

## Development of PBL Stem-Based Science Learning E-Module to Increase Critical Thinking and Creativity in Global Warming Materials

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**Abstract:** The study aims to develop and evaluate STEM PBL-based science learning media to enhance students' critical thinking and creativity. The objectives include describing, producing, and assessing the feasibility, validity, practicality, and effectiveness of these media for grade VII students. This Research and Development (R&D) study follows the 4D model: define, design, develop, and disseminate. The developed media take the form of a digital Flipbook accessible via smartphones and PCs. A limited trial involved 22 students and one educator, while a field test included 51 students from SMPN 1 Binongko, Wakatobi Regency, divided into experimental and control groups. Data were collected through tests, interviews, questionnaires, and validation sheets. Feasibility, validity, and practicality were analyzed descriptively, while effectiveness was evaluated using the N-Gain, MANOVA, and Cohen's effect size tests. The results indicate that the STEM PBL-based Flipbook presents real-life problems, their causes, and solutions, encouraging critical thinking and creativity. It meets validity and feasibility criteria as assessed by expert lecturers. Educators and students also rated it as highly practical for learning. Finally, the Flipbook was found to be effective in improving students' critical thinking and creativity, with a significance value of  $0.000 < 0.05$ .

**Keywords:** Creativity; Critical Thinking; Science Flipbook Media; STEM PBL Model

### 1. Background

In the 21st century, Indonesia needs superior, creative, and innovative human resources, in the world of education, a school curriculum is needed that can develop these aspects in order to help students develop their skills and potential. According to (Munandar, 2016) creativity is the ability that a person has to create something new, as the ability to provide new ideas that can be applied in solving problems, or as the ability to see new relationships between pre-existing elements. Indicators of student creativity according to Munandar (Susanto, 2016) are having the ability to think fluently, the ability to think flexibly or flexibly (flexibility), the ability to think originally, and the ability to elaborate (elaboration).

Critical thinking skills must be possessed by students in improving human resources. Critical thinking teaches students to examine problems and find effective solutions to face challenges in the 21st century. In the modern era, skills learning is known as the 4Cs of skills: creativity, critical thinking, communication and collaboration. It is expected that students have a balance between cognitive knowledge and skills (Alawiah & Yassi, 2022); Mardiyah, Aldriani, Chitta, & Zulfikar, 2021; Muhali, 2019).

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Students have the ability to think critically if they meet the criteria for critical thinking ability, as stated by the Assessment of Critical Thinking Ability (ACTA), which is to be able to integrate conflicting knowledge to produce a complete conclusion, be able to design experiments to solve problems in the material, and be able to make other opinions related to a material or estimate other interpretations of the certain knowledge (B, B. White et al., 2011).

The critical thinking of Indonesian students is still at a poor level. Peserta didik has low critical thinking As shown by research conducted at SMPN 1 Balitang, the level of critical thinking of students is still low, with 58.1% of students not meeting the critical thinking stage, especially in terms of interpretation and reference indicators (Rosmalinda, Syahbana, & Nopryanti, 2021). Similar research shows that the percentage of students who think critically is low at 40.66% (N. Dewi & Riandi, 2015). Thinking research using interpretive, analytical, evaluated, conclusive, illuminated, self-regulating indoctrinators shared that students were still lacking in critical thinking, especially in terms of explanatory indicators of 29.03% and conclusions of 40.65% (Irawan, Rahardjo, & Sarwanto, 2017).

The results of the PISA Indonesia exam show a high level of critical thinking that students have. PISA assessment has literacy skills in reading, science and mathematics with a focus on the skills that students learn that can be applied in the real world (Johar, 2012). Questions such as PISA can improve students' critical thinking skills (H. Saputra, 2024). The results of PISA 2018 show that the science literacy score in Indonesia is 396, down from 403 in 2025 (Scheicher, 2019). These results show that Indonesian students have very low abilities in problem solving, problem thinking and logical.

In the STEM-based science learning process, there needs to be media that can support the implementation process so that learning is more interesting and can achieve learning goals so that it can develop student creativity. Learning media is any form and means of conveying information that is made or used in accordance with learning theories, can be used for learning purposes in channeling messages, stimulating students' thoughts, feelings, and willpower so that it can encourage the occurrence of a deliberate, purposeful, and controlled learning process (Suryani, Setiawan, & Putra, 2018).

The learning model is a series that serves as a reference for designing learning activities to achieve the learning goals that have been set (Nurbaya, 2020). The learning model that can be applied is the Problem Based Learning (PBL) learning model. Problem Based Learning (PBL) is a learning model that challenges students to learn through problems that are carried out cooperatively in groups, involving students in real situations so that students are formed into independent and reliable learners (Mutiani, 2019). In the Problem Based Learning (PBL) model, teachers no longer play the role of learning centers but as facilitators for students by providing guidance and direction to students (Wijaya et al., 2020).

Problem Based Learning (PBL) by going through 5 stages, namely (1) Orienting students to problems, (2) Organizing students to learn, (3) Investigating both in groups and individuals,

(4) Developing and presenting works, (5) Analyzing and evaluating the problem-solving process. Where at the individual investigation stage, it can train students to be independent and responsible for a problem with the role of a teacher who always guides and directs the investigation process well. This can improve student learning outcomes (Suryani, 2021).

The problems described above require a research to develop e-modules to help with teaching. Researchers are interested in conducting a study entitled "Development of STEM PBL-Based Science Learning E-Module to Improve Critical Thinking and Creativity in Global Warming Materials".

## 2. Theoretical Studies

The essence of science learning is as a process, as a product, and as a procedure. Science as a process is defined as all scientific activities to discover new knowledge. Science into a product is the result of a process. Science as a procedure is a scientific method, it is a method that collects information (Trianto, 2014). Science is a method of thinking in identifying the surrounding environment, and becomes a material concept (Collette & Chiappetta, 1994). The purpose of science learning is to produce positive development (Mariana & Praginda, 2009). Science learning emphasizes exclusive experiences to build students' ability to understand nature through the process of finding out and shaping (Trianto, 2014).

The STEM approach is an interdisciplinary learning approach that links science, technology, engineering and mathematics to everyday life (Arifin, Pujiastuti, & Sudiana, 2020). STEM emphasizes several aspects, namely being able to ask questions (science) and define problems (engineering), being able to develop and use models, plans and conducting investigations, analyzing data (mathematics), being able to use mathematics, information technology and computers, building explanations (science) and designing solutions (engineering), engaging in an argument based on existing evidence and being able to obtain, evaluate and communicate existing information (Afriana et al., 2016).

PBL is a model that is applied to many problems that require a lot of authentic research by students so that students' skills grow and are in accordance with the skills needed by society in the 21st century (Belf, 2012). The purpose of the PBL model is for students to be able to process and search for data, critical thinking, teamwork, interpersonal skills and active communication with students (Amir, 2009).

Critical thinking is the ability to be directed to determine the solution to a problem. It helps learners learn more, draw conclusions using strategies and tactics, and provide explanations (Agnafia, 2019). Critical thinking skills themselves are the ability of students to acquire knowledge independently through observation of scientific phenomena in their surroundings.

Creativity is the interaction between talents, processes and the environment that produces ideas, actions or artifacts that are considered new and valuable or meaningful in a

particular sociocultural context. According to (Ayu, 2019) creativity is also known as person, process, press and product. Creativity can therefore also be defined as a creative person, who involves himself in the creative process with the support and encouragement of the environment, to produce a new product or useful product.

The greenhouse effect is the entry of long-wave radius emitted by the sun to the earth which will be absorbed through Greenhouse Gases in the atmosphere so that it will cause the earth's surface temperature to increase and cause heat (Martono, 2012). Global warming is an increase in the average temperature on the earth's surface because greenhouse gases are in the atmosphere for some time, causing climate change.

### **3. Research Methods**

This research is Research & Development to produce viable products (Sugiyono, 2015). The basis for considering the use of the 4-D model is because each step of the development procedure stage is explained in detail and clearly what steps will be carried out at each stage. The trial was limited with several students who were selected by purposive sampling which had a low cognitive level of 7 students, medium 7 students and high 8 students. Extensive trials with experimental and control classes. The selection of limited trial subjects using purposive sampling , namely considering certain things by looking at the average class that is relatively the same in science learning achievement.

Data collection techniques are in the form of tests (pretest and posttest) and non-tests (observation sheets, questionnaires, interview sheets). Data acquisition in this study was carried out through questionnaires, observations, interviews and tests. Questionnaires are used for preliminary studies, validation of products and instruments and measuring creativity.

### **4. Results and Discussion**

This research produced a product in the form of Flipbook Science media that is integrated with the STEM PBL model to improve critical thinking and creativity. Media in the form of Flipbooks for computers, smartphones and laptops. The material used is global warming which is integrated with the STEM PBL model in its presentation. The development model used is 4D including define, design, develop and disseminate (Thiaragajan et al., 1947). Details of the product results are outlined below.

#### **4.1. Initial Product Development Results**

##### **a. Define**

In this process, preliminary analysis, student analysis, task analysis and concept analysis are carried out. Based on the results of observations and interviews, the results obtained from the curriculum in schools are the Independent curriculum. The learning methods used are varied and in accordance with materials such as demonstrations in class. However, they still often apply conventional learning such as lecture or discussion

methods. The Problem Based Learning model is often used by educators. The results of observations and interviews found that the problem of low critical thinking and creativity of students was due to educators teaching material by explaining the material so that students were unable to practice critical thinking.

b. Design

At this stage, it is the preparation of research instruments, media selection, format selection, and initial design. The learning media uses the STEM PBL model on global warming materials and uses the Flipbook application. Learning activities in the media are based on the learning objectives and syntax of the STEM PBL model. The media development format is in the form of Flipbook science media application software used on smartphones, computers and laptops.

c. Development

At this stage, expert assessments are carried out which include media validation, critical thinking ability validation, creativity validation, creativity skills observation sheet validation, and creativity attitude observation sheet and questionnaire validation. In addition, at this stage, limited trials and field tests are also carried out.

d. Disseminate

Dissemination of product results in order to get feedback on product results. The dissemination of the product was carried out by providing science learning media application software to educators at SMPN 1 Binongko as a research place so that it could be used by educators.

## 4.2 Product Trial Results

The extensive trial was carried out in two classes, namely the control class with a total of 26 students and the experimental class with a total of 25 students. Extensive tests use test instruments, questionnaires and observation sheets. The experimental class, namely class VII A, was given treatment by learning using STEM PBL-based Flipbook science media. The control class, namely class VII B, is not given treatment and learning using package book media. The material taught in both classes is global warming.kk

a. Critical Thinking

Critical thinking data to obtain N-Gain scores that show the large difference in students' acquisition before and after learning. Table 1. showing the results of the N-Gain analysis of critical thinking.

**Table 1.** Results of Critical Thinking Measurement

It	Component	Experimental Classes		Control Classes	
		Pretest	Posttest	Pretest	Posttest
1	Number of students	25	25	26	26
2	Highest score	80	100	47	93
3	Lowest score	26,7	93	0	73

<b>4</b>	<b>Average</b>	<b>52,8</b>	<b>98,7</b>	<b>42,3</b>	<b>83,8</b>
<b>5</b>	<b>Standard deviation</b>	<b>56,6</b>	<b>2,72</b>	<b>16,6</b>	<b>6,01</b>
<b>6</b>	<b>N-Gain score</b>	<b>0,90</b>		<b>0,68</b>	
	<b>Category</b>	<b>Tall</b>		<b>Keep</b>	

Based on table 1, it shows that the ability to think critically as seen from the completeness of KKM in the experimental class before and after learning has increased by 20 students, while the control class has not improved. After it is known that the improvement in the completeness of critical thinking skills is known, the next thing is to determine the Gain value for each student and then determine the value of improving critical thinking skills for all students, namely N-Gain.

The results of the N-Gain analysis show that in the experimental class obtained 0.90 with the high category and the control class obtained 0.68 with the medium category (Hake, 1999). The difference in N-Gain scores of the experimental class and the control class was 0.22.

**Table 2.** Average Results of Achievement of Critical Thinking Skills in Each Aspect

<b>No</b>	<b>Indicator</b>	<b>Experimental Classes</b>		<b>Control Classes</b>	
		<b>Pretest</b>	<b>posttest</b>	<b>Pretest</b>	<b>Posttest</b>
<b>1</b>	<b>Categorizing</b>	<b>1,92</b>	<b>3,8</b>	<b>1,84</b>	<b>3,61</b>
<b>2</b>	<b>Providing a reason for a Decision</b>	<b>1,88</b>	<b>3</b>	<b>1,19</b>	<b>2,73</b>
<b>3</b>	<b>Conclude</b>	<b>1,52</b>	<b>3</b>	<b>1,30</b>	<b>2,92</b>
<b>4</b>	<b>Declaring results</b>	<b>0,92</b>	<b>3</b>	<b>0,96</b>	<b>1,65</b>
<b>5</b>	<b>Providing Solutions</b>	<b>2,12</b>	<b>2</b>	<b>1,61</b>	<b>2,65</b>

Based on table 2, it shows the improvement of critical thinking in each aspect in both classes. However, one aspect in the experimental class has decreased, albeit slightly. The results of the research obtained on the N-Gain Score and the improvement of each aspect show the findings and this study is that STEM PBL-based science media is more effective in improving critical thinking on the topic of global warming than textbook media with an N-Gain Score of 0.68 in the medium category.

The application of PBL-STEM significantly improves students' systems thinking skills compared to conventional learning on global warming materials (Saputri, S. A. 2024). The application of the STEM-based PBL model significantly improves students' critical thinking skills compared to control classes that use ordinary textbooks (Mustafaroh, V. A., & Hariyono, E. 2024). The PBL model has a positive effect on improving students' critical thinking skills in the context of climate change, which is relevant to the issue of global warming (Gustina, M. 2023).

## b. Creativity Ability

The data obtained was analyzed to obtain an N-Gain score which shows the large difference in student acquisition before and after learning. The results of the N-Gain analysis of creativity ability can be seen in table 3.

**Table 3.** Results of Measuring Creativity Ability

No	Component	Experimental Classes		Control Classes	
		Pretest	Posttest	Pretest	Posttest
	<b>Number of students</b>	<b>25</b>	<b>25</b>	<b>26</b>	<b>26</b>
	<b>Highest score</b>	<b>64</b>	<b>100</b>	<b>0</b>	<b>42</b>
	<b>Lowest score</b>	<b>0</b>	<b>86</b>	<b>0</b>	<b>14</b>
	<b>Average</b>	<b>39</b>	<b>89,7</b>	<b>0</b>	<b>39</b>
	<b>Standard deviation</b>	<b>17,9</b>	<b>6,55</b>	<b>0</b>	<b>37,8</b>
	<b>N-Gain score</b>	<b>0,2</b>		<b>0,1</b>	
	<b>Category</b>	<b>Tall</b>		<b>Keep</b>	

Based on table 3, it shows that the ability of creativity when reviewed from the number of students who meet the KKM or completeness in the experimental class before and after the training has increased by 7 students and in the control class has been tied to 1 student. After it is known that the increase in the completeness of creativity is known, the Gain value for each student is determined and then the value of increasing creativity for all students is determined, namely N-Gain.

The increase in creativity is marked by the acquisition of N-Gain Scores. The N-Gain score obtained for the experimental class was 0.2 with the low category and for the control class was 0.1 with the high category, the difference in N-Gain score was 0.1

**Table 4.** Average Achievement of Creativity Ability in each Aspect

No	Aspects	Experimental Classes		Control Classes	
		Pretest	Posttest	Pretest	Posttest
<b>1</b>	<b>Smooth</b>	<b>0,92</b>	<b>1,88</b>	<b>0</b>	<b>1,38</b>
<b>2</b>	<b>Flexibility</b>	<b>1,19</b>	<b>2,07</b>	<b>0</b>	<b>0,84</b>
<b>3</b>	<b>Authenticity</b>	<b>0,88</b>	<b>1,96</b>	<b>0</b>	<b>0,5</b>
<b>4</b>	<b>Development</b>	<b>0,42</b>	<b>1,11</b>	<b>0</b>	<b>0</b>

Based on table 4, it shows the improvement of creativity in each aspect in both classes. The flexibility aspect in the experimental class experienced the highest increase of 88%. Because the experimental class uses STEM-based PBL-based flipbook media.

The control class of the aspect that experienced the highest increase was the smoothness aspect, which was 1.38%. This is because when using package book media, students are able to evaluate the information presented. Students understand whether the information is accurate, relevant and credible because of learning with the lecture method.

The lowest aspect in the experimental class was the development aspect of 1.11%. This is because students are more likely to immediately believe the information presented in the form of animation without considering whether it is really accurate or not. In addition, students are not educated to understand clear and structured guidelines in

evaluating STEM PBL-based media content. Students have difficulty criticizing content and there is a limited time in learning.

The lowest control class is the aspect of authenticity and development, which is 0%, because the learning of students with package books is by the lecture method. So that the class becomes passive and participants are unable to find concepts independently.

## 5. Conclusions And Suggestions

### 5.1 Conclusion

The science learning media products developed are considered very feasible and valid to be used in science learning to improve the critical thinking skills and creativity of SMPN 1 Binongko grade VII students with the results of the media assessment by expert lecturers getting a score of 132, the results of material assessment by material expert lecturers getting a score of 156. The science learning media products developed are considered very practical to be used in science learning to improve the critical thinking skills and creativity of students of SMPN 1 Binongko grade VII with a readability test score of 36.98 and practicality by educators with a score of 68. The STEM PBL-based Flipbook science media developed is considered effective to improve the critical thinking skills and creativity of students of SMPN 1 Binongko grade VII with a sig.  $0.000 < 0.05$  so that there is a significant difference in the use of media in the control and experimental classes.

Sections must summarize briefly and concisely the contents of the document or essay. This section may contain (1) A summary of the main results, findings, and evidence from your research or analysis. (2) Synthesis of findings, namely the relationship between findings and research objectives, and show how these findings support arguments or hypotheses. (3) The author may also be able to discuss the implications of research findings for research benefits. What is the contribution or impact on the knowledge or topic discussed? (4) Limitations and suggestions for further research.

### 5.2 Suggestion

STEM PBL-based Flipbook Science Media can be used by junior high school students in learning global warming material

STEM PBL-based Flipbook science media can be used by students to improve their critical thinking and creativity.

STEM PBL-based Flipbook science media can be used by educators in supporting learning in the classroom, especially on global warming materials.

STEM PBL-based Flipbook science media can be used by educators to train students' critical thinking and creativity.

STEM PBL-based Flipbook science media can be used by educators as an alternative and variety of media used in classroom learning.



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