses primarily on visualization, material presentation, and the creation of conflicts, while the process of reinforcing understanding after a conflict through concept linking and reflection still has room for development.

The deep learning approach is relevant for addressing these limitations. The deep learning approach positions the learning process as an activity of comprehending concepts holistically, rather than merely memorizing information (Hidayah & Hulyana, 2025). This approach encompasses meaningful learning, mindful learning, and joyful learning, which help students connect new knowledge with prior experiences, become aware of their thought processes, and build meaningful learning experiences (Feriyanto & Anjariyah, 2024). In the context of misconceptions remediation, the deep learning approach can reinforce cognitive conflict because conflict serves as a trigger for conceptual change, while the deep learning approach supports the processes of meaning-making, reflection, and conceptual consolidation after the change occurs.

The relationship between cognitive conflict and the deep learning approach can be explained through the theory of conceptual change proposed by Posner et al. (1982). This theory explains that conceptual change occurs through the processes of assimilation and accommodation. Cognitive conflict plays a role in generating dissatisfaction with initial conceptions, while the deep learning approach supports the process by which new concepts can be understood (intelligible), accepted (plausible), and applied in broader contexts (fruitful). Thus, the integration of cognitive conflict and the deep learning approach has a complementary theoretical foundation in supporting students' conceptual change processes.

Based on the above discussion, the novelty of this study lies in the analysis of the need to develop e-modules that integrate the cognitive conflict model and the deep learning approach to the topic of light waves. Unlike previous studies, which have largely emphasized cognitive conflict as a trigger for conceptual change through experiments, technology, or digital instructional materials, this study positions the deep learning approach as a means of reinforcing the process after conflict occurs through concept-linking activities, reflection, and deepening understanding. The needs analysis was conducted to obtain an overview of the condition of instructional materials, the needs of teachers and students, the use of technology, and the characteristics of the required learning activities. Based on this description, this study aims to analyze the needs for developing e-modules based on cognitive conflict and the deep learning approach to remediate students' misconceptions regarding light waves.

2. Method

This study is a preliminary research project within the framework of development research using the Plomp model. The Plomp development model consists of three main stages: preliminary research, the development or prototyping phase, and the assessment phase. The preliminary research stage is the initial stage aimed at conducting a needs analysis, identifying problems, and gathering information before the product design process begins (Akker et al., 2013). In this study, the preliminary research stage was conducted to analyze the design needs for an e-module based on cognitive conflict and a deep learning approach to remediate students' misconceptions regarding light waves.

The study was conducted at MAN 3 Padang, with research subjects selected using purposive sampling based on the relevance of the information required for the needs analysis phase. The research subjects consisted of 2 physics teachers and 3 twelfth-grade students from Class F as interview informants, as well as 31 twelfth-grade students from Class F as respondents for the diagnostic test on conceptual understanding of light waves. The teachers and students involved in the interviews were selected because they had direct experience with the learning process for light waves, while the 31 students were used to obtain an overview of the categories of students' conceptual understanding and misconceptions before the e-module was developed.

The research instruments consisted of an interview guide and a diagnostic test of conceptual understanding. The interview guide was developed based on needs analysis indicators, which included the conditions of physics learning, students' difficulties in understanding light wave material, the use of teaching materials, teachers' efforts to address misconceptions, and the need for e-modules based on cognitive conflict and a deep learning approach. The interview guide was developed through the following stages: determining the aspects to be analyzed, formulating question indicators, and developing questions in accordance with the research objectives. The interview guide was tested through content validation to ensure the appropriateness of the indicators, the relevance of the questions to the research aspects, and the clarity of the instrument's language before it was used in data collection.

The diagnostic test instrument used a four-tier multiple-choice diagnostic test format consisting of four levels: answer choices, level of confidence in the answer, reason choices, and level of confidence in the reason. This instrument was used to identify categories of students' conceptual understanding—namely, understanding the concept, not understanding the concept, and misconceptions—regarding light wave material. The use of a tiered diagnostic test allows for a more comprehensive identification of students' understanding because it considers the accuracy of answers, the reasons provided, and the students' level of confidence in their answers (Caleon & Subramaniam, 2010).

Before being used in the main study, the diagnostic test instrument was pilot-tested at another school with similar learning characteristics. The instrument was evaluated for item validity, reliability, difficulty level, and discriminative power. The validity of the instrument was analyzed using Pearson's product-moment correlation, while its reliability was analyzed using Cronbach's alpha. The reliability test results showed a Cronbach's alpha value of 0.820 for the 20 test items, indicating that the instrument has a good level of consistency and meets the reliability criteria for research instruments.

Research data were collected through interviews and diagnostic tests of conceptual understanding. The interview data were used to obtain qualitative information regarding learning conditions, the use of instructional materials, students' difficulties in understanding the concept of light waves, teachers' strategies for addressing misconceptions, and the need for an e-module design based on cognitive conflict and the deep learning approach. Data from the diagnostic tests were used to obtain quantitative information regarding the categories of students' conceptual understanding of light wave material.

Data analysis was conducted using quantitative and qualitative descriptive analysis. The diagnostic test results were analyzed quantitatively by calculating the percentage of each category of student conceptual understanding using the following equation:

$$P = \frac{f}{N} \times 100\%$$

Explanation :
P = Percentage of Conceptual Understanding Category
f = Number of responses in a specific category
N = Total Number of Student Responses

The results of the percentage analysis were used to describe the distribution of students' conceptual understanding categories based on the diagnostic test results. Interview data were analyzed qualitatively through the stages of data reduction, grouping data by theme, data presentation, and drawing conclusions (Miles et al., 2023). The themes of the analysis included learning conditions, the use of teaching materials, students' difficulties in understanding light wave material, teachers' strategies for addressing misconceptions, and the need for e-module designs based on cognitive conflict and deep learning approaches.

3. Results and Discussion

The results of the needs analysis indicate that the main problems in learning about light waves are related to high levels of student misconceptions and the limitations of the instructional materials used to support the process of conceptual change. Research data were obtained through a four-tier multiple-choice diagnostic test and interviews with teachers and students to gain an understanding of the level of conceptual understanding, learning problems and the need for e-module designs based on cognitive conflict and a deep learning approach.

The results of the diagnostic test administered to 31 twelfth-grade students in Phase F at MAN 3 Padang show the categories of students' conceptual understanding as presented in Table 1.

Table 1. Percentage of Students' Conceptual Understanding of Light Waves

Understanding Category	Percentage (%)
Understands the concept	18,1
Does not understand the concept	12,3
Misconceptions	69,7

Based on Table 1, the “misconception” category had the highest percentage at 69.7%, while students in the “understands the concept” category accounted for only 18.1%. These findings indicate that most students already have prior conceptions regarding light waves, but some of the understandings they have formed do not align with scientific concepts. This situation suggests that learning challenges are not only related to the mastery of information but also to the existence of prior conceptions that have been formed and are still held by students.

The high prevalence of misconceptions regarding light waves is related to the abstract nature of the concept and the need to connect various forms of representation, such as physical phenomena, images, graphs, and mathematical models. Students tend to build their understanding based on everyday experiences, resulting in interpretations that seem logical but do not always align with scientific concepts. Chantaranima & Yuenyong (2014) xplain that students have prior conceptions about light formed through everyday experiences, so some of these understandings may differ from scientific explanations.

These findings are also consistent with the research by Setiaji & Ermawati (2022) which shows that the concept of light waves is one of the physics topics that students find difficult to understand because it involves abstract phenomena and complex relationships between conceptual representations. In this study, the analysis was expanded by identifying concept indicators associated with misconceptions, thereby providing an empirical basis for determining instructional material design needs.

The analysis of misconceptions based on light wave concept indicators is presented in Table 2.

Table 2. Percentage of Misconceptions Based on Light Wave Concept Indicators

Concept Indicator	Percentage of Misconceptions (%)
Electromagnetic spectrum	67,7
Light Dispersion	67,7
Light diffraction	35,5
Light interference	67,7
Refraction of light	61,3
Relationship between the angle of	93,5
Reflection of light	64,5
Rayleigh Scattering	93,5
Polarization of Light	87,1
Applications of Light Polarization	58,1

Based on Table 2, the highest rate of misconceptions was found in the concepts of the relationship between the angle of incidence and the angle of refraction, as well as Rayleigh scattering, with respective percentages of 93.5%. In addition, the concept of light polarization also showed a high rate of misconceptions, at 87.1%. These results indicate that students have difficulty understanding concepts that require a connection between observed phenomena and the underlying physical mechanisms.

Regarding the concept of refraction, students still struggle to understand the relationship between a change in medium and a change in the direction of light propagation. Meanwhile, regarding the concept of Rayleigh scattering, students have difficulty connecting the phenomenon of light color to differences in wavelength. These conditions indicate that instruction that focuses solely on conveying concepts and mathematical exercises is insufficient for building a comprehensive conceptual understanding.

The findings from the diagnostic test were reinforced by interviews with physics teachers. The teachers explained that students' difficulties primarily arise with concepts that cannot be directly observed. One teacher stated: "Students still frequently make conceptual errors regarding light, especially when explaining the reasons behind refraction and reflection. "They know the formulas, but they still struggle to understand the concepts." (Teacher 1). This statement indicates that some students still understand the material procedurally without grasping the underlying conceptual relationships behind physical phenomena. This situation is one of the factors contributing to misconceptions, as students tend to memorize problem-solving procedures without reconstructing their understanding.

In addition to conceptual understanding, the interview results show that the instructional materials used do not yet fully support the learning needs regarding light waves. Teachers reported that instruction still relies primarily on textbooks and worksheets as the main resources. One teacher stated: "The instructional materials used are still textbooks and worksheets. E-modules specifically addressing light waves and helping students correct misconceptions are not yet available." (Teacher 2). This situation indicates that the need for e-module development is not only related to the provision of digital instructional materials but also to the need for learning activities that can help students identify and correct inappropriate prior conceptions.

Interview results with students indicate that students need teaching materials that are flexible and can be used independently. One student stated: "Using digital teaching materials is easier because I can open them again on my phone whenever I want to review the material." (Student 1). These findings suggest that e-modules need to be designed with consideration for ease of access, conceptual visualization, and support for independent learning.

Based on the results of the diagnostic test and interviews, the e-module design requirements are summarized in Table 3.

Table 3. E-Module Design Requirements Based on Needs Analysis Results

Findings of the Needs Analysis	Implications for E-Module Design
High incidence of student misconceptions regarding light wave material	Activities to reveal initial conceptions and cognitive conflicts
The concept of light waves is abstract	Visualization through images, animations, videos, and simulations
Instructional materials are still dominated by printed books and worksheets	Flexible and easily accessible digital teaching materials
Students still rely on the teacher's explanations	Guidelines for independent learning, summaries, and assessments
No activities to address misconceptions are available	Prediction, concept testing, reconstruction, and reflection activities

Based on Table 3, the need for e-module development is not only directed toward changing the format of instructional materials from print to digital but also toward designing activities that support students' conceptual change. Based on the results of this needs analysis, the e-modules to be developed need to have several key features, namely phenomenon-based orientation activities to identify students' prior conceptions, the presentation of cognitive conflicts through phenomena that contradict their initial understanding, the presentation of concepts through various multimedia representations, comprehension assessment exercises, and reflection activities to help students become aware of the conceptual changes taking place.

These needs support the use of cognitive conflict as the basis for e-module design. Mufit et al (2020) explain that cognitive conflict can facilitate conceptual change by exposing students to the inconsistencies between their prior conceptions and scientific concepts. These findings align with the research by Parwati et al (2019) which shows that the cognitive conflict approach in the conceptual change model can help reduce students' misconceptions through the process of reconstructing understanding from initial conceptions toward scientific concepts. Therefore, the cognitive conflict approach is relevant for addressing the misconception issues identified during the needs analysis phase.

Furthermore, the deep learning approach reinforces the process following the resolution of cognitive conflict through activities that support meaningful learning, mindful learning, and joyful learning. The integration of these two approaches forms the basis for determining the characteristics of the e-module, which not only presents content but also supports students' processes of meaning-making, reflection, and reconstruction of understanding.

Overall, the results of the needs analysis indicate that the development of e-modules based on the cognitive conflict approach and the deep learning approach is necessary, given the high prevalence of student misconceptions across various indicators of the concept of light waves, as well as the limitations of existing instructional materials in supporting the process of conceptual change. The results of this study serve as the basis for determining the characteristics, activity structure, and features of the e-modules to be developed in the next phase of the research.

4. Conclusion

Based on the results of the needs analysis in the preliminary research phase, it can be concluded that students' conceptual understanding of light wave material is still dominated by misconceptions, with a percentage of 69.7%. This issue is related to the abstract nature of the light wave material and the limitations of the instructional materials used to support students' conceptual change process, particularly regarding the provision of for concept visualization, the identification of initial conceptions, and learning activities that help correct understandings inconsistent with scientific concepts. The results of the needs analysis provide an empirical basis for designing an e-module based on cognitive conflict and a deep learning approach as instructional material aimed at supporting the remediation of students' misconceptions regarding light wave concepts. The scientific contribution of this study lies in the formulation of e-module design characteristics that integrate cognitive conflict as a strategy to raise awareness of the discrepancy between initial concepts and scientific concepts, as well as the deep learning approach to reinforce the processes of meaning-making, reflection, and reconstruction of students' understanding. Practically, the results of this study have implications for physics teachers and instructional material developers, indicating that the development of e-modules must address students' needs for more visual concept presentation, learning activities that support active engagement, and learning stages that help students identify and correct misconceptions. The results of this needs analysis can serve as a foundation for the development and testing phases of e-module products based on cognitive conflict and the deep learning approach in future research.

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