




Needs Analysis in Developing a Multiple Representation Inquiry-Based Learning Module for Promoting Conceptual Change in Basic Physics

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ABSTRACT

Understanding waves and optics remains a major challenge for undergraduate physics students, leading to persistent misconceptions and weak representational skills. This study conducted a needs analysis to guide the design of a multiple representation inquiry-based learning module aimed at improving conceptual understanding and supporting conceptual change. Using a descriptive quantitative design based on the Analyze stage of the ADDIE model, data were collected through a validated Google Forms questionnaire from 31 Physics Education undergraduates at Universitas Islam Negeri Mahmud Yunus Batusangkar. Findings show that over 70 % of students struggle to master waves and optics, and more than 80 % have difficulty interpreting mathematical representations and graphs. Students strongly prefer visual and contextual learning resources such as images, videos, simulations, and real-life examples over traditional text-based instruction. Learning videos and interactive modules were the most preferred materials, and students requested real-world examples, explanatory videos, and problem-solving tutorials. Although investigative activities received lower priority, structured scaffolding can help sustain engagement in inquiry-based tasks. These results highlight the urgent need for an innovative learning module that integrates visual, mathematical, and contextual representations within an inquiry framework to reduce misconceptions and foster deeper conceptual understanding in undergraduate physics education.

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1. Introduction

Physics, as a natural science, plays a crucial role in developing students' scientific reasoning and critical thinking. However, many students still face difficulties in understanding abstract physics concepts such as waves, sound, light, and optics (Ate et al., 2025; Wahyuni & Taqwa, 2022). These difficulties often stem from pre-existing misconceptions or alternative conceptions, either through everyday experiences or inadequate formal learning (Widiastuti & Purwanto, 2019). Previous research has revealed that misconceptions in physics learning, particularly regarding the topics of waves and sound, are still very common across various levels of education. Studies at the high school and college levels indicate that students frequently misunderstand the relationship between frequency, amplitude, and wave velocity (Goodhew et al., 2019). Furthermore, students also experience difficulties in explaining wave propagation phenomena, formulating general equations, and describing the general properties of waves (Haliza & Hadi, 2022; Yana et al., 2020). These misconceptions negatively impact students' ability to understand advanced concepts in physics (Marisda et al., 2024).

Despite the literature's widespread emphasis on misconceptions, this study does not directly diagnose students' misconceptions. Rather, the discussion of misconceptions serves as a theoretical justification for the urgent need for innovative learning materials, particularly in the topics of waves and optics. The needs analysis undertaken in this study is focused on identifying students' preferences regarding content formats, learning styles, and the types of multiple representation supports they require. In this way, the study remains relevant to the issue of misconceptions, as the findings of the needs analysis can provide a solid foundation for designing new learning modules that are more responsive to students' needs and hold the potential to help reduce misconceptions previously reported in the literature.

Various learning approaches have been developed to address misconceptions. One such approach is inquiry-based learning, which has proven effective in improving students' conceptual understanding by providing opportunities for active engagement through independent exploration, investigation, and knowledge construction (Gillies, 2020; Thacker, 2023). Longitudinal research in Malaysia also indicates that innovative inquiry-based pedagogical strategies can drive educational transformation and significantly increase student engagement (Wong, 2024). Similarly, other experimental studies have reported that students learning using inquiry methods demonstrated greater improvements in conceptual understanding compared to those using conventional methods (Ceháková & Kopriva, 2025).

In addition to inquiry, the use of multiple representations has also been identified as an effective approach to improving students' understanding of abstract physics concepts. Multiple representations, including visual, mathematical, graphical, computer simulation, and verbal representations, have been shown to help students build a holistic and integrative understanding of physics (Hahn & Klein, 2025; Najib et al., 2020). Multiple representation inquiry learning is grounded in Vygotsky's theory of social constructivism, which emphasizes that understanding is built through social interaction, the zone of proximal development (ZPD), cognitive apprenticeship, and scaffolding (Moreno et al., 2022; Slavin, 2018).

However, the effective use of multiple representations in learning still faces challenges, particularly regarding how students and lecturers integrate these various representations coherently (Ate et al., 2025). This obstacle is further exacerbated by the fact that most available physics teaching materials are still textual and mathematical, thus providing limited opportunities for students to actively interact with various forms of conceptual representation (Marisda et al., 2024; Rahmawati et al., 2022). This condition results in the low effectiveness of the physics learning process in facilitating student conceptual change.

Conceptual change itself is understood as the process by which someone changes or expands their understanding of a topic until it becomes scientifically sound (Disessa & Sherin, 1998). Posner et al. (1982) emphasized that conceptual change in learning can occur if four conditions are met: (1) students are dissatisfied with their existing concepts, (2) the new concept is understandable, (3) the new concept seems plausible, and (4) the new concept demonstrates its

usefulness. Thus, alternative strategies or teaching materials are needed that are able to facilitate the process of changing this concept

Needs analysis is a crucial stage in developing multiple representation-based inquiry learning modules. This analysis ensures that the developed modules truly align with students' learning styles and needs (Branch, 2010a). Previous research has shown that college students tend to have a predominantly visual learning style. As many as 95% of students prefer the use of visual representations such as images, graphs, and computer simulations in physics learning (Marisda et al., 2024). Furthermore, students also require flexibility in accessing learning materials through digital devices such as smartphones and personal computers (Rahmawati et al., 2022). However, very few inquiry-based physics modules explicitly integrate multiple representations to help reduce misconceptions and support conceptual change. This gap opens up opportunities for further research in developing learning modules that meet the needs of modern students (Hahn & Klein, 2025).

This research provides a novel contribution by integrating inquiry, multiple representations, and conceptual transformation approaches in the development of a physics learning module. The needs analysis demonstrates the importance of visual, contextual, and interactive representations as a basis for building a stronger conceptual framework. These findings provide practical guidance for module development and enrich the literature with new perspectives on transforming students' conceptual understanding at the university level.

1.1. Research Objectives

This research aims to:

- i. Analyze student needs in basic physics learning, specifically on the topics of waves and optics.
- ii. Design a foundation for developing a multiple representation, inquiry-based physics learning module that can facilitate student conceptual change.

1.2. Research Significance

This research has both theoretical and practical significance. Theoretically, this research enriches the literature by integrating conceptual change theory, the inquiry approach, and multiple representations within the context of developing physics teaching materials. Practically, this research makes a significant contribution to providing physics learning modules that meet the needs of today's students, who tend to be visual and digital. This module is expected to help students overcome misconceptions, improve conceptual understanding, and build a stronger scientific framework.

2. Literature Review

2.1. Inquiry-Based Learning in Physics Education

Inquiry-based learning (IBL) has long been recognized as an effective approach in improving students' conceptual understanding in science, particularly physics (Bostan Sarioglan & Gedik, 2020). Unlike traditional lecture methods, the inquiry approach emphasizes active student involvement in formulating questions, designing experiments, analyzing data, and drawing conclusions based on evidence. Various studies have shown that inquiry-based learning not only supports the acquisition of conceptual knowledge but also encourages the development of scientific reasoning and higher-order thinking skills (Charles et al., 2022). In basic physics, inquiry has proven effective for challenging topics such as mechanics, waves and optics, where misconceptions often persist despite conventional instruction (Planinic et al., 2024).

2.2. The Role of Multiple Representations in Conceptual Learning

The use of multiple representations—whether verbal, mathematical, graphic, or visual—is a crucial component in facilitating the understanding of abstract physics concepts (Ainsworth, 1999; Treagust & Duit, 2017).

Representational competence enables students to translate, connect, and integrate knowledge across representations, thereby strengthening understanding while reducing misconceptions (Malone et al., 2023). In fundamental physics topics such as oscillations, waves, and optics, the ability to flexibly switch between equations, graphs, and physical demonstrations is crucial (Meter et al., 2020). Recent studies emphasize that the synergy between multiple representations and inquiry-based learning enables students to use various forms of reasoning to design and test hypotheses (Andersson & Jääskeläinen, 2024).

2.3. Conceptual Change as the Primary Goal of Physics Education

Physics education researchers emphasize that meaningful learning can only occur through a process of conceptual change, namely when students' alternative conceptions are replaced or restructured into accepted scientific models (Posner et al., 1982; Vosniadou, 2012). Traditional instruction often fails to address misconceptions because students may simply memorize formulas without changing erroneous mental models (Paivio, 1990). Inquiry-based learning environments, especially when combined with multiple representations, are considered powerful catalysts for conceptual change because they encourage cognitive conflict, provide plausible explanations, and offer a useful context for applying new knowledge (Rachmawati & Supardi, 2021). Empirical research shows that interventions combining guided inquiry with representational scaffolding can significantly reduce misconceptions, particularly in the topics of waves and optics (Auliyani et al., 2023; Espinoza, 2020).

2.4. Needs Analysis in Learning Module Development

Learning module development requires a systematic needs analysis to ensure that the designed tools truly address student learning difficulties and instructional gaps (Branch, 2010a). In physics education, needs analysis typically includes diagnosing students' prior knowledge, identifying common misconceptions, and mapping the competencies required by the curriculum (Fraenkel et al., 2019). Studies on waves and optics show that many first-year students still equate frequency with speed, assume that sound travels faster in air than in solids, or misunderstand the factors that influence the period of oscillation (Periago et al., 2009). Therefore, a robust needs analysis is a crucial first step in designing modules that address these conceptual difficulties through inquiry activities supported by multiple representations.

Recent studies have underscored the pivotal role of needs analysis as an evidence-based foundation for developing physics learning modules. Syafitri & Syafriani (2023) reported that students' reading interest was categorized as low (65.14%), while their critical thinking skills were also weak (62.13%), highlighting the urgency of e-modules that promote both engagement and higher-order thinking. In a complementary study, Nilyani & Ratnawulan (2023) found that 92% of schools still relied on printed textbooks, whereas 95% of students expressed the need for digital modules that incorporate problem-based learning and 21st-century competencies. Similarly, Marisda et al. (2024) demonstrated that physics students predominantly displayed visual learning styles and possessed smartphones that enabled flexible access to digital resources, reinforcing the importance of designing interactive flipbook-based e-modules accessible via mobile devices. At the secondary school level, Karim & Karim (2024) revealed that teachers identified gravitation as one of the most challenging topics for students, due to both mathematical and visualization demands, and recommended the integration of technological supports such as augmented reality, videos, and visual simulations. Collectively, these findings indicate that needs analysis is not merely a preliminary step but a critical mechanism to ensure that physics modules are aligned with students' cognitive characteristics, technological access, and contextual learning challenges.

2.5. Research Gaps and Rationale

While previous research has documented the effectiveness of inquiry-based and multiple representation learning separately, few studies have systematically integrated these two approaches in a learning module explicitly aimed at fostering conceptual change in fundamental physics. Existing modules in physics education are often designed with a strong emphasis on content delivery rather than a diagnostic approach that explores students' preconceptions and learning needs. As a result, many instructional materials fail to address misconceptions effectively or provide tailored scaffolding to support conceptual change. Recent studies highlight that teachers themselves encounter challenges in

diagnosing students' difficulties and integrating problem-based or inquiry-oriented models in ways that foster deeper understanding (Nurhayati et al., 2023). Likewise, phenomenological research on physics teachers' practices underscores the lack of systematic use of diagnostic assessments to uncover students' misconceptions, which consequently limits the potential of instructional modules to bring about meaningful conceptual change (Mutmainna et al., 2025).

Although previous studies have highlighted the effectiveness of inquiry-based learning and multiple representations, only a limited number of investigations have systematically incorporated needs analysis into the development of physics modules. As a result, many existing materials remain misaligned with students' learning preferences, digital accessibility, and cognitive characteristics. This study addresses this gap by integrating inquiry, multiple representations, and a comprehensive needs analysis to design a physics learning module explicitly aimed at fostering conceptual change.

3. Methodology

This research is quantitative descriptive research that aims to conduct a needs analysis as an initial stage of development of a multi-representation integrated inquiry-based physics learning module to facilitate students' conceptual changes in vibration and wave materials. This methodology refers to the needs analysis procedure in the development of teaching materials as suggested by Branch (2010b) in the ADDIE (Analyze, Design, Develop, Implement, Evaluate) model, where the analysis stage is carried out to identify learning needs before the module design process is carried out.

3.1. Research Location and Time

The research was carried out from February 1 to 20, 2025, at the State Islamic University (UIN) Mahmud Yunus Batusangkar, Indonesia.

3.2. Research Subjects and Populations

The research population is all undergraduate program (S1) students in the Physics Education Study Program who take Basic Physics courses in the even semester of the 2024/2025 academic year. The research sample was chosen using purposive sampling, which means the researchers picked students who are taking courses related to vibration and wave topics and are actively participating in the inquiry-based learning process (Creswell & Guetterman, 2018). The sample consisted of two classes totaling 31 students.

3.3. Data Sources and Research Instruments

Primary data is obtained through a Google Forms-based questionnaire designed to collect information on students' needs for the development of learning modules. This instrument includes indicators: (1) students' learning difficulties in understanding the concept of vibration and waves; (2) preferred learning methods; (3) the desired form of teaching materials; (4) the content of the material that is considered important; and (5) the types of representations (visual, graphic, video, or simulation) expected in both print and digital modules. The questionnaire design refers to the principle of learning needs analysis according to Setyowati et al. (2021), which emphasizes the mapping of the gap between actual conditions and ideal learning conditions.

To ensure its validity, the initial draft of the questionnaire was evaluated by two experts in physics education. They assessed the clarity of language, content relevance, and suitability of the indicators with the objectives of the study. Based on their feedback, several items were revised for improved readability and alignment with the constructs being measured. Following expert review, a limited pilot test was conducted with a small group of students outside the main sample to identify ambiguous items and confirm usability. The reliability of the instrument was then examined using Cronbach's alpha, which yielded a coefficient of 0.77, indicating acceptable internal consistency for the questionnaire items (Nunnally, 1978).

3.4. Data Collection Techniques

The questionnaire is distributed online through Google Forms to students. Before distribution, the instrument is substantially validated by two physics education experts to ensure readability and suitability of the content for the purpose of the study.

3.5. Data Analysis Techniques

Data were analyzed using descriptive statistical techniques, including percentages and descriptive interpretation. This analysis aimed to profile student needs comprehensively, including learning preferences, content formats, and the required supports for multiple representations. Sampling limitations were also acknowledged in this study, as the relatively small sample size ($n = 31$) and purposive sampling technique restrict the generalizability of findings beyond the study context (Creswell & Guetterman, 2018).

3.6. Research Ethics

The ethical aspects of this research were strictly adhered to. The researchers obtained official permission from the university through an ethics clearance and approval from the lecturer in charge of the Basic Physics course before involving students in the research. Each participant was given an explanation of the research objectives, benefits, and data collection procedures, as well as their right to withdraw without academic consequences. Student participation was voluntary, and the data collected was kept confidential and used solely for academic purposes.

4. Results

The following responses were obtained from students through a questionnaire via Google Forms. The needs analysis data from this study include difficulties of students in learning, preferred methods for understanding physics concepts, teaching materials most preferred by students for understanding the concepts of vibration and waves, the content students need in the module, and the expected form of video representation in the printed module.

4.1. Difficulties of Students in Learning

Table 1 shows the difficulties of students in learning physics, particularly in the topic of vibration and wave. Results found that students experienced several difficulties in understanding the concepts of waves and optics.

Table 1

Difficulties in learning physics

No	Statement	Student response (%)			
		SS	S	TS	STS
1	I find it difficult to learn the concepts of waves and optics	3.2	67.7	29.0	0
2	I find it difficult to understand material in the form of mathematical representations	6.5	77.4	16.1	0
3	I have difficulty understanding the concepts of waves and optics because they are difficult to observe with direct eyes (abstract).	6.5	77.4	16.1	0
4	I find it difficult to read and analyze charts.	6.5	80.6	12.9	0
5	I had trouble understanding the concept because lecturers tended to use verbal representations with explanations on the board	12.9	83.9	3.2	0

Description: SS=Strongly Agree; S=Agree; TS=Disagree; STS=strongly disagree

From Table 1, a majority of students (71 %) reported have difficulties in learning the concepts of waves and optics. Students struggle with understanding mathematical representations of concepts (84%) and reading and analyzing graphs (87%). A similar finding was found Theasy (2023), indicating that prospective physics teachers experience difficulties in learning physics due to challenges in understanding mathematical representations, such as interpreting the language of the problem, determining equations, distinguishing physics symbols, applying formulas, performing calculations, and checking and evaluating their work. Additionally, 84% of students find it difficult to understand the concept of waves and optics because these materials are challenging to observe directly or are abstract. Ansyah et al. (2021) also found that students have difficulty in understanding the concept of waves because the material was abstract, which often leads to misconceptions.

Researchers found that students struggle to understand concepts due to lecturers' tendency to use verbal representations with explanations on the board (96.8%). In order for students to have a deep understanding of concepts, lecturers should adopt more interactive and visual learning methods, such as using graphs and mathematical symbols equipped with detailed and interactive explanations. Additionally, lecturers can also use more comprehensive and interactive teaching materials, such as learning modules (Chandra & Lizelwati, 2024), which can significantly aid students in better grasping the concept of waves and optics.

4.2. Preferred methods for understanding physics concepts

Table 2 shows the methods students prefer to use to understand physics concepts, particularly those of waves and optics

Table 2

Tabulates the preferred methods for understanding physics concepts.

No	Statement	Student response (%)			
		SS	S	TS	STS
1	Verbal representations or reading texts that are complemented by image representations, can make it easier for students to understand the concepts waves and optics	22.6	77.4	0	0
2	Students preferred when the concept of waves and optics displayed in the form of visualizations in the form of moving images such as animated videos or simulations	19.4	80.6	0	0
3	Students easily understand the concept of waves and optics they use a discovery-based approach in a group	12.9	80.6	6.5	0
4	Students are actively involved in discovery-based learning	9.7	87.1	3.2	0

Description: SS=Strongly Agree; S=Agree; TS=Disagree; STS=strongly disagree

The results of the study showed that to achieve in-depth conceptual understanding, all students (100%) preferred verbal representations or reading texts supplemented with pictorial representations, as well as visualizations of vibration and wave concepts presented in dynamic media, such as animated videos or simulations. Furthermore, as shown in Table 2, 93.5% of students understood the concept of waves and optics when engaged in discovery-based learning in groups, and 96.8% actively participated in discovery-based activities. These findings align with the opinion of Aregehagn et al. (2022), who emphasized that inquiry-based learning provides students with opportunities to improve science process skills, develop critical thinking skills, and construct knowledge independently.

4.3. The teaching materials most preferred by students for understanding the concepts of wave and optics.

Table 3 shows that the percentage of teaching materials that are most preferred and needed by students for understanding the concept of waves and optics.

Table 3

The teaching materials most preferred by students for understanding the concepts of waves and optics.

No	Types of teaching materials	Number of students	Number (%)
1	Textbooks	2	6.45
2	Learning modules	8	25.8
3	Practicum Activity Sheet	2	6.45
4	Learning videos	15	48.4
5	PowerPoint slides	4	12.9

Based on Table 3, it is evident that the learning modules are the second most preferred teaching material among students (25.8%). This is also in accordance with the results of previous research conducted by Wijayadi et al. (2021), which found that 84.3% of students prefer modules for online learning. This preference suggests that students favor learning modules over other teaching materials, such as textbooks. Textbooks are often less engaging for students, leading to low interest in learning. Textbooks typically do not facilitate active interaction between students and materials, resulting in a less active and less dynamic learning process. Learning videos received the highest preference (48.4%). Only a small percentage (6.45%) of students prefer teaching materials in the form of textbooks and practical activity sheets. The findings align with previous research by Nurwahidah et al. (2021), which showed that 54.55% of students prefer using videos for learning, and 56.27% of students are motivated to attend lectures with video media. Learning videos are the most preferred teaching media for students because they facilitate the delivery of messages, overcome space and time limitations, and cater to students' senses, making the learning process faster and easier to understand (Nasution et al., 2022).

4.4. The content students need in the module teaching materials.

Table 4

The content students need in module teaching materials

No	Content that needs to be there	Number of students	Number (%)
1	A real example is a contextual image or video	22	71.0
2	Concept map	8	25.8
3	Description of the material	16	51.6
4	Questions and sample questions accompanied by answer keys	18	58.1
5	Investigation activities	11	35.5

Table 4 summarizes the types of content students need in the proposed learning module. The analysis shows that the highest-priority component is real-world examples presented in the form of contextual images or videos, as reported by 71% of respondents. Furthermore, students prioritized the availability of practice questions and examples accompanied by answer keys (58.1%), comprehensive explanations of the material (51.6%), and concept maps (25.8%). Conversely, investigative activities received the lowest priority, with only 35.5 % of students considering them important. These findings show that students prefer learning materials that include lots of visuals and real-life examples to help them understand concepts and solve problems, instead of activities that involve exploration and investigation.

4.5. The expected form of video representation in the printed module.

The expected form of video representation in the printed module is shown in Table 5.

Table 5*The expected form of video representation in the printed module*

No	Forms of video representation	Number of students	Number (%)
1	Concept simulation video	13	41.9
2	Problem-solving tutorial videos	19	61.3
3	Practicum videos	13	41.9
4	Explanatory video	19	61.3
5	Concept application video	11	35.5

The findings in Table 5 reveal that students expressed the strongest preference for video tutorials and Explanatory videos (61.3%), indicating a clear demand for structured guidance that can supplement traditional text and support independent learning. In contrast, concept simulation and practicum videos (both 41.9%) were moderately valued, reflecting an interest in visual demonstrations of abstract phenomena and experimental processes, but with less priority compared to explanatory resources. The lowest preference was found for concept application videos (35.5%), suggesting that while students recognize the importance of applied problem-solving, they are more inclined toward resources that first help them build foundational understanding. Overall, these results highlight students' tendency to favor guided and explanatory video formats over purely application-oriented resources, suggesting that learners require modules that integrate multimedia elements to scaffold conceptual understanding before moving into higher-order applications.

5. Discussion

The results of the needs analysis reveal that more than 90% of students experience difficulties in understanding abstract concepts in waves and optics, especially in linking mathematical representations with physical phenomena. This finding aligns with Ate et al. (2025), who reported that students often face cognitive barriers when transitioning across representations such as words, images, and mathematical equations. From a theoretical perspective, these difficulties can be explained through Vosniadou's (2012) framework of conceptual change, which suggests that deeply rooted mental models must be restructured rather than simply supplemented. Similarly, the low level of representational literacy found in this study highlights a core obstacle to problem-solving, echoing Hahn & Klein (2025) emphasis on the role of sketching and simulations as scaffolds that reduce cognitive load and promote integrative understanding.

Students' strong preference for interactive and visual-based learning materials further underscores the need for inquiry-based modules with multiple representations integrated. According to Multimedia Learning Theory Mayer (2014), learning is enhanced when information is presented through both visual and verbal channels, as dual coding fosters deeper processing while reducing extraneous cognitive load. While this preference for videos over textbooks may appear unsurprising in the digital era, it nonetheless highlights a pedagogical imperative: instructors must design modules that harness students' multimedia inclinations without compromising conceptual depth. This study therefore expands on Rahmawati et al. (2022), who demonstrated that multiple representation-based e-modules can boost engagement, by showing that representations need to be systematically orchestrated through inquiry phases to facilitate conceptual change rather than mere engagement.

Interestingly, investigation activities received the low rating of 35.5%, even though they are considered the cornerstone of inquiry-based learning. This tension is pedagogically significant. One possible interpretation is that students associate "investigation" with effortful, open-ended tasks that may trigger cognitive overload or uncertainty. However, Posner et al. (1982) argue that cognitive conflict and dissatisfaction with prior conceptions are necessary conditions for conceptual change. Thus, rather than removing investigative elements, the implication is that inquiry modules must provide structured scaffolding—such as guided inquiry by multiple representations,

stepwise simulations, or collaborative investigation—to build students’ confidence and gradually transition them into authentic investigative practices.

The preference for hybrid formats that combine video simulations with print materials also reflects a broader shift in higher education toward blended and technology-enhanced learning. This aligns with Mayer’s principles of contiguity and modality, which suggest that learners benefit from a balanced integration of textual and digital representations to optimize cognitive processing. In this regard, the present study fills the gap identified by Ate et al. (2025) who noted the lack of higher education research leveraging digital technology to support multiple representations. Unlike prior efforts such as Marisda et al. (2024), which developed STEM-based e-modules without explicitly targeting conceptual restructuring, the findings here emphasize the synergy of inquiry, multiple representations, and technology as a framework for conceptual change.

Finally, the results reaffirm the importance of needs analysis as the foundation of instructional design. Branch (2010a) emphasized that development without needs analysis risks producing learning resources misaligned with user contexts. In contrast, this study identifies three core requirements for module design: alignment with students’ predominantly visual learning styles, scaffolding of critical thinking through inquiry stages, and integration of verbal, visual, and symbolic representations to support the building of scientific mental models. Unlike Novitra et al. (2021), who emphasized 21st-century skills development, the present study explicitly situates conceptual change as its central objective.

Overall, the main contribution of this study is its integration of constructivist learning theory, multimedia learning principles, and the inquiry approach to guide module development. By using multiple representations as a structured component of inquiry, the study proposes a pathway for overcoming representational and conceptual barriers more effectively than traditional step-by-step instruction. In doing so, the findings not only justify the urgency of innovative module development but also expand the discourse on how evidence-based design can address persistent misconceptions in physics education in the digital era.

6. Conclusion

The results of the questionnaire analysis indicate that students experience difficulties in understanding the concepts of vibration and waves, particularly in the aspects of mathematical representation and graphical analysis. Students prefer these concepts presented through visual aids such as images and videos. Among various learning resources, videos and learning modules are the most popular teaching materials to help understand the concepts of waves and optics. In addition, students want real-world examples presented contextually in the form of images or videos in printed modules, as well as the inclusion of video tutorials that facilitate problem-solving and conceptual explanations. These findings point out the urgent need for the development of alternative learning resources, particularly inquiry-based learning modules that integrate multiple representations, to support deeper conceptual understanding in the Basic Physics course on the topic of waves and optics at the State Islamic University (UIN) Mahmud Yunus Batusangkar.

Declarations

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Competing Interests

None.

Ethical Approval

The ethical aspects of this research were strictly adhered to. The researchers obtained official permission from the university through an ethics clearance and approval from the lecturer in charge of the Basic Physics course before involving students in the research. Each participant was given an explanation of the research objectives, benefits, and data collection procedures, as well as their right to withdraw without academic consequences. Student participation was voluntary, and the data collected was kept confidential and used solely for academic purposes.

Author's Contribution

Author¹: Conceptualization, Data curation, Formal analysis, Writing – original draft

Author²: Review and editing

Author³: Review and editing

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