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# Can case-based learning-oriented science teaching materials improve critical thinking skills?

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**Abstract:** Case-based learning-oriented science teaching materials are increasingly recognized as essential tools to enhance students' critical thinking skills. This study examines the feasibility and effectiveness of science teaching materials developed using a case-based learning (CBL) approach. This research employed a research and development (R&D) design based on the Borg and Gall model. The sample was selected randomly from 66 undergraduate students from the Primary School Teacher Education Program at Nusa Cendana University, Indonesia. Data analysis techniques included descriptive statistics, feasibility analysis based on expert judgment using a set of criteria scores, and critical thinking test results analyzed using t-tests and normalized gain (N-gain) scores. The results indicated that: (1) The CBL-based science teaching materials were considered highly feasible for use in the Elementary Science Concepts course, as evidenced by expert validation scores: linguistic expert (82.7%), subject matter expert (84.2%), instructional design expert (84.0%), and practitioner (86.4%), all of which fall into the "outstanding" category. (2) The materials were also found to be effective in enhancing students' critical thinking skills, with a significance value of 0.000 < 0.005 and an N-gain score of 0.645, which is categorized as moderate improvement.
***Keywords:*** *Case-based learning, Critical thinking, Elementary teacher education students, Science teaching materials.*

## 1. Introduction

Critical thinking skills are widely recognized as a core competency in 21st-century education, particularly for pre-service teachers. This skill encompasses the ability to analyze, evaluate, and synthesize information logically, objectively, and reflectively when making decisions [1, 2]. In the context of elementary teacher education programs, critical thinking forms a foundational capacity that enables students to master subject content, foster creativity, and independently and adaptively solve instructional problems. Consequently, there is a growing need to prioritize the development of critical thinking, especially in courses related to science education.

Despite its importance, multiple studies indicate that critical thinking proficiency among Indonesian elementary teacher education (PGSD) students remains relatively low [3, 4]. Preliminary assessments of students enrolled in the Basic Science Concepts course at Nusa Cendana University revealed average scores below the satisfactory threshold, with the majority scoring under 70. Several factors contribute to this issue, including non-contextual teaching methods, limited exposure to challenging problem sets, and the absence of instructional materials that systematically promote critical thinking [5-8].

Previous research has demonstrated the effectiveness of case-based learning (CBL) approaches in enhancing students' cognitive engagement and critical thinking abilities [9-11]. Through collaborative work and evidence-based reasoning, CBL immerses students in real-world problems requiring analysis, discussion, and solutions. In the context of elementary science education, such an approach is regarded as effective in stimulating higher-order thinking and enhancing the relevance of scientific content to everyday life.


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However, studies focused on developing science-based teaching materials using the CBL approach tailored explicitly for elementary teacher education students remain scarce, particularly in Eastern Indonesia's higher education landscape. There is a notable lack of research that systematically designs, develops, and tests the feasibility and effectiveness of such materials within a local context, especially those aligned with the Merdeka Belajar (Freedom to Learn) framework.

Based on the considerations above, this study aims to develop CBL-oriented science teaching materials and evaluate their feasibility and effectiveness in improving critical thinking skills among PGSD students at Nusa Cendana University. The outcomes of this research are expected to contribute to the advancement of innovative and contextually relevant learning strategies and strengthen the pedagogical capacity of pre-service elementary teachers to become critical, reflective, and adaptive educators equipped to meet future educational challenges.

## 2. Methodology

### *2.1. Research Design*

This study employed a Research and Development (R&D) approach guided by the Borg and Gall [12] model. The model outlines ten systematic stages, including: (1) research and information collecting, (2) planning, (3) developing a preliminary product, (4) preliminary field testing, (5) revising the main product, (6) main field testing, (7) revising the operational product, (8) operational field testing, (9) final product revision, and (10) dissemination and implementation. This model was chosen as it provides a comprehensive framework for developing learning products that are valid, practical, and effective based on empirical needs in real educational contexts.

### *2.2. Data and Data Sources*

#### *2.2.1. Population and Sample*

The population of this study comprised all students enrolled in the Elementary Teacher Education (PGSD) Program at Nusa Cendana University, Indonesia. The sample was divided into three groups: six third-semester students and one lecturer for the preliminary field testing, 30 third-semester students (Class C) for the small-scale testing, and 66 first-semester students from Class B and C (33 students each) for the large-scale testing. Sampling was conducted using random sampling techniques to ensure proportional data representation.

#### *2.2.2. Instrument Development*

The instruments utilized in this study included (1) validation questionnaires completed by language, content, design experts, and practitioners; (2) student and lecturer response questionnaires; and (3) a critical thinking test. The critical thinking test was developed based on nine indicators drawn from frameworks on higher-order thinking in science education [2]. It consisted of 45 multiple-choice items derived from five main topics within the Basic Science Concepts course. Both the validation and response questionnaires adopted a five-point Likert scale.

#### *2.2.3. Instrument Development Process*

The instrument development process included blueprint design, item writing, content validation, and reliability testing. Ten expert validators assessed content validity using Aiken's V analysis, with a minimum threshold of 0.70 to indicate validity [13]. All questionnaire and test items were deemed valid. Instrument reliability was measured using Cronbach's alpha, yielding a coefficient of 0.9726, indicating a high-reliability level (citation needed). Validation procedures were conducted via a Focus Group Discussion (FGD) on August 30, 2024, involving ten field experts.

### *2.3. Pilot Study*

After initial validation, a pilot study assessed the instructional materials' readability, visual clarity, and content substance. The preliminary trial involved six students and one lecturer teaching the Basic

Science Concepts course. The pilot study led to several refinements, including adding illustrations, correcting numerical inaccuracies, and enhancing sample problems to align with the course content. Based on the pilot results, the materials were revised before small-scale testing.

### *2.4. Data Collection*

Data was collected by distributing validation instruments to experts, administering pretests and post-tests to students, and student and lecturer response surveys after the instructional materials were used. Data were collected in three phases: preliminary, small-scale, and large-scale field testing. This process was conducted throughout September 2024 and aligned with the regular academic schedule of the PGSD program at Nusa Cendana University.

### *2.5. Data Validation*

Data validation involved several techniques. Content validity was confirmed through Aiken's V analysis, with all items exceeding the 0.70 threshold, indicating high validity. Instrument reliability was confirmed via Cronbach's alpha, resulting in a coefficient of 0.9726, which is considered highly reliable for research instruments. Additional validation was conducted through triangulation methods, including interviews and classroom observations, to enhance the credibility of the findings.

### *2.6. Data Analysis*

Data were analyzed using both descriptive and inferential statistical approaches. Descriptive analysis assessed the feasibility and practicality of the teaching materials based on validation scores and response questionnaire results. Inferential analysis was used to evaluate the effectiveness of the materials in enhancing students' critical thinking skills. Assumption tests included the Kolmogorov-Smirnov and Shapiro-Wilk tests for normality and Levene's test for homogeneity. Once assumptions were met, a paired-sample t-test was conducted to measure pretest-post-test differences within groups, and an independent-sample t-test was used to compare the control and experimental groups. Additionally, normalized gain (N-gain) scores were calculated to assess the magnitude of improvement in students' critical thinking skills. All analyses were performed using SPSS version 23.

## 3.Results

### *3.1. Initial Needs Assessment*

The initial phase aimed to identify the instructional material development needs. Several topics were identified as challenging for students based on observations, interviews, and document analysis of the *Basic Science Concepts* course in the PGSD program at Nusa Cendana University. These included measurement, matter and its changes, motion and simple machines, vibrations and waves, energy and heat, and basic electricity. The existing materials were found to be incomplete, lacking contextualized cases, and did not adequately support independent learning or critical thinking development. Furthermore, initial critical thinking test results revealed that students did not meet expected benchmarks across nine essential indicators of thinking, with an average achievement of only 46%. These findings underscore the urgent need for instructional materials based on pedagogical approaches that enhance critical thinking skills [2, 14].

### *3.2. Instructional Material Planning and Initial Design*

Based on the needs analysis, a prototype of science teaching materials was designed using a case-based learning (CBL) approach. The materials were developed in A5 book format, focusing on elementary physics topics contextualized through real-life cases. Each chapter included two case studies and group discussion worksheets, explanatory content, independent assignments, and critical thinking tests. Content sources were drawn from reputable science encyclopedias and introductory physics textbooks. The development process emphasized readability, visual appeal, and relevance to daily life.

*3.3. Expert Validation*

Expert validation was carried out by three linguists, three content specialists, two instructional designers, and two teaching practitioners. The results showed that the teaching materials were highly suitable for use. Average validation scores were: language experts – 49.6 out of 60 (82.7%), content experts – 59 out of 70 (84.2%), design experts – 155.5 out of 185 (84.0%), and practitioners – 60.5 out of 70 (86.4%). All scores fell into the "outstanding" category according to Budiyono's [28] criteria. Feedback from validators included suggestions for motivational language revision, content enrichment (especially wave topics), local context alignment, image labeling consistency, and higher-order thinking action verbs in learning objectives.

*3.4. Pilot Study*

The limited-scale pilot involved six students and one course lecturer. Observations indicated that the materials presented comprehensive content, relevant and accurate case studies, and visually appealing layouts. However, several issues were identified, including incomplete example problems and unclear illustrations. The lecturer noted that the content flow was well-structured and facilitated comprehension. Based on this feedback, revisions were made to replace unclear images, enhance case illustrations, refine questions, and improve visual design.

*3.5. Small-Scale Field Testing*

This phase involved 30 third-semester students from Class C. After three sessions using the instructional materials, students completed a critical thinking test. Tests for normality and homogeneity confirmed that pretest and post-test data were normally distributed and homogeneous. A paired sample t-test showed a significance value of 0.000, indicating a statistically significant improvement in critical thinking skills.

*3.6. Large-Scale Field Testing (Operational Field Testing)*

The large-scale testing phase included two first-semester classes: an experimental group using the developed instructional materials and a control group using conventional teaching methods. Tests confirmed that post-test scores were normally distributed and homogeneous across groups. An independent sample t-test yielded a significance value of 0.000, indicating a significant difference in critical thinking outcomes between the experimental and control groups. The experimental group achieved a higher mean post-test score.

**Table 1.**
Independent t-test Results.

| **Independent Samples Test** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Levene's Test for Equality of Variances** | | **t-test for Equality of Means** | | | | | | |
| | | **F** | **Sig.** | **T** | **df** | **Sig. (2-tailed)** | **Mean Difference** | **Std. Error Difference** | **95% Confidence Interval of the Difference Lower** | **95% Confidence Interval of the Difference Upper** |
| Critical thinking test | Equal variances assumed | 3.363 | 0.071 | 12.948 | 64 | 0.000 | -23.7909 | 1.83739 | 27.4615 | 20.1203 |
| | Equal variances not assumed | | | 12.948 | 59.701 | 0..000 | -23.7909 | 1.83739 | 27.4615 | 20.1152 |

Furthermore, the N-gain analysis showed an increase of 0.645 in the experimental group, classified as moderate.

**Table 2.**
N-Gain score.

| | N | Sf | Si | N-Gain |
|---|---|---|---|---|
| Ngain | 66 | 86.96 | 63.17 | 0.645 |

These results support the conclusion that CBL-based instructional materials effectively enhance students' critical thinking skills [5, 10, 11].

*3.7. Response Questionnaire Results*

The student response questionnaire yielded an average score of 4.558 out of 5**, or** 91.6%**,** which falls into the "convenient" category. Similarly, the lecturer response questionnaire scored an average of 4.43 (88.6%)**,** also categorized as "highly practical." These results suggest that the instructional materials were perceived as feasible, user-friendly, and supportive of the learning process by both students and instructors.

## 4. Discussion

*4.1. Preliminary Stage*

The preliminary stage illustrates the learning context of the *Basic Science Concepts* course in the PGSD Program at Nusa Cendana University. As part of the national higher education agenda, the university implements the Merdeka Belajar–Kampus Merdeka (MBKM) curriculum, in which *Basic Science Concepts* is a mandatory course for elementary teacher candidates [15].

Observations and interviews revealed that many students perceive this course as difficult, particularly due to the abstract and calculation-heavy nature of its physics-related topics. This aligns with Bijker [16] view that science requires experimentation and observation, which demands complex cognitive processes—often challenging for undergraduate students.

Specifically, PGSD students struggled with physics topics such as measurement, matter and its changes, motion and simple machines, energy and heat, and basic electricity. Instructional resources for this course were mostly limited to online materials and PowerPoint slides, with no systematically developed teaching materials by lecturers. However, such materials are crucial as they can be tailored to students' needs and structured to facilitate independent learning [17].

Student engagement also significantly influences learning outcomes. According to Çakır [18] student responses during learning are a key determinant of academic success. When students perceive a course as difficult, their motivation and critical thinking engagement tend to decrease [19].

Interviews and observations also revealed a lack of instructional materials to develop critical thinking. One promising approach is case-based learning (CBL). Reed and Brunson [10] argued that CBL is a powerful strategy for fostering students' critical thinking. However, *CBL-based materials have not been developed for the Basic Science Concepts course* at Nusa Cendana University.

Although lectures and group discussions are used, they do not engage students in solving structured cases or conducting brainstorming, which are vital in CBL. Brainstorming has been found to positively impact students' cognitive skills [20] and is one of the core components of CBL models [21].

Despite critical thinking being a key educational objective in higher education [2] the initial assessment at Nusa Cendana University showed underwhelming results. All nine critical thinking indicators scored below 51% and an overall average of 46%. This falls short of the six domains of critical thinking in higher education as proposed by Davies and Barnett [22] which include critical argumentation, judgment, disposition, action, public engagement, and ideological critique.

Critical thinking is also an essential benchmark in science education [23]. Lecturers and students alike recognized the need for comprehensive, accessible teaching materials that support independent learning, facilitate brainstorming, and link science to everyday life. Therefore, there is a clear need to develop CBL-based materials for this course.

*4.2. Development Stage*

The development stage focused on designing and producing a CBL-based science teaching material for the *Basic Science Concepts* course in the PGSD Program at Nusa Cendana University. The development followed the Borg and Gall model, resulting in instructional materials designed to meet curriculum goals [24].

During the planning phase, instruments were prepared for expert validation (covering content, language, and graphics), student and lecturer response surveys, and a critical thinking test.

All instruments were validated: the expert validation tools were approved by supervisors, and the response questionnaires were analyzed using Aiken's V, which requires a validity index ≥ 0.70 for item acceptance [13]. Fifteen items in the student response questionnaire were validated by ten experts and found valid.

The critical thinking test was developed based on nine indicators and comprises 45 test items. Aiken's V analysis confirmed all items as valid (V > 0.70), and reliability testing using Cronbach's alpha yielded a coefficient of 0.9726, indicating excellent reliability.

The teaching materials covered key physics concepts: measurement, matter transformation, motion, energy, and electricity, and followed a structured format [25]: cover, introduction, core content, and conclusion. The core section includes learning objectives, sub-Course Learning Outcomes (CPMK), contextual case studies, group discussions, summaries, individual tasks, and critical thinking tests.

CBL methodology emphasizes case-driven instruction [11] where students solve problems using prior knowledge and relevant concepts [26]. Group discussions were also integrated, in line with Hammond [27] who emphasized real-life scenarios in CBL.

A Focus Group Discussion (FGD) was held on August 30, 2024, involving 10 validators. Validation results showed high scores across all expert groups: language (82.7%), content (85.2%), design (84.0%), and practitioner (86.4%), which fall into the "outstanding" category [28].

According to Downing [29] and Ghaderi, et al. [30] validated materials can be deemed fit for use when the content and data accuracy meet expert expectations. Thus, the developed material was considered feasible and of high quality.

In the limited pilot, lecturers and students found the material engaging, mainly due to the visual content, real-life case examples, and structured discussions. Feedback led to refinements in illustrations, cases, and design.

The small-scale trial involved 30 third-semester PGSD students using a one-group pretest-post-test design. Statistical results showed a significant improvement in critical thinking ($p = 0.000 < 0.05$), indicating a positive effect of the developed material, consistent with findings by Sapeni and Said [31].

Response questionnaires also supported these findings, with students giving an average score of 4.558 (91.6%) and lecturers 4.43 (88.6%), both categorized as "very practical" [32]. This confirms that the material was practical and highly usable in classroom settings.

*4.3. Testing Stage*

The testing stage assessed the effectiveness of the developed CBL-based materials for improving students' critical thinking. A pretest-posttest control group design was implemented with 66 first-semester PGSD students. Before hypothesis testing, normality, and homogeneity assumptions were met, justifying independent sample t-tests [28].

An initial balance test showed no significant difference between the control and experimental groups ($p = 0.109 > 0.05$), confirming comparable baseline critical thinking skills. However, post-test analysis revealed a significant difference ($p = 0.000 < 0.05$) between the two groups, with the experimental group performing better. This aligns with findings by Hodijah, et al. [7] and Reed and Brunson [10] who emphasized CBL's potential to foster critical thinking.

Further effectiveness was demonstrated through N-gain analysis, with an N-gain of 0.645, categorized as a moderate improvement. This indicates that CBL-based materials effectively improved students' critical thinking, consistent with the results of Hall and Starzec [33]; Jones [11] and Fauzi, et al. [5].

## 5. Conclusion

Based on the results of the study and discussion on the development of science teaching materials using a case-based learning (CBL) approach, the following conclusions can be drawn:

1. The developed CBL-based science teaching materials were feasible for use in the *Basic Science Concepts* course for PGSD students. This is supported by expert validation scores, including language experts (82.7%), content experts (85.2%), instructional design experts (84.0%), and practitioners (86.4%)—all falling within the "outstanding" category.
2. The CBL-based teaching materials were also proven effective in improving students' critical thinking skills. The independent sample t-test yielded a significance value of 0.000 (< 0.05), indicating a statistically significant difference in critical thinking performance between the experimental and control groups. Moreover, the N-gain score was 0.645, which falls into the moderate effectiveness category. This suggests that students in the experimental group showed greater post-test improvement in critical thinking than those in the control group.

## Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

## Copyright:



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