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Effectiveness of Integration of Exit Slips Formative Assessment in Problem Based Learning in Improving Critical Thinking Skills of High School Students on Heat Material

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ABSTRACT

This study was motivated by the need to address the lack of critical thinking skills among students in order to meet the demands of the 21st century. The purpose of this study was to demonstrate the effectiveness of integrating formative assessment in the form of Exit Slips into problem-based learning to improve students' critical thinking skills related to current issues. The research design used was quasi-experimental with matching only pretest posttest control group, involving 69 eleventh-grade students in Bandung. Data were collected using the ACTA test for critical thinking, formative assessment called Exit Slips, and student questionnaires. Data analysis was conducted using the N-Gain test, effect size, and quantitative descriptive analysis. The results of the study showed a significant difference in the improvement of critical thinking skills between the experimental group and the control group, with N-Gain values in the moderate category and effect sizes in the high category. Student responses to the integration of Exit Slips formative assessment into problem based learning were also in the good category. Overall, the integration of Exit Slips formative assessment into problem-based learning was highly effective in improving critical thinking skills.

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1. INTRODUCTION

In this case, students must demonstrate 4C skills: critical thinking, communication, collaboration, and creativity (Partnership for 21st Century learning, 2015). 21st century education must integrate critical thinking, communication, creativity, and collaboration skills into the learning process. One such skill is critical thinking, which must be integrated into students' learning experience. The changing education paradigm emphasizes that teachers should not only teach students what to understand, but also how to think critically (Mansyur & Elvira, 2024).

The results of a preliminary study conducted by researchers at a high school in Bandung revealed that the learning process has not stimulated critical thinking among students. This is evidenced by

students' inability to answer questions measuring critical thinking skills related to heat material given by the teacher. The study was conducted through interviews with physics teachers at the school. This is reinforced by the daily test scores related to heat material which only get an average score of 60. In addition to conducting interviews, researchers also had the opportunity to make observations in one of the classes by asking questions directly to 36 students related to everyday problems that use the concept of heat critically. However, the problem was only able to be answered correctly and accompanied by reasons in accordance with the concept of physics by 5 students out of 36 students or around 13.9%. Thus, physics learning in the school has not been able to stimulate students to think critically on heat material.

This certainly illustrate the gap between the demands of 21st century education and the reality in the field. The low level of think critically, especially in physics lessons, is caused by teachers who are less creative in packaging the learning models used, and tend to lecture more. In addition, students still have difficulty in solving problems and difficulty in linking physics concepts with real phenomena (Sugiarti & Dwikoranto, 2021). In addition, low critical thinking skills are also caused by teachers' difficulties in providing learning assessments and feedback aimed at obtaining information related to the need for improvement at the next meeting, even though this assessment is very necessary to support the Merdeka curriculum (Ardiansyah et al., 2023).

Thus, several previous studies have revealed that think critically skills can be improved through appropriate learning assessments (Budiarta et al., 2021). In this case, the effective learning assessment to do is formative assessment, because this assessment can improve the ongoing learning process through feedback thus, the think critically skills of high school students can increase (Wulandari et al., 2024). The form of formative assessment used is Exit Slips which is an exit ticket containing a set of true and false statements that must be completed with the reasons given to students at the end of the class. After students work on Exit Slips, students will get feedback and the teacher can determine the follow-up at the next meeting (Basco, 2021).

However, it seems that Exit Slips formative assessments need to be integrated with an appropriate learning model to effectively improve of students to think critically (Hartono & Sari, 2022). In this case, the Problem Based Learning model is one of the models intended to improve critical thinking ability (Rusman, 2021). This model is always associated with daily life problems, making it easier for students to understand the learning material. It also requires students to actively think (Suryadi et al., 2023). For this reason, the problem based learning model has the potential to improve students' critical thinking skills.

Previous research is still lacking in discussing formative assessment with the learning model used, the formative assessment discussed has not been studied in depth, it is still too general by not including the types or techniques of formative assessment used. In addition, some previous studies have not integrated formative assessment with the learning model expected in the Merdeka curriculum. Thus, this study focuses on determining the effectiveness of integrating Exit Slips formative assessments into Problem-Based Learning to improve high school students' critical thinking skills regarding heat. This research provides new insights regarding the integration between formative assessments and learning models that are still rarely researched, this will allow the results of the study to be used as a reference for educators and other researchers.

2. METHODS

This study employed a quasi-experimental, quantitative research design with matching only pretest-posttest control group (Fraenkel & Wallen, 2012). In this study, participants were assigned to both the experimental and control groups. Initially, both groups completed a preliminary test, followed by a final test at the conclusion of the teaching period. However, only the experimental group received a specific intervention involving formative assessment Exit Slips integrated into the problem-based learning model over eight hours of instruction across three sessions. The control group, on the other hand, utilized only the problem-based learning model, as detailed in Table 1. The study's population comprised 11th grade students from a high school in Bandung, with the research sample consisting of

classes XI-1 and XI-2, selected through a targeted sampling method. The sample included a total of 69 students from these two classes.

Table 1. Matching-Only Pretest Posttest Control Group Design

Experiment	M	O	X	O
Control	M	O	C	O

Information

M : Matching

O : Pretest Posttest

X : Integration of Exit Slips formative assessment in Problem Based Learning

C : Problem Based Learning

In this study, data were collected through formative assessments using Exit Slips questionnaires and critical thinking tests, developed in accordance with the Assessment of Critical Thinking Ability (ACTA) indicators at the end of each session. The ACTA comprises three indicators: integrating conflicting studies into a unified conclusion, designing experiments to resolve ambiguities in particular studies, and conjecturing other interpretations of particular studies (White et al., 2011). Additionally, data was collected using a student response questionnaire on the integration of Exit Slips formative assessments in Problem-Based Learning. Five experts validated the instrument using construct validity, which was analyzed using Aiken's V formula for material, construction, and linguistic aspects. Construct validation was carried out by providing an assessment on a validation sheet containing aspects of material, construction, and language, with a range of numbers from 1 to 5. After the instrument was declared valid, it was tested on 33 high school students who had learned the material. A reliability value of 0.70 in the high category was obtained, so the instrument was declared valid and reliable for research purposes. Additionally, data processing was conducted using N-Gain to evaluate critical thinking skill improvement, an independent t-test and effect size to assess the effectiveness of integrating assessments into learning, and descriptive statistics to analyze student responses to integrating Exit Slips formative assessments into Problem-Based Learning.

3. RESULT AND DISCUSSION

The analysis used to determine the effectiveness of integrating Exit Slips formative assessments into Problem-Based Learning in order to improve high school students' critical thinking skills regarding the use of thermal materials uses N-Gain and the size effect. Before that, however, preliminary tests were carried out: a normality test and a homogeneity test. The normality test of the pre-test and post-test in the control and experimental classes was carried out using the Shapiro-Wilk test, as the sample size was less than fifty (Mohd Razali & Bee Wah, 2011). The normality test results show a significance value of over 0.05, which means that the data meets the normality assumption. To see if the data comes from a population with the same variance, a homogeneity test was done using the Levene test on normally distributed data. The Levene test was performed using the post-test scores for the experimental and control groups. The results yielded a significance value of 0.533, indicating that the data meet the assumptions of homogeneity.

3.1 Improvement of Critical Thinking Skills of High School Students

To assess whether there is an improvement in critical thinking skills following the integration of Exit Slips formative assessment into Problem-Based Learning, Normalized Gain (N-Gain) is utilized. The N-Gain calculation can be performed using SPSS 26 software. The formula used to compute N-Gain is as follows:

$$\langle g \rangle = \frac{\langle posttest - pretest \rangle}{\langle 100 - pretest \rangle} \quad (3.1)$$

Table 2. N-Gain Test

Variable	Experiment	Control
Total Data	35	34
N-Gain	0,69	0,55
Category	Medium	Medium

According to Table 2, it can be inferred that the N-gain for the experimental group (0.69) is greater than that of the control group (0.55), even though both are categorized as average. This indicates an enhancement in critical thinking skills within the experimental group following the integration of Exit Slips formative assessments into problem-based learning. While the pre-test scores were relatively similar, the experimental group exhibited a higher N-Gain due to the consistent application of Exit Slips formative assessments in the Problem-Based Learning model during each session. This approach helped students become more accustomed to new information and developed their critical thinking abilities. Consequently, when the post-test was administered at the conclusion of the study, students in the experimental group performed significantly better and achieved higher scores than those in the control group. Additionally, the N-Gain value for the experimental group was in the moderate range but leaned towards high, indicating a notable improvement in critical thinking skills compared to the control group.

This is consistent with the results of Sukma Pradita's 2021 research, which indicates that formative assessment can improve students' critical thinking skills in physics, especially when implemented over three consecutive sessions, yielding average scores of 73, 81, and 86. The study utilized ten descriptive questions along with three formative assessment questions designed to assess critical thinking abilities. Furthermore, an increase in critical thinking skills was measured and analyzed using N-Gain, resulting in a value of 0.31, which is categorized as moderate (Dita et al., 2021). So in this case, the formative assessment applied in physics learning is able to improve critical thinking skills.

In addition to analyzing the overall N-Gain results, this study also investigated how enhancements in critical thinking skills across each ACTA (Assessment of Critical Thinking Ability) indicator influenced the N-Gain test outcomes in the experimental group. The questions in the study were tailored to align with the three ACTA critical thinking indicators. Table 3 presents the average N-Gain values for the experimental group corresponding to each ACTA critical thinking indicator.

Table 3. Average N-Gain value for each ACTA indicator

ACTA Indicator	Pretest	Posttest	N-Gain	Interpretation
CTA 1: integrating conflicting studies into a unified conclusion	53,90	89,71	0,78	High
CTA 2: designing experiments to resolve ambiguities in particular studies	33,14	71,64	0,58	Medium
CTA 3: conjecturing other interpretations of particular studies	50,10	88,38	0,77	High

According to the findings presented, the enhancement of students' critical thinking skills following the incorporation of Exit Slips formative assessments into problem-based learning in the experimental group is clearly reflected in the N-Gain values for each indicator. The N-Gain value for the CTA 1 indicator is 0.78, categorizing it as high. The CTA 2 indicator has an N-Gain value of 0.58, placing it in

the medium category. Meanwhile, the CTA 3 indicator shows an N-Gain value of 0.77, which is also classified as high.

In this finding, the N-Gain value is quite different in each indicator, this is because the CTA 1 indicator includes student skills to be able to provide explanations, interpretations, or understandings and personal views on conflicting knowledge into a conclusion. In this case, students are given conflicting problems to critically examine the explanation in the form of conclusions. For CTA indicator 1, it is in question items number 1 and 2 with heat and temperature changes and black principle. In addition, this indicator has been widely trained to students related to the presentation of conflicting problems so that students feel familiar and have no difficulty in integrating conflicting knowledge into a unified conclusion. This finding is in line with relevant research conducted by Amaningsih in 2021 which suggests that the integrating indicator (CTA 1) tends to be easier for students to do because this indicator is the basic indicator of the ACTA indicator so it is possible if the N-Gain value obtained gets good results (Amaningsih et al., 2021).

Furthermore, designing experiments to resolve ambiguities in knowledge is an indicator of CTA 2, which was proposed by Brian White in 2011. This indicator encompasses students' ability to design experiments, from determining the purpose and necessary tools and materials to planning the steps for processing experimental data. This certainly requires students to have a higher level of basic knowledge compared to CTA indicator 1. CTA indicator 2 is addressed in questions 3 and 4, which involve heat and form change sub-materials. In these questions, students are asked to design experiments related to the effect of heat on changes in the form of substances. CTA 2, the indicator of designing experiments, has an N-Gain value in the medium category (0.58). This indicates a decrease in students' critical thinking skills in designing experiments. This is because most students have not been able to utilize the basic knowledge gained from the integrating indicator. Additionally, the designing indicator requires more complicated instruments than the previous indicators. Therefore, this indicator has not been widely taught to students. Additionally, designing experiments is still very abstract for some students. This finding aligns with Brian White's 2011 theory that students tend to find the designing experiments indicator (CTA 2) more difficult to understand in a short period of time. This indicator requires long-term practice so students can become accustomed to designing experiments (White dkk., 2011).

CTA indicator 3, conjecturing other interpretations of particular studies includes students' skills to be able to predict other interpretations of the knowledge or problems presented. In this case students are given problems to predict about how other interpretations of the problem. For CTA indicator 3, it is in question items number 5 and 6 with heat transfer sub-material. The N-Gain results on the integrating indicator (CTA 3) are in the high category, this indicates an increase in students' critical thinking skills, because the estimating indicator is more concrete and contextual than the indicator of designing experiments. So that students have less difficulty in this indicator. For example, in item number 5 students are asked to predict related to factors that affect heat transfer. In this case, most students were able to answer correctly but not accompanied by a complete explanation. This result is in line with the relevant theory proposed by Brian White in 2011 which states that the estimating indicator (CTA 3) tends to be easier for students to do because this indicator tends to have a clearer and more concrete context than CTA 2.

As a result, students in the experimental group showed a notable enhancement in their critical thinking skills by incorporating Exit Slips formative assessments into Problem-Based Learning, particularly in their ability to synthesize conflicting research into a cohesive conclusion and to propose alternative interpretations of specific studies.

3.2 Effectiveness of Exit Slips Formative Assessment Integration in Problem Based Learning

The effect size was used to determine how effective the integration of Exit Slips formative assessments into the problem-based learning model is in developing critical thinking skills (Cohen, 1988). The effect size was calculated using Cohen's d effect size calculator, which involved inputting the

mean values and standard deviations from the posttest results of both the experimental and control groups, as presented in Table 4.

Table 4. Cohen's d Effect Size

Variable	Experiment	Control
Mean (M)	82,09	73,24
Standard Deviation(SD)	8,311	7,394
d	1,125	
Category	High	

Based on the data presented above, it can be concluded that integrating Exit Slips formative assessments into problem-based learning is highly effective in improving critical thinking skills, with an effect size of 1.125 in the upper category. This demonstrates the effectiveness of integrating Exit Slips formative assessments into problem-based learning, which enhances students' critical thinking skills.

Furthermore, in terms of N-Gain value, both in the experimental and control groups, the N-Gain value falls within the average range, with a high magnitude effect. This is consistent with research conducted by Jelita in 2022, according to which the difference between the criteria obtained between N-Gain and the effect size is due to internal variations in the experimental and control classes. Although there is a significant overall difference that determines a high effect size, the pre-test and post-test scores of the experimental and control classes show that most students show significant growth, while some do not. This makes the N-Gain value obtained fall into the medium category, and the effect size value obtained into the high category (Jelita dkk., 2022). This is confirmed by research conducted by Khairunnisa in 2022, according to which the N-Gain value falls into the medium category, while the Effect Size falls into the high category. This difference in category may be due to a significant difference in pre-test scores between the experimental group and the control group. However, after completing treatment, neither group experienced a significant increase (Khairunnisa dkk., 2022).

The integration of Exit Slips formative assessment into problem-based learning is considered effective if statistical test results show a significant difference between experimental and control classes, and effect size results show a moderate ($0.5 \leq d \leq 0.8$) or high ($0.8 \leq d \leq 2.0$) impact. Based on the results presented in Table 4.6, which compares the critical thinking results of the experimental and control classes, there is a significant difference in critical thinking abilities. The effect size results meet high criteria. Thus, the integration of Exit Slips formative assessments into problem-based learning effectively improves students' critical thinking skills. This is consistent with the idea that critical thinking skills can improve learning effectiveness through the inclusion of formative assessment (Bulunuz dkk., 2014).

The Exit Slips formative assessment is in the form of true and false statements equipped with critical reasons for students to answer right or wrong which have been adjusted to the ACTA critical thinking indicators. The Exit Slips formative assessment aims to see the extent to which students are able to master their knowledge during the learning process. By doing Exit Slips, this has made it easier for researchers to monitor how students' knowledge is so that researchers can provide appropriate feedback for each student (Gunawan & Soesanto, 2022). From this feedback, researchers need to conduct follow-up for students in order to improve critical thinking skills. These Exit Slips are done at the end of learning at each meeting. So that at the next meeting students receive feedback, they also receive follow-up from the teacher. So that from each administration of the Exit Slips formative assessment for three meetings can describe how the development of students' critical thinking skills at each meeting.

The formative assessment Exit Slips enables teachers to monitor the development of students' critical thinking skills at each meeting. Therefore, the formative assessment Exit Slips is effective in improving critical thinking skills in problem-based learning. Figure 1 shows the development of students' critical thinking skills after the integration of the formative assessment Exit Slips into problem-based learning.

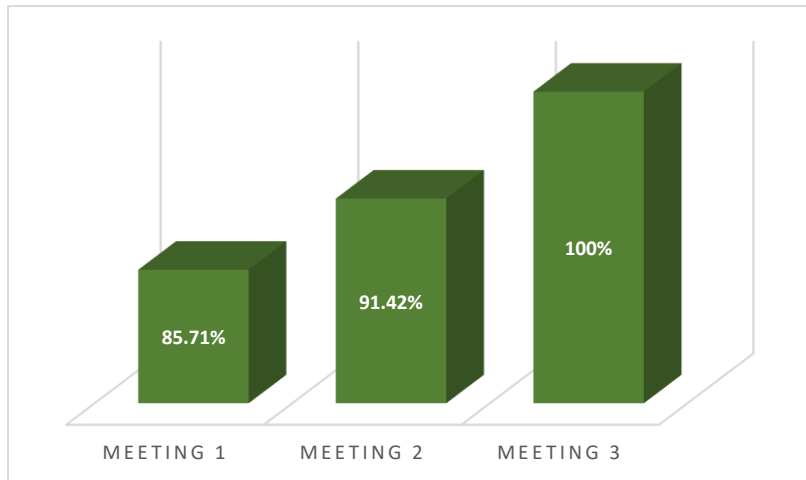


Figure 1. The Development of Critical Thinking on the Exit Slips Formative Assessment

Based on Figure 1, there was a significant increase in the results of the Exit Slips formative assessment in improving students' critical thinking skills at each meeting. At meeting 1, 30 students or 85.71% were in the complete category in answering the Exit Slips formative assessment, at meeting 2, there was an increase of 2 students, so that 32 students or 91.42% were in the complete category, and at meeting 3, 35 students or 100% were in the complete category with scores between 75 - 100. By seeing significant developments at each meeting, this proves that the integration of Exit Slips formative assessment in Problem Based Learning is very effective in improving students think critically skills on heat.

3.3 Student Response to the Integration of Exit Slips Formative Assessment on Problem Based Learning on Heat Material

In addition to seeing the improvement and effectiveness of assessment integration, it was also seen related to student responses to the integration of Exit Slips formative assessments which were analysed using descriptive quantitative obtained from the results of student response questionnaires distributed via google form in experimental classes using a Likert scale with five answer options, namely strongly agree, agree, hesitate, disagree, and strongly disagree (Sugiyono, 2019), with the following results.

Table 5. Student Response Questionnaire

No	Statement	Percentage (%)	Category
1.	I feel that learning physics in class is more fun after integrating the Exit Slips formative assessment in the Problem Based Learning model.	77,7	Good
2.	I find it difficult to think critically on heat material after integrating the Exit Slips formative assessment in the Problem Based Learning model.	64,0	Good
3.	I am more motivated in learning the heat material after integrating the Exit Slips formative assessment in the Problem Based Learning model.	75,4	Good

No	Statement	Percentage (%)	Category
4.	I feel that the integration of Exit Slips formative assessment does not affect physics learning in class.	72,0	Good
5.	The Exit Slips formative assessment really helps me in recalling the heat material that has been learnt	78,9	Good
6.	The integration of Exit Slips formative assessment in Problem Based Learning does not stimulate me to think critically.	68,6	Good
7.	I experienced difficulties when learning the heat material after integrating the Exit Slips formative assessment in Problem Based Learning.	65,1	Good
8.	My ability to think critically on heat material increased after integrating Exit Slips formative assessment in learning.	74,3	Good
9.	The feedback given by the teacher on the Exit Slips formative test really helped me in understanding the heat material.	78,9	Good
10.	I believe integrating Exit Slips into the Problem-Based Learning model is an effective way to improve think critically skills.	77,1	Good
Average		73,2	Good

Based on the above data, students' responses to integrating Exit Slips formative assessments into the Problem-Based Learning model meet the good criteria. Through this questionnaire, we can see that the lowest percentage, 64.0%, is for statement 2 (negative statement), which shows that most students disagree that students find it difficult to think critically after the integration of Exit Slips formative assessment in the Problem Based Learning model. These results suggest that most students find the integration of Exit Slips formative assessment in Problem Based Learning helpful for honing critical thinking skills.

While the highest percentage was 78.9% with good criteria in statements 5 and 9 (positive statements). In this case, the average student agrees with the Exit Slips formative assessment statement can help recall heat material, and some students also agree with the statement that the feedback provided by the teacher on the Exit Slips formative assessment is very helpful for students in understanding heat material. Based on this, it means that students feel that formative assessments really help make learning easier and students are happy when they get learning results in the form of Exit Slips formative assessments accompanied by feedback, so that students can find out which parts are lacking and need to be improved and improved during the learning process. So that in the end it is expected that students' critical thinking skills can also increase. This is in accordance with relevant research conducted by Dianti in 2025, which states that formative assessment contains teacher and student activities that aim to monitor and evaluate learning so that students can make improvements after getting suggestions and input from the teacher (feedback) (Dianti dkk., 2025).

If recapitulated from all statements, an average of 73.2% is obtained which is in the good criteria. This questionnaire contains 6 positive statements and 4 negative statements with a scoring rubric that has been adjusted to the statement. In positive statements the answer choice strongly agree has a score of 5, while in negative statements the answer choice strongly agree has a score of 1, so the highest score in the questionnaire is 5 and the lowest score is 1.

Thus, most students responded well to the integration of Exit Slips formative assessments into the Problem Based Learning model to improve think critically skills regarding the subject matter. This suggests that the integration of Exit Slips formative assessments in the Problem-Based Learning model can continue to be used and developed in future research.

4. CONCLUSION

Integrating Exit Slips formative assessments into Problem Based Learning significantly improves high school students' think critically skills, especially with regard to integrating conflicting studies into a unified conclusion and conjecturing other interpretations of particular studies. Furthermore, statistical test results show that incorporating formative assessment Exit Slips into problem-solving learning is effective in improving students' think critically skills regarding heat-related teaching materials. Most students responded positively to the incorporation of formative assessment Exit Slips into problem-solving learning in heat-related teaching materials. Therefore, integrating formative assessment Exit Slips into problem based learning effectively improves high school students' think critically skills regarding thermal materials. Future research should focus on further optimizing critical thinking skills in experimental design to address specific research uncertainties by increasing the number of exercises related to the design of physics experiments. Additionally, it is recommended to verify the effectiveness of integrating Exit Slips into other educational models and conduct further research to help students reach the excellent category in their responses. In this way, this study contributes to innovation in physics education and adds a new reference point for the integration of formative assessment.

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