Development of a Pbl-Based E-Module of Substance Transport and Exchange Process to Improve Critical Thinking Skills of Students of SMAS Jenderal Sudirman Kalipare Malang

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Article Info	ABSTRACT
	21st century education must be adapted to the demands of the times so that students are able to compete in the future. One of the 21st century skills needed in learning is critical thinking. Learning that supports critical thinking skills is the problem-based learning model (PBL). The problem-based learning model can have a significant effect on critical thinking skills. Students are required to have critical thinking skills to be able to compete competitively. One of the innovations in biology learning is the development of e-module of Substance Transport and Exchange Process to train students' critical thinking skills. This e-module development uses the ADDIE development model. The e-module of the Substance Transport and Exchange Process after being validated obtained a very valid validity, namely the results of media validation obtained an average of 95.5% with a very valid category, the results of material validation were 100% with a very valid category. The results of practicality are very practical, namely individual trials (one to on trial) obtained an average of 82.22% with a very practical category, small group trials obtained an average of 86.26% with a very practical category, practicality of biology education practitioners obtained an average of 100% with a very practical category. Effectiveness test to improve students' critical thinking skills. The average result of each indicator of critical thinking skills pretest is 35.86 and posttest is 59.78 which indicates an increase in students' critical thinking skills with N-Gain results of 0.3 with moderate effectiveness category. Data on the percentage of PBL model implementation showed an average value of each stage carried out of 91.7% with a very implemented category.

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1. INTRODUCTION

21st century education must be adapted to the demands of the times, so that students are able to compete in the future. 21st century skills can be achieved by updating the quality of learning and adjusting learning to encourage 21st century skills in students. Through education, students are expected to be proficient in various 21st century skills such as critical thinking (Tang et al., 2020). However, education is currently experiencing problems, namely the lack of empowerment of critical thinking skills, so that critical thinking skills are still relatively low (Hamdani et al., 2019). These problems require students to be skilled in determining solutions to solve problems so that students' critical thinking skills need to be improved (Fox, 1962; Elin Driana, 2019).

Based on the results of the analysis of the needs of students of SMAS Jenderal Sudirman Kalipare Malang using the daily test scores on the material of the Substance Transport and Exchange Process, it shows that students' critical thinking skills obtain an average of 39.54 which is included in the category (low). This shows that it is important to improve students' critical thinking skills (Rachmawati and Rohaeti 2018). The low critical thinking skills of students can be caused by material that is difficult to understand, learning methods that are less interesting and learning resources that are incomplete and less relevant. Classroom learning that is carried out is still in the form of memorizing information (Lestari & Irawati, 2020). Learning like this results in students being less able

to connect what is learned with how the knowledge will be utilized or applied in new situations. Students will lose motivation to be active in learning which can lead to a decrease in students' critical thinking skills (Putriningtyas et al., 2022). Students' difficulties are evidenced by the fact that students state that the material is abstract and complex, another reason is that it is difficult to apply concepts to everyday life, and the learning process is less effective. Media and teaching materials used in learning have a very important role in the implementation of learning. The use of media in learning can increase the effectiveness of learning, especially in learning Biology.

One of the innovations in learning biology on the material of the Process of Transport and Exchange of Substances that can be used is the development of e-modules of the Process of Transport and Exchange of Substances with the learning model used, namely problem-based learning with the hope of making learning more effective and students become more active. Students become more active by being guided to build initial knowledge with a problem orientation that is presented to students. The problem-based learning model can have a significant effect on students' critical thinking skills (Fadilla et al., 2021). In learning, teachers must be more creative in using technology as a learning medium. Developing interesting learning media and adding certain features to learning materials is needed to show something abstract.

The development of this e-module is designed to provide opportunities for students to actively participate in learning and improve students' critical thinking skills (Prabasari et al., 2021). E-module is an independent learning material presented in a systematic and coherent electronic format (Puspitasari et al., 2020). E-module is an ICT-based module, which is interactive, facilitates and can display/load images, audio, video, and animation and is equipped with tests/quizzes (Wahyuni, 2020). Electronic teaching materials can make the learning process more interesting, interactive, can be done anytime and anywhere and can improve the quality of learning (Ramadhina & Pranata, 2022). The development of this e-module can be an alternative learning resource and biology learning media to increase the utilization of technology and assist teachers in delivering biology material (Astuti & Riefani, 2022).

2. RESEARCH METHOD

This research uses research development (research development) with the ADDIE model in producing media using the Problem Based Learning (PBL) learning model to improve students' critical thinking skills. The sample used is XI-2 MIPA class students of Jenderal Sudirman Kalipare Malang High School, totaling 23 students with 15 male students and 8 female students. The choice of the ADDIE development model is based on the advantages of the ADDIE model, namely 1) simple development stages, 2) there are revisions at each stage, 3) the stages are not linear, that is, they can return to the previous stage (Andi Rustandi & Rismayanti, 2021). The steps of the ADDIE development model that researchers use are analyzing (analyze), designing (design), developing (develop), implementing (implement) and evaluating (Evaluate). The ADDIE model development design is shown in Figure 1.
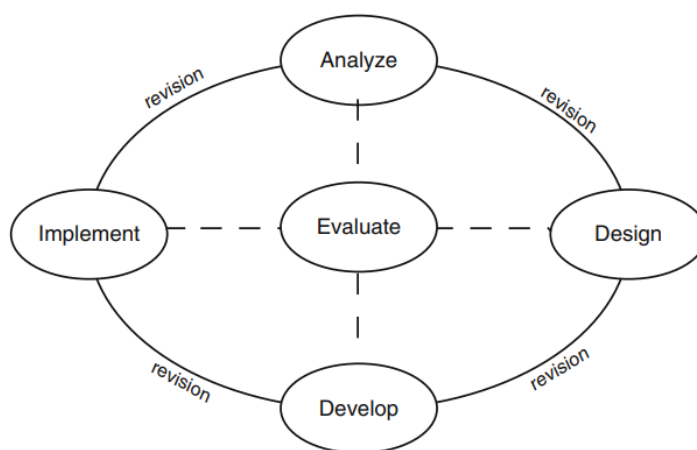

Figure 1: ADDIE Research and Development Model Chart

3. RESULT AND DISCUSSION

The validity of the e-module of the Process of Substance Transport and Exchange can be seen from the results of the validation of material experts, the results of media experts. The practicality of the e-module of the Process of Substance Transport and Exchange can be seen from the individual trial one to one trial, small group trial, field test trial, conduct a pilot test, and practicality of biology education practitioners. The validity and practicality of the e-module is carried out with a rubric of material and media feasibility assessment criteria in Table 1.

Table 1. Criteria for Evaluating the Validity/Practicality of E-modules

Skor (%)	Validity/Practicality Level	Description
85,01-100,00	Very Valid/Practicality	Product can be used without revision
70,01-85,00	Valid/Practicality	Product can be used with minor revisions
50,01-70,00	Less Valid/Practicality	Product can be used with many revisions
01,00-50,00	Not Valid/Practicality	Produk masih perlu perbaikan dengan intensif

Source: Akbar, (2013:41).

Measurement of the effectiveness of the e-module of the Process of Transport and Exchange of Substances is done by giving a pretest and posttest in the form of critical thinking questions. Calculation of the increase in the value of critical thinking skills is done by calculating the n-gain score. The formula for calculating the n-gain value (average gain) is as follows.

$$<g> = \frac{((Sf) - (Si))}{(100 - (Si)}$$

Description:

$<g>$: Normalized score gain

Sf : Average posttest score

Si : Average pretest score

The calculation of the n-gain score has several categories for the interpretation of the results. The categories of the n-gain score calculation results can be seen in Table. 2.

Table 2. Category of *N-Gain* calculation results

No	Range	Effectiveness Level
1	$<g> \geq 0,7$	High effectiveness
2	$0,3 \leq (<g>) < 0,7$	Medium effectiveness
3	$(<g>) < 0,3$	Low effectiveness

Source: Hake, (1999:1).

Analysis of the Validity Results of the E-module of Substance Transport and Exchange Processes
a) Media Expert Validation

The aspects assessed for validation of the e-module development of the Substance Transport and Exchange Process by media experts are: cover, content, e-module characteristics, cover. The results of validation from media experts can be seen in Table 3.

Table 3. Media Expert Validation Results

No	Indicator	Average	Score %	Category
1.	Front cover	4,8	96	Very Valid
2.	Contents	4,5	90	Very Valid
3.	E-module Characteristics	4,8	96	Very Valid
4.	Back Cover	5	100	Very Valid
	Average		95.5	Very Valid

Source: Adaptation of Permendikbud (2017:23) adjusted to learning objectives

The criteria for validity by media experts are categorized as very valid with a percentage of 95.5%. Media expert validation was conducted once with the validation results showing that the e-module already has an attractive appearance, easy-to-understand language related to the explanation of the material in the video, complete media illustrations and ease of operating the media with various existing features. The validated e-module is suitable for use as learning media and can attract students' interest in learning.

b) Material Expert Validation

The aspects assessed for the validation of the e-module development of the Substance Transport and Exchange Process by material experts include title, completeness of presentation, language suitability, identifying, and analyzing. The results of validation from material experts can be seen in Table 4.

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Table 4. Results of E-module Validation by Material Experts

No	Average	Average	Score %	Category
1.	Title	5	100	Very Valid
2.	Completeness of presentation	4,5	100	Very Valid
3.	Language appropriateness	4,6	100	Very Valid
4.	Identify	4,8	100	Very Valid
5.	Analyze	4,6	100	Very Valid
	Average		100	Very Valid

Source: Adaptation of Permendikbud No. 8 (2016:23) adjusted to learning objectives

Material expert validation involves two stages, where in the first stage validation is carried out by obtaining a percentage of 87.2% with a very valid category. The material expert validation process obtained suggestions from material experts for the validated e-module of the Process of Transport and Exchange of Substances, namely adding supporting images, and adding a series of materials. The results of the revision add supporting images have been added so that it is easy to understand the abstract material, adding a series of material has been added so that it is easy to understand clearly. According to Prasasti & Anas (2023) in developing media, the arrangement of words and sentences must be clear, straightforward, simple and easy to understand. The material expert validation process after revision received a percentage of 100% with a very valid category.

The criteria for validity by material experts is very valid with a percentage of 100% after validating after revision. According to Akbar (2017) the number 100% indicates that the e-module has very valid criteria. The results of the material expert validation must get a percentage of 100% which is classified into very valid criteria because it greatly affects the learning process and to educators so that there are no misconceptions when delivering material. Fidayani & Ammar (2023) explained that teachers who do not master the material or have an incorrect understanding of a concept will cause students to experience misconceptions.

Analysis of the Practicality Results of the E-module of the Process of Substance Transport and Exchange
a) Individual Trial Results (One to One Trial)

Individual trials were conducted on students who had taken the material on the Process of Transport and Exchange of Substances. The individual trial was conducted in class XII MIPA SMAS Jenderal Sudirman Kalipare Malang City. The instrument used was a student response questionnaire. The individual trial selected 3 students with different academic abilities, namely high, medium, and low academics based on the report card scores given by the biology teacher. The purpose of selecting students with different categories is intended so that this e-module can be used by all students with heterogeneous abilities in the classroom (Imas, 2022). The results of individual trials obtained an average score of 82.22% with a very practical category. The results of the individual trial can be seen in Table 5.

Table 5. One to One Trial Results

No	Respondents	Total Score	Score Max	Average Score %	Category
1	Students 1	81	90	90	Very Practical
2	Students 2	73	90	81.11	Very Practical
3	Students 3	68	90	75.55	Practical
	Average			82.22	Very Practical

b) Results of Small Group Trial

The small group trial was tested on 11 students who were chosen to represent students with low, medium and high academic abilities. The small group trial was conducted in class XII MIPA SMAS Jenderal Sudirman Kalipare Malang City. The small group trial was conducted by giving student response questionnaires to students to find out student responses to the e-module developed. The results of the small group trial obtained an average score of 86.26% with a very practical category. The results of the small group trial can be seen in Table 6.

Table 6. *Small Groub Trial*

No	Respondents	Total Score	Score Max	Average Score %	Category
1	Students 1	68	90	75.55	Practical
2	Students 2	68	90	75.55	Practical
3	Students 3	68	90	75.55	Practical
4	Students 4	81	90	90	Very Practical
5	Students 5	76	90	84.44	Very Practical
6	Students 6	80	90	88.88	Very Practical
7	Students 7	81	90	90	Very Practical

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No	Respondents	Total Score	Score Max	Average Score %	Category
8	Students 8	81	90	90	Very Practical
9	Students 9	81	90	90	Very Practical
10	Students 10	85	90	94.44	Very Practical
11	Students 11	85	90	94.44	Very Practical
	Average			86.26	Very Practical

c) Field Test Trial

Field trials were conducted to determine the feasibility of the e-module before it was implemented. If the field trial shows that the e-module is not feasible to use, it is necessary to revise the e-module. Field trials were conducted by giving student response questionnaires to students to find out student responses to the e-module developed. The results of the field trial were used as the basis for improving the e-module before it was implemented. However, researchers used the wrong class, namely the class used as the implementation class, so for future researchers to use a class that has learned the material to be implemented in the Field Test Trial stage. The results of the Field Test Trial obtained an average score of 82.26% with a very practical category. Field test results can be seen in Table 7.

Table 7. *Field Test Trial*

No	Respondents	Total Score	Score Max	Average Score %	Category
1	Students 1	81	90	90	Very Practical
2	Students 2	65	90	72.22	Practical
3	Students 3	63	90	70	Practical
4	Students 4	80	90	88.88	Very Practical
5	Students 5	81	90	90	Very Practical
6	Students 6	70	90	77.77	Practical
7	Students 7	79	90	87.77	Very Practical
8	Students 8	71	90	78.88	Practical
9	Students 9	71	90	78.88	Practical
10	Students 10	81	90	90	Very Practical
11	Students 11	77	90	85.55	Very Practical
12	Students 12	62	90	68.88	Practical
13	Students 13	78	90	86.66	Very Practical
14	Students 14	78	90	86.66	Very Practical
15	Students 15	58	90	64.44	Practical
16	Students 16	78	90	86.66	Very Practical
17	Students 17	77	90	85.55	Very Practical
18	Students 18	86	90	95.55	Very Practical
19	Students 19	81	90	90	Very Practical
20	Students 20	82	90	91.11	Very Practical
21	Students 21	78	90	86.66	Practical
22	Students 22	72	90	80	Practical
23	Students 23	89	90	98.88	Practical
24	Students 24	68	90	75.55	Practical
25	Students 24	76	90	84.44	Very Practical
26	Students 26	43	90	47.77	Practical
	Average			82.26	Very Practical

d) Conduct A Pilot Test

Conduct a pilot test is conducted to find out the e-module media of the Process of Substance Transport and Exchange before carrying out the implementation. Conduct a pilot test is tested in class XI or other classes that are studying the material of the Process of Transport and Substance Exchange. At the conduct a pilot test stage, the author decided not to conduct a pilot test. This decision is based on very tight and limited time constraints, given the implementation schedule that will soon be implemented.

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e) Practicality of Biology Education Practitioners

Practicality by biology education practitioners is carried out to determine the feasibility of e-modules before implementation. If the practicality test by biology education practitioners shows that the e-module is not feasible to use, it is necessary to revise the e-module. Practicality of biology education practitioners is done by giving practicality sheets to biology teachers. The results of practicality by biology education practitioners are used as the basis for improving the e-module before it is implemented. The results of practicality by biology education practitioners obtained a score of 100% with a very practical category. The results of practicality by biology education practitioners can be seen in Table 8.

Table 8. Biology Education Practitioner Validation Results

No	Indicator	Average	Average Score %	Category
1.	Component Completeness	5	100	Very Practical
2.	Characteristics	5	100	Very Practical
3.	Presentation	5	100	Very Practical
4.	Language	5	100	Very Practical
5.	Material	5	100	Very Practical
6.	Access and Use	5	100	Very Practical
7.	Learning Objectives	5	100	Very Practical
	Average		100	Very Practical

Practicality by biology education practitioners is based on designing media that can assist student learning in electronic form. E-module of students' Substance Transport and Exchange Process is a media designed to carry out learning in students. E-modules in non-print form resemble printed books but products in the form of soft files so that they can be distributed efficiently and economically to overcome the limitations of printed books (Raihan et al., 2018). The electronic form can make students easier to access through computers, laptops or smartphones with the aim that students are smoother in receiving understanding of learning materials (Rahmawati et al., 2019).

The criteria for practicality by biology education practitioners is very practical with a percentage of 100%. According to Akbar (2017), the number 100% indicates that the e-module of Substance Transport and Exchange Process has very practical criteria. The results of practicality by biology education practitioners indicate that the e-module of Substance Transport and Exchange Process can be used as learning media by teachers in the learning process. The material contained in the E-module of Substance Transport and Exchange Process is in accordance with the learning outcomes and learning objectives. The Substance Transport and Exchange Process E-module has a media display that attracts student interest and is easy to access. The practicality results have a 100% practicality level on each indicator such as completeness of components, characteristics, presentation, language, material, access and use, learning objectives. The substance transport and exchange process e-module is very practical to use to make it easier for students to learn the substance transport and exchange process material.

Analysis of the Results of the Effectiveness of the E-module of the Process of Transport and Exchange of Substances on Critical Thinking Skills

The effectiveness of the e-module measures students' critical thinking skills seen from the results of students' pretest and posttest. Pretest and Posttest of critical thinking skills are based on indicators of critical thinking skills according to Greenstein (2012) contained in each essay question. Students' pretest results have an average of 36.6 which is classified as low while students' posttest results have an average of 60.6 which is classified as moderate.

The results of the N-Gain calculation show that the e-module of the Transport and Exchange Process of Substances is moderately effective to improve students' critical thinking skills. The results of the n-gain calculation are in accordance with research from Suyatna et al., (2017) which states that e-modules can build critical thinking skills when arranged in accordance with the stages of the scientific approach. Critical thinking skills are observed from the indicators of critical thinking skills according to Greenstein on each question, namely applying, evaluating, developing data for critical knowledge, analyzing, and synthesizing. The n-gain results of critical thinking skills can be seen in Table 9.

Table 9. N-Gain Results of Critical Thinking Skills

Spretest	Sposttest	N-Gain	Category
35.86	59.78	0.3	Medium Effectiveness

Based on Table 8. The results of the pretest-posttest N-gain calculation of critical thinking obtained a pretest and posttest N-gain value of critical thinking of 0.3 which is included in moderate effectiveness. Comparison of pretest-posttest results can be seen in Figure 2, while the comparison of gains in each indicator can be seen in Figure 3.

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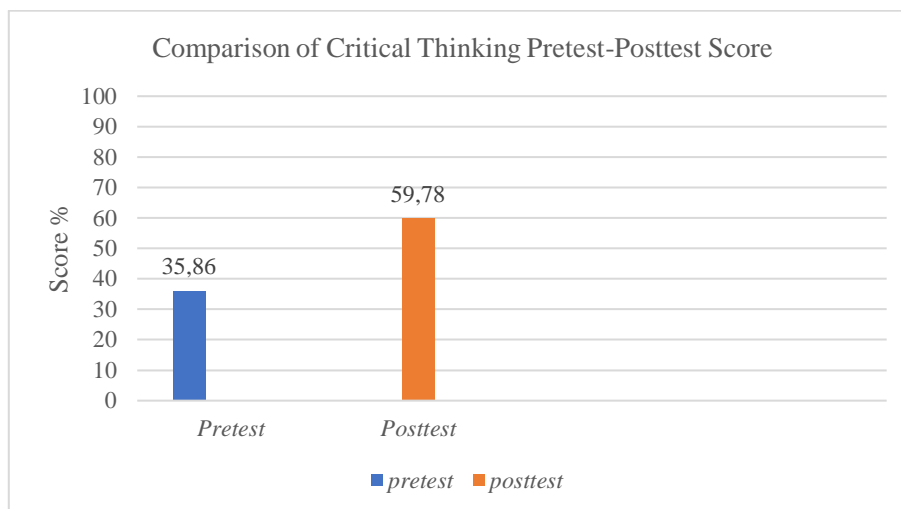
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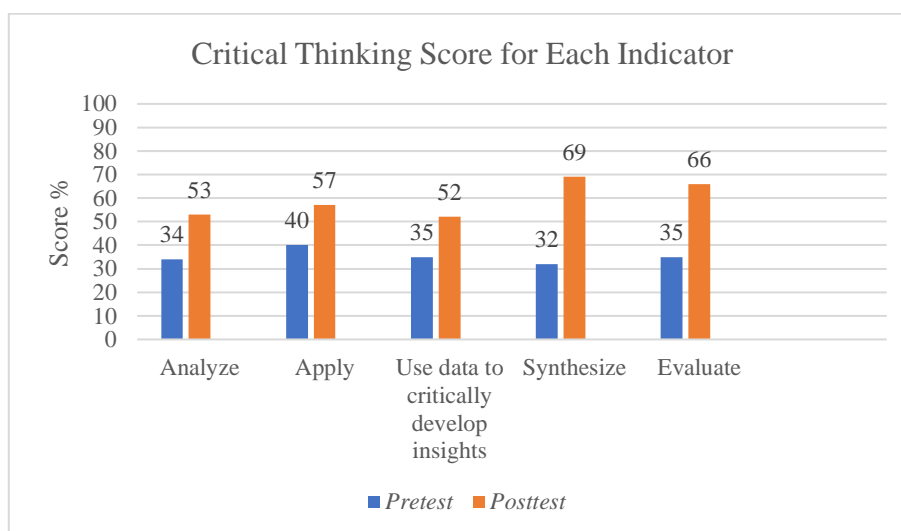Figure 2. Comparison of Critical Thinking Pretest-Posttest Score

Figure 3. Critical Thinking Score for Each Indicator

The average result of each critical thinking skills pretest indicator is 35.86 and on the posttest is 59.78 which indicates an increase in critical thinking skills with an N-Gain result of 0.3 with a moderate effectiveness category. Critical thinking skills can be improved by the presence of contextual media. Susilawati et al.'s research (2020) states that critical thinking skills will be more developed if they are related to everyday life (Kusumaningtyas & Yanti, 2021).

Analysis of the Implementation of the Syntax of the Problem Based Learning (PBL) Model
The implementation of the learning process stages was analyzed using observation data conducted by observers using the observation format for the implementation of the Problem-based Learning (PBL) model. The results obtained from the learning process in the research activities can be seen in Table 10.

Tabel 10. Results of the Implementation of PBL Syntax

| Meeting | Score for each activity | | | | | | | Rate % | Category |
	Introduction	1	2	3	4	5	Cover		
1	4.33	4.25	4.33	4.66	5	4	4	87.34	Very well done
2	4.33	5	4.66	4.66	5	5	4	93.29	Very well done
3	4.33	5	4.66	4.33	5	3.5	4	88.06	Very well done

Meeting	Score for each activity							Rate %	Category
	Introduction	1	2	3	4	5	Cover		
4	5	4.5	5	4.66	5	4	4.5	93.31	Very well done
5	5	3.75	5	5	5	4	5	93.57	Very well done
6	5	5	4.66	5	5	4	4.5	94.74	Very well done
Average								91.7	Very well done

Source: Adaptation of Greenstein (2012: 411)

Data on the percentage of implementation of Problem Based Learning (PBL) in Table 10 shows the average value of each stage carried out is 91.7%. The implementation of the PBL model is at a percentage between 81% - 100%; meaning that it is in the category of highly implemented. The implementation can be declared successful because it is supported by several factors, namely the problems discussed in the learning process are not new, meaning that students face these problems in everyday life in their environment (original), the teacher has explained how to solve these problems. The learning process is carried out using the Problem-based Learning (PBL) model, students are accustomed to learning both individually and in groups, discovering and discussing the learning process, a supportive environment and community helps students to collaborate actively.

4. CONCLUSION

Based on the results of the study, it is concluded that the e-module of Substance Transport and Exchange Process is very valid, practical and effective to improve students' critical thinking skills. This can be seen through the results of validation by media experts obtained an average of 95.5% with a very valid category, material experts obtained an average of 100% with a very valid category. Practicality with a very practical category includes individual trials (one to on trial) obtained an average of 82.22% with a very practical category, small group trials obtained an average of 86.26 with a very practical category, practicality of biology education practitioners obtained an average of 100% with a very practical category. Effectiveness test to improve students' critical thinking skills. The average result of each indicator of critical thinking skills pretest is 35.86% and on the posttest is 59.78% which indicates an increase in students' critical thinking skills with N-Gain results of 0.3 with moderate effectiveness category. Data on the percentage of PBL model implementation showed an average value of each stage carried out of 91.7% with a very implemented category.

5. ACKNOWLEDGEMENT

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