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Development of Case-Based Learning Modules on Wave Topics to Improve Students' Cognitive Abilities

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Abstract Students' cognitive abilities in physics learning, particularly on wave topics, still need to be improved through more contextual and innovative instructional materials. Therefore, this research aims to develop a physics learning module on wave material in accordance with Case-Based Learning (CBL). In addition, it also examines its feasibility, experience and effectiveness in improving students' cognitive abilities. This research uses the Research and Development (R&D) method using 3D models, limited to the definition, design, and development stage where 12th grade students are the subject of learning. The feasibility of the developed modules was evaluated using the Learning Object Review Instrument (LORI), while the practicality was assessed through the User Experience Questionnaire (UEQ). The effectiveness of the module was measured using N-Gain analysis based on pretest and posttest results. The results show that the developed CBL-based modules are categorized as very feasible and provide a positive user experience. In addition, the N-Gain analysis showed an improvement in the cognitive abilities of the learners, with most of the learners achieving scores in the medium category. These findings suggest that CBL-based physics learning modules on wave materials are quite effective and suitable for use as an alternative instructional resource to improve the quality of physics learning in high school.

Keywords: Case-Based Learning, Research and Development, modules

1. Introduction

The success of education is highly determined by efforts to improve the learning process and assessment in determining competency achievements [1]. Studying science education or natural sciences is a subject that is often considered difficult by some students [2]. One of the science subjects includes studying natural phenomena or events, the learning process is not only to master concepts but also apply the concepts learned in solving Physics problems [3], students' understanding is not always wrong but is highly context-dependent and productive [4]. For this reason, more innovative learning strategies are still needed that can effectively incorporate these elements in science teaching [5], visual aids are also required to fully understand the material [6].

Research by Rahimah, Hadma Yuliani and Nur Inayah Syar [7], students had difficulty in understanding Physics lessons, and data were obtained "books (14.3%), modules (23.8%), Student Worksheets (28.6%), Microsoft PowerPoint (PPT) (14.3%), portable documents (PDF) (28.6%), and learning videos (9.5%)" with 21 grade XI students needing teaching materials to be a bridge for students to understand Physics. Teaching materials are a set of learning tools that contain learning materials, learning methods, limitations, and evaluation methods that are designed in a systematic and interesting manner in order to achieve the expected goals [8]. The benefits obtained by applying teaching materials in learning according to Santayasa in Tampubolon et al (2015) are as follows: (1) increasing student motivation; (2) after evaluation, the teacher and students know correctly; (3) students achieve results according to their abilities; (4) teaching materials are divided more evenly in one semester, and (5) education is more useful, because teaching materials are arranged according to academic levels [9].

Modules are one of the teaching materials needed for learning. With the Physics module, it is hoped that it can facilitate understanding and also shape the character of students [10]. Modules are printed teaching materials that contain subject matter that contains specific topics that are compiled systematically, operationally, and geared towards use by students along with guidelines for their use [11]. Well-designed teaching modules can include elements that encourage active student engagement, such as project assignments, interactive exercises, or reflective questions [12]. Teaching modules that fit the learning model are important so that learning can be useful and achieve its goals [13].

Case-Based Learning (CBL) is a strategy that promotes students' active learning. One way that can stimulate students' active learning is to use case studies [14]. Through case solving (case method), it can foster learning motivation, gain contextual learning experience, and science process skills can be improved [15].

CBL is a teaching approach that uses real-world or realistic scenarios (cases) as a basis for active learning. Existing cases are factual records of past events and reflect real-world situations, or even open-ended challenges designed to simulate critical thinking. Case-based learning offers a dynamic approach to learning, this approach goes beyond rote and requires students to apply their language knowledge and skills to the real-world scenarios presented in the case study [16].

Figure 1. Case-based learning measures [16].

CBL implementation steps shown in Figure 1 (Williams, 2005): (1) case presentation; (2) analysis and discussion by the group; (3) the formulation of learning adjectives; (4) the division of topics among students; (5) independent learning; (6) sharing knowledge among students; (7) Discussion and Summary [16]. To be able to go through these stages well**,** students are required to exert all of their cognitive abilities.

Cognitive ability is the process of thinking, which is a person's ability to connect, assess, and consider an event or event [17]. The cognitive domain consists of six hierarchical levels arranged from the simplest to the most complex. The first level, remembering (C1), involves remembering previously learned information. Understanding (C2) refers to understanding and explaining ideas. Applying (C3) involves using knowledge in new situations. Analyzing (C4) requires breaking down information into parts and identifying relationships between them. Evaluating (C5) involves making judgments based on specific criteria. The highest level, creating (C6), refers to generating new ideas or developing original solutions [18]. The six aspects above are arranged based on the pyramid structure from the simplest to the most complex aspects [19]. The first two aspects are called low-level cognitive *(Low Order Thinking)* and the next four aspects include high-level cognitive *Higher Order Thinking (HOT)* [18]. Senior high school content competency requires scientific communication skills, to present and record results in the form of graphs and tables and report them in writing or orally [20].

This research is specifically designed for wave material by integrating contextual problems, analysis activities, and problem-solving activities that focus on developing students' cognitive abilities. The modules developed not only convey concepts conceptually, but also relate them to real situations so as to encourage students to think critically, conduct analysis, and draw conclusions based on wave concepts. The purpose of this study is to determine the feasibility of the module, user experience and effectiveness of the module.

2. Method

This research was conducted at SMA Mutiara Insan Nusantara grade XII in Tangerang Regency, Banten. Data collection was carried out in 1 meeting, on December 9 in the odd semester of the 2025/2026 school year.

This research applies *Research and Development (R&D).* R&D is a research method that aims to produce a specific product, through research on educational problems solutions can be found so that they can develop and implement more innovative education [21]. The most prominent methodology in R&D is the 4D model, introduced by Thiagarajan, Semmel, and Semmel (1974), this model consists of four sequential phases: Definition, Design, Develop, and Deploy, each of which has a different purpose [22]. This research uses a 4D development model *(Four-D Model)* which is modified into 3D, including the stages of define, design, and develop. This model was chosen because it is flexible and suitable for the development of interactive educational product-oriented learning media [23]. Modifications are carried out by not carrying out the disseminate stage, considering that the research is focused on developing and testing the feasibility of products on a limited scale to obtain validity and practicality data [24]. On stage Determine the stages define (Definition) that aim to determine and determine learning needs. Design is in the second stage for developers to design the initial product based on the results of the analysis. Develop (*Development*) is the stage of the design realization and validation process. *Disseminate* (*Dissemination*) is a stage for disseminating products for use by a wide audience.

At the data development stage, validation was carried out by 2 lecturers and 1 teacher. by filling out validation sheets from 22 assessment components on a scale of 1-5. For students, product validation is carried out to assess the extent to which the product is feasible to use. In the development stage, limited trials are conducted with the aim of identifying the advantages, weaknesses, and feasibility of the product. This assessment is carried out using the User Experience Questionnaire, A data analysis approach is used to ensure the practical relevance of the scale being built, i.e. the scale is derived from data relating to a larger set of items [25]. The distribution of research instruments which includes pretest, posttest, expert test, and teacher and student response questionnaire is shown in Table 1.

Table 1. Stages of data collection.

Stages	Subject	Instruments
Expert Validation Trial	2 (three) lecturers and 1 (one) teacher who are material experts, construction experts, and linguists.	Questionnaire for expert tests
Trial	30 grade XII students of SMA Mutiara Insan Nusantara	Test instruments and response questionnaires

2.1. *Research Instruments*

2.1.1. Questionnaire for expert testing. Expert lecturer and teacher questionnaires were taken from *LORI (Learning Object Reviewer Instrument)*, with the assessment criteria mentioned in Table 2 [26].

Table 2. Questionnaire for expert tests.

No	Criteria
1	Content Quality
2	Alignment of Learning Objectives
3	Feedback (Feedback and Adaptability)
4	Motivation
5	Presentation Design and Design
6	Usability and Interaction
7	Accessibility

2.1.2. *Student experience questionnaire.* User Experience Questionnaire for teacher and student Instrument with the indicators mentioned in Table 3 [25].

Table 3. Student response questionnaire.

Aspects	Meaning
Interesting	General impressions, pleasure, satisfaction of using teaching materials
Intelligence	Ease of learning and use (easy to understand, not confusing)
Efficient (Efficiency)	How quickly and efficiently the teaching materials are used
Reliability	Reliability and control in use
Stimulation (stimulation)	Positive and motivating effects of use
Novelties	Innovation and a sense of novelty from the appearance or interaction

2.2. *Data Analysis Techniques*

2.2.1. *Feasibility analysis.* According to Riduwan (2013), to see the level of validity of the products made, the categories developed in Tables 4 and 5 and the formula in equations 1 and 2 below [27]:

$$\text{Percentage} = \frac{\sum \text{Validator given}}{\text{Maximum score}} \times 100\% \quad (1)$$

Table 4. Product feasibility testing interpretation criteria [28].

No	Rating	Interpretation Criteria
1	0 – 25%	Very unworthy
2	26 – 50%	Not eligible
3	51 – 75%	Worthy
4	76 – 100%	Highly feasible

$$\text{X} = \frac{\sum \text{Validator given}}{\text{Number of validators} \times \text{number of items}} \quad (2)$$

Table 5. Product eligibility criteria [28].

No	Average	Criteria
1	4.21 – 5.00	Awesome
2	3.41 – 4.20	Good
3	2.61 – 3.40	Enough
4	1.81 – 2.60	Less
5	1.00 – 1.80	Very few

2.2.2. *User experience test analysis.* The analysis of the questionnaire using UEQ was carried out by calculating the average of each item and variable. Next, the average results are converted into a value index. Each scale obtained can then be grouped into three categories, namely positive, neutral, and negative. If the results of data processing with Microsoft Excel in all six aspects of UEQ shows a value above 0.8, then digital teaching materials can be categorized as very practical to use [25].

2.2.3. *Analysis of effectiveness tests.*In this test analysis, the study used the value of the calculation results from N-Gain by calculating student learning outcomes before and after the use of web-based teaching materials using Google Sites. The increase can be seen from the results of the initial test score (Pretest) and the final test score (Posttest) so that the measurement of learning outcomes is calculated using the N-Gain result value as shown in Table 6.

$$N_{\text{gain}} = \frac{\text{posttest score} - \text{pretest score}}{\text{ideal score} - \text{pretest score}} \quad (4)$$

Table 6. Category N-Gain [29]**.**

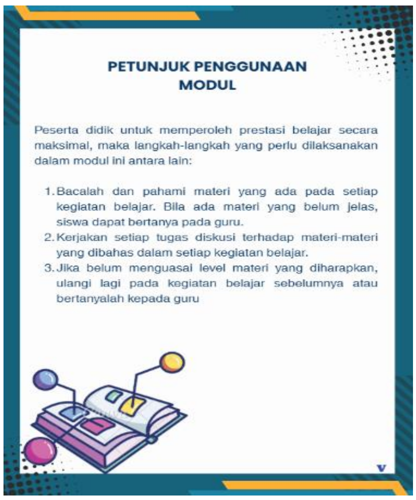
N-Gain	Category
g ≥ 0.7	Height
0.3 ≥ g ≥ 0.7	Medium
g < 0.3	Low

3. Results and discussion

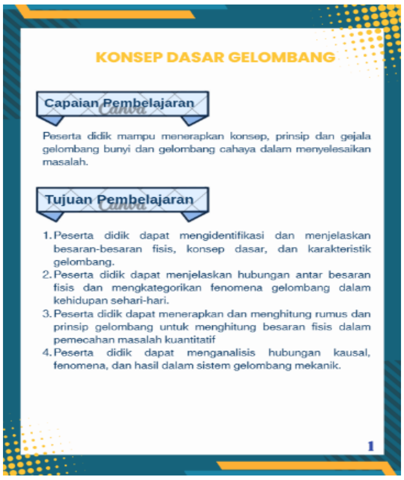
The results of the development of CBL-based learning modules for wave materials are presented in this section. The development process adapts the *Four-D* (4D) model into a three-D model, which includes the specified stages, design, and development. This learning module comes as an innovative solution to help students overcome difficulties in visualizing concepts in wave material.

At the definition stage in the 3D model, it is carried out through a literature study to identify learning problems and needs. Relevant journal reviews are used to analyze student characteristics, learning difficulties, material coverage, and curriculum demands. In the design stage in the 3D development model, the goal is to design teaching materials based on the results of analysis at the definition stage. At the design stage, the design of the visual display of the module is carried out as an initial description of the developed product. The design of this module reflects the characteristics of CBL-based learning on wave materials.

(a)



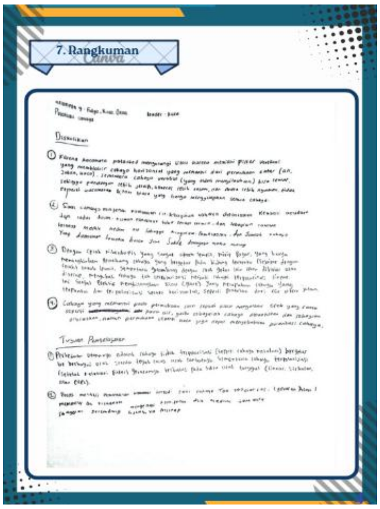
(b)



(c)

(d)

(b)



(f)

(g)

Figure 2. Learning module design: (a) module cover, (b) module usage instructions (c) CP and TP, (d) concept map, (e) module content, (f) student's handwriting summary, (g) student presentation

Figure 2 shows the design of learning modules that are systematically and structured to support the physics learning process. The module begins with a module cover that contains an identity and an overview of the material, followed by instructions for using the module as a guide for students to use the module independently. Furthermore, Learning Outcomes and Learning Objectives are presented as a reference for competencies that must be achieved, as well as concept maps that provide an overview of the relationship between material concepts. The main part of the module contains the content of the learning material that is arranged contextually, then supplemented by a student summary. Finally, the module provides student presentation activities, which is in the last stage of CBL

In the third stage, development consists of two stages, namely expert appraisal accompanied by revision and developmental testing. At the development stage that has produced a product, then it is assessed by material, media, and language experts to see its validity, after going through the revision stage the learning module is piloted for students. On December 9, 2025, the learning module will be piloted on 30 grade XII students and teachers of Physics class XII.

3.1. Product Eligibility Testing

Table 7. Product feasibility test results.

Aspects of LORRY	Average score	Percentage	Category
Content Quality	4.31	86.25	Highly Worth It
Alignment of Learning Objectives	4.25	85.00	Highly Worth It
Feedback & Adaptability	3.88	77.50	Worthy
Motivation	4.08	81.67	Highly Worth It
Presentation Design	4.17	83.33	Highly Worth It
Uses & Interactions	3.75	75.00	Worthy
Accessibility	4.67	93.33	Highly Worth It
Average	4,31	83,15	Highly Worth It

In Table 7, the feasibility test of teaching materials is carried out using the LORI method which includes seven aspects of assessment. The results of the analysis showed that aspects *of content quality*, *alignment of learning objectives*, *motivation*, *presentation design*, and *accessibility* were in the very feasible category, while the *aspects of feedback and adaptivity* as well as *usability and interaction* were in the feasibility category. Overall, the teaching materials developed were stated to be very feasible for use in learning with some improvements in feedback aspects and ease of user interaction. The feasibility test in this study was carried out through an assessment by 2 lecturers and 1 teacher who are material experts, construction experts, and linguists to find out whether the developed learning media is suitable for use. Expert assessments are used to provide input related to the content of the material, the appearance of the media, and its suitability with the learning objectives.

Based on the results of the feasibility test through the validation of experts, using the LORI instrument, the learning media developed showed a very feasible level of eligibility. The average score of 4.31 is included in the very feasible category, This study is in line with the research [30], A high level of feasibility indicates that the developed media has met quality standards in terms of material, presentation, and technical aspects. This assessment is in line with the LORI framework. These findings confirm that the product is not only theoretically effective, but also practical and relevant for vocational learning, with adequate design and practical validity based on expert judgment. According to [31], the validation results carried out using all LORI indicators, the learning media developed were declared suitable for use in the learning process. These results show that the media has met the quality criteria in accordance with the learning objectives and supports the improvement of student learning outcomes.

3.2. Testing the Student's Experience

Table 8. Module experience test results response.

Category	Results
Attraction	1.850
Clarity	1.383
Efficiency	1.650
Reliability	1.758
Stimulation	1.733
Novelty	1.125

The module experience test analysis was carried out using UEQ. Based on UEQ guidelines, an index with a > value of 0.8 is categorized as a positive response that indicates a good evaluation of the scale used, while an index with a value of < -0.8 is categorized as a negative response [25]. From the results obtained in Table 11, the results obtained > 0.8 are categorized as positive evaluations.

This research is in line with research [32], the learning media developed showed a good level of feasibility with an average score of 1.583 and was in the category of positive evaluation, so it could be declared as a practical medium. In addition, the performance aspect also received a positive assessment with the same average score, reflecting the performance of the media that is efficient, fast, easy to use, and structured. Table 8 shows that the result with the highest value is attractiveness, this is in line with the research conducted by [33], the modules are made likeable, interactive, easy to use, and understood by students and teachers alike. In terms of clarity, it also gets positive results according to [34], learning media can be said to be practical if the users, especially students and teachers, consider the developed product to be easy to use and can explain the learning process.

3.3. Analysis of Effectiveness Tests

Table 9. N-Gain value.

Pre-test Average	Pos-test Average	N-Gain	Category
32.80	71.20	0.53	Medium

These results show an improvement in students' cognitive abilities with scores *N*-Gain of 0.53, including the medium category. This research is in line with [35], Based on Table 9, the results of the effectiveness analysis use a percentage *N*-Gain, obtained that from all students who participated in learning, as many as 24 students in the category of Quite Effective**,** 4 students are in the less effective category**,** and 2 students are included in the ineffective category**.** These results show that in general, the implementation of learning modules is able to have a positive impact on improving student learning outcomes, even though the level of improvement is uneven among all students [36]. Based on the overall average, as many as 30 students had a score *N*-Gain with the medium category, in general the N-Gain score shows a significant improvement with the medium category [36].

4. Conclusion

Based on the results of the research, the CBL-based learning module for wave material developed using the modified Three-D model is feasible, practical, and effective. The feasibility test using the LORI method showed high feasibility with an average score of content quality (4.31; 86.25%), alignment of learning objectives (4.25; 85.00%), motivation (4.08; 81.67%), presentation design (4.17; 83.33%), and accessibility (4.67; 93.33%), while feedback and adaptability (3.88; 77.50%) and usability and interaction (3.75; 75.00%) were categorized as feasible. Overall, this module has a positive impact on student learning outcomes in the category of moderate effectiveness. This shows that CBL-based learning modules are quite effective in improving students' understanding of wave material. Thus, the modules developed are suitable for use as teaching materials to support Physics learning in secondary schools. The limitation of this study is that the module is only applied to wave material and tested in a relatively short time with a limited number of subjects. Therefore, the effectiveness of modules on other physics materials as well as the long-term impact of learning cannot be thoroughly known.

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