JPPIPA 11(4) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

The Development of Science Learning Modules Based on PjBL-STEM to Improve Creative Thinking Skills on Environmental Pollution Materials

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Received: December 12, 2024
Revised: February 24, 2025
Accepted: April 25, 2025
Published: April 30, 2025

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DOI: 10.29303/jppipa.v11i4.10729

Abstract: PjBL-STEM is a project-based learning model integrated with Science, Technology, Engineering and Mathematics (STEM). The study developed a PjBL-STEM-based science module to improve creative thinking skills. The type of research and development used is ADDIE, namely analysis, design, development, implementation, evaluation. The feasibility of the module uses expert validation consisting of 3 material experts, 4 media experts, and 3 language experts. The module's practicality test by teachers consists of 4 teachers, and the readability test consists of 32 students. The module's effectiveness test uses a quasi-experiment with control and experimental classes. The control class is in VII C and the experimental class is in VII D. In each class there are 32 students with 16 females and 16 males. Based on the results of the study, it can be concluded that the average results of the validation of material experts (0.89), media experts (0.90), and language experts (0.86). Practicality by teachers (96%) and module readability (90%). The N-Gain value is 0.57 with a moderate category, which means that this module is quite effective in improving students' creative thinking skills.

Keywords: Creative thinking; Module; PjBL-STEM

Introduction

The development of technology in the 21st century also has a big impact and influence on society and students, especially in the fields of education and technology. Education is a planned effort with the aim of realizing effective learning activities, exploring self-potential, and honing abilities. Through education, it is expected to create quality resources, so that education becomes an absolute necessity that must be met. All children have the right to receive quality education. Guidance in learning to gain good understanding is very helpful in improving students' cognitive and creative abilities. According to Rohman et al. (2021), society in the 21st century is increasingly aware of the importance of a young generation that is educated, creative, and proactive in solving and understanding the concept of problems both individually and in groups.

As time goes by and technology develops, the current education system is very different from the previous education system, one of which is learning activities. In the current independent curriculum, the term independent is inseparable from new paradigm learning. New paradigm learning is learning that ensures that learning practices are centered on students (Sufyadi et al., 2021). This learning positions students as learning subjects based on their awareness and critical abilities, while the teacher is not the main subject but rather a facilitator to learn together with students in solving a problem. New paradigm learning shifts the orientation of the old paradigm whose learning is still centered on the teacher. According to Salma et al. (2023),

How to Cite:
Shodiq, D. E., Muzzazinah, & Setyono, P. (2025). The Development of Science Learning Modules Based on PjBL-STEM to Improve Creative Thinking Skills on Environmental Pollution Materials. *Jurnal Penelitian Pendidikan IPA*, *11*(4), 41–47. https://doi.org/10.29303/jppipa.v11i4.10729

old paradigm learning must be abandoned because teachers are considered only to deliver material, so that students are less able to participate actively. In addition, learning tends to use lecture methods, taking notes and memorizing so that it only develops cognitive abilities. This can also cause students to be less motivated and bored with learning because the teacher is the center of learning (Adilah & Minsih, 2021).

The learning process greatly influences the way students think because there is interaction with the learning environment. Effective learning makes students learn easily, enjoyably, and with deep understanding so that students are more courageous in exploring themselves and are creative (Marheni et al., 2025). Creative thinking is the ability to generate a variety of ideas, manipulate ideas in unusual ways, and make unusual connections to outline new possibilities that have the potential to meet specific goals (Ramalingam et al., 2020). Creative thinking skills enable finding connections, facing new challenges, and seeking unusual, original, and new resolutions (Gafour & Gafour, 2020). Creative thinking indicators include five indicators, namely 1) fluent thinking (*fluency*), finding ideas/answers to solve problems; 2) flexible thinking (*flexibility*), providing varied solutions from various points of view), 3) original thinking (*originality*), producing unique and new answers, 4) *elaboration*, expanding an idea or describing an answer in detail (Torrance, 2018).

Based on the results of observations and interviews at SMP Negeri 2 Toroh, the science learning that was carried out was still teacher-centered, using the lecture method so that communication is one-way, and students are asked to listen to the material presented by the teacher. Students usually memorize and do not understand in depth. The use of learning media is less than optimal, only using Kemendikbud textbooks so that it is less varied. The evaluation questions given are not yet HOTS-based so that they do not train students in creative thinking skills. It is emphasized in the study (Kurnia et al., 2021) that students' creative thinking abilities are still low, with the research results showing that the fluency indicator is 39.81%, flexibility is 45.87%, originality is 38.02% and elaboration is 35.67%, so there is a need to improve creative thinking skills.

One of the solution is to develop a PjBL-STEM based module. The PjBL-STEM module integrates the Project Based Learning (PjBL) learning model with the STEM approach. Project based learning (PjBL) is a learning model that gives students the freedom to plan learning activities, carry out projects collaboratively, and produce work products that can be presented to others. PjBL has important characteristics, namely that students create a framework for a problem, determine solutions, collaborate to explore information, evaluate, and reflect on activities that have been carried out (Rani, 2021). The STEM approach is defined as the integration of disciplines into the curriculum and learning in the aspects of science, technology, engineering and mathematics (STEM). The benefits of the STEM approach can improve students' abilities in science learning, students' activeness in learning, and encourage students to create a product. In this STEM learning, practical activities are implemented by linking science, technology, engineering, and mathematics which make students more interested during learning (Aulya et al., 2021).

The skills that a student must have in learning in project activities are being able to observe objects, collect data, collaboration, analyze, and convey opinions. The implementation of project-based learning activities will be more optimal if integrated with the STEM approach. Implementing PjBL-STEM has a greater influence on the higher thinking skills of participants and students and can develop students' soft skills. PjBL-STEM learning can train students' abilities and talents in facing 21st century problems. PjBL-STEM can improve scientific literacy, motivation, understanding of material, creative thinking skills, effectiveness, meaningful learning, and support future careers (Rahmania, 2021).

One of the way to support student-centered learning in interesting and active learning activities, learning media can be the solution. One of the learning media that can be used is a learning module. A module is a teaching material that is oriented towards training students to build their own thinking about a concept so that they understand the concept and apply it in real life (Sari & Montessori, 2021). The module contains learning materials, methods, learning objectives based on basic competencies or competency achievement indicators, instructions for independent learning activities and provides students with the opportunity to test themselves through practice questions presented in the module (Hamdani, 2011). The module is arranged systematically and uses language appropriate to students so that it is easy to understand.

The development of PjBL-STEM based modules aims to enable students to identify problems, provide creative ideas and design a product. With the integration of PjBL-STEM, it helps students in identifying, analyzing, and solving problems in everyday life. Other than that, with this integration, students become highly curious and are able to achieve high achievements so that it is very effective to be used as a guideline for implementing effective learning (Riyasni et al., 2023). Thus, researchers developed a PJBL-STEM based science learning module device to improve students' creative thinking skills.

Method

This study uses the research and development (RnD) method. Research and development is a study that produces a product and determines the effectiveness of the product. The research model developed is ADDIE (Analysis, Design, Development, Implementation, Evaluation) developed by Dick et al. (2005).

The analyze stage aims to analyze product development and collect initial data to determine the needs that can support product development. This stage includes needs analysis, curriculum analysis, student characteristics analysis, and analysis of teaching materials used. The design stage is carried out after the analyze stage. The design stage is a systematic process that begins with the design of the concept and contents of the module. The selection of the module is based on the analysis process that has been carried out. The design stages include determining learning outcomes and objectives, selecting formats and media, and designing module designs. The development stage is an activity to realize the product design that has been previously created. This stage aims to produce a PjBL-STEM-based science module to improve creative thinking skills.

At this development stage, the module is validated by material experts, media experts, and language experts. The module is validated by four lecturers who were material experts, three lecturers who were media experts, and three lecturers who were language experts. The validation assessment used an expert validation sheet with a Likert scale. The assessment results were analyzed using the Aiken Index with the following formula,

$$V = \frac{\Sigma s}{[n(c-1)]} \quad (1)$$

Information:
s = r –lo
lo = The lowest validity assessment score
c = The highest validity assessment number
r = A score given by the assessor
n = The number of assessors

The validity category of the PjBL-STEM module to improve students' creative thinking skills with the Aiken Index obtained can be seen in the following table 1.

Table 1. Aiken Index Criteria

Interval	Criteria
> 0.8	High
0.4 – 0.8	Medium
< 0.4	Low

In the readability and practicality test by students and teachers. The readability test is to find out the students' response to the developed module, while the practicality test aims to find out the ease of the module in its use in learning. The practicality test consisted of 4 science teachers and the readability test consisted of 32 students. The formula used to analyze the readability and practicality of the module is as follows:

$$\text{Grade} = \frac{\text{Obtained score}}{\text{Maximum score}} \, x \, 100\% \quad (2)$$

The scoring criteria for readability and practicality of the module are shown in Table 2.

Table 2. Scoring Criteria for Module Readability and Practicality (Puspitasari et al., 2024)

Interval	Criteria
90% -100%	Very Good
70% -89%	Good
50% -69%	Fair Enough
30% -49%	Not Good
20% -29%	Bad

To test the effectiveness of the PjBL-STEM module using a quasi-experimental method with a non-equivalent control group design consisting of control and experimental classes. The research design can be seen in table 3.

Table 3. Quasi Experimental Research Design Nonequivalent Group Design

Class	Pretest	Treatment	Posttest
Control	O1	X1	O2
Experiment	O1	X2	O2

Description: O1 = Pretest score; O2 = Posttest score; X1 = Book from school; X2 = PjBL-STEM Module

The control class is in VII C and the experimental class is in VII D. In each class there are 32 students with 16 females and 16 males. To find out that the PjBL module can improve creative thinking skills, it is tested using N-gain. The equation for determining the N-gain score is as follows:

$$(g) = \frac{\text{Posttest} - \text{Pretest}}{\text{Max Score} - \text{Pretest}} \quad (3)$$

The results of the *N-gain score* test calculations are then interpreted using the following classification in table 4.

Table 4. Gain Classification

Normalized average gain	Classification
0.0 < g < 0.3	Low
0.3 ≤ g < 0.7	Medium
0.7 ≤ g ≤ 1.0	High

If there is an increase, then the hypothesis test is continued with the Independent Sample T-test to determine the difference in the use of the PjBL-STEM module in improving students' creative thinking skills. Data analysis uses SPSS 25. Before conducting the Independent Sample T-Test, a prerequisite test for normality and homogeneity is carried out. In the Independent Sample T-test if the Sig. (2-tailed) value in the Independent Sample T-test <0.05, then there is a significant difference between the use of the PjBL-STEM module in improving creative thinking skills. Meanwhile, if the Sig. (2-tailed) value in the Independent Sample T-test > 0.05, then there is no significant difference between the use of the PjBL-STEM module in improving creative thinking skills.

Result and Discussion

The research and development that has been carried out has produced a product in the form of a learning module with the PjBL-STEM learning model on the Environmental Pollution material. The material in the developed module refers to the learning outcomes listed in the Decree of the Head of BSKAP Number 032/H/KR/2024 concerning Learning Outcomes in Early Childhood Education, Elementary Education Level, and Secondary Education Level in the Independent Curriculum are that students identify interactions between living things and their environment, and can design efforts to prevent and overcome pollution and climate change. The PjBL-STEM learning module on environmental pollution material is expected to improve students' abilities in solving problems in everyday life creatively and innovatively.

The PjBL-STEM module that has been developed is then validated by experts to determine the suitability of the module as a learning medium. Expert validation includes material experts, media experts, and language experts. Validators are expert lecturers in their fields. Material expert validation consists of three lecturers. The results of material expert validation can be seen in table 5.

Table 5. Validation Results by Material Experts

Component	Indicator	Validity Value	
Content Eligibility	Corresponding of materials with Learning Outcomes (CP) and Learning Objectives (TP)	0.83	0.91
	Material Accuracy	0.93	
	Material Updates	0.94	
Presentation Eligibility	Presentation Techniques	0.875	0.87
	Presentation Support	0.875	
	Presentation Learning Process	0.94	
	Presentation Completeness	0.83	
Average			0. 89
Classification			Very High

The validation results by material experts show that the PjBL-STEM module has a content validity value of 0.91 and presentation validity of 0.87 with an average of 0.89. This shows that the PjBL-STEM module has a very high feasibility. However, in validation by material experts there are improvements for module development. The validator suggests that the material be further supplemented and the concept map does not yet depict the actual concept map. Next, the validation results by material experts consisting of four lecturers. The validation results can be seen in table 6.

Table 6. Validation Results by Media Experts

Aspect	Validation Value
Physical Size	0.94
Front Page Design (*Cover*)	0.88
Content Design	0.90
Average	0.90
Classification	Very High

The results of the media expert validation show that the PjBL-STEM module has an average validity value of 0.90. In terms of physical size 0.94, cover page design 0.88, and content design 0.90. Media expert validation shows that the module has very high media feasibility. The validator's suggestion is that images should be given image captions/narrations to make it clearer and easier for students to understand.

The results of the validation by language experts consisting of three expert lecturers can be seen in table 7.

Table 7. Validation by Language Experts

Component	Validity Value
Direct	0.83
Communicative	0.91
Dialogic and interactive	0.79
Compliance with student development	0.86
Use of terms, symbols or icons	0.92
Conformity to language rules	0.83
Average	0.86
Classification	Very High

The results of the validation by linguists showed an average validation value of 0.86 with a very high validity category. Suggestions from the validator include that the writing must be adjusted, for example in writing chemical formulas, degrees and exponents, one word with another word is also still combined and the spelling used is adjusted to The Enhanced Spelling System (EYD).

After the module has been validated by material, media and language experts, and revised, the next step is the readability and practicality test. The readability

test is carried out by students, while the practicality test is carried out by teachers. The results of the readability and practicality tests can be seen in table 8.

Table 8. Module Readability and Practicality Test

Indicator	Readability (%)	Practicability (%)
Material	91	97
Language	88	97
Design/Display	91	93
Average	90	96
Classification	Very High	Very High

The results of the readability test by students and the practicality of the module had an average value of 90% and 96%. This shows that the PjBL-STEM module to improve creative thinking skills can be understood by students and is practical for use in learning process. Based on the feasibility test that has been carried out on the PjBL-STEM module that was developed, the next step is to test the effectiveness of the module in improving creative thinking skills.

The effectiveness test is used to determine the use of the PjBL-STEM module can improve creative thinking skills. The indicators of creative thinking skills refer to Torrance, namely fluent thinking (fluency), flexible thinking (flexibility), original thinking (originality), and elaboration. Effectiveness test using pretest and posttest in experimental class and control class. Based on the test results using N-Gain Score, there is an increase in module usage. The N-Gain Score results can be seen in table 9.

Table 9. The N-Gain Score Results

Grade	N-Gain Score	Criteria	N-Gain Percent	Categori
Control	0.36	Medium	36%	Not Effective
Experiment	0.57	Medium	57%	Quite Effective

In the control class there is an increase of 36%, while in the experimental class it is 57%. The use of the PjBL-STEM module is quite effective in improving student's creative thinking skills. In line with a research Cahyani et al. (2020) that the effectiveness of the Project Based Learning e-module integrated with STEM is categorized as moderate. The results of the increase in the experimental class on each indicator of creative thinking can be seen in Figure 1.

In each indicator of creative thinking, the fluency indicator has an increase of 34%. The flexibility indicator has an increase of 27%. The originality indicator is 32% and the elaboration indicator is 20%. The highest increase in creative thinking indicators is in the fluency indicator. Fluency is the ability to produce many ideas that come out of one's mind quickly. This is supported by research conducted by Yulianingtias et al. (2016), students who have the ability to think fluently will provide complete answers and the more answers given, the more fluent the student is in thinking. In the elaboration indicator, it has the lowest increase among other indicators. This is because good elaboration skills not only provide short and simple answers, but they are also able to provide precise, clear, and logical reasons (Firdaus et al., 2018).

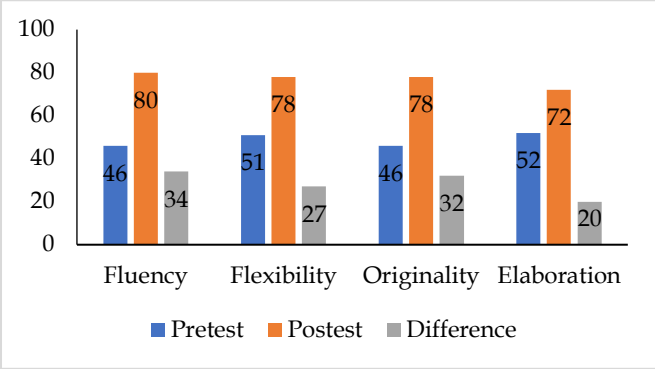

Figure 1. Percentage of pretest and posttest values in the experimental class

Normality prerequisite test of preset control class (0.071), posttest (0.122), and experimental class pretest (0.053) and posttest (0.059). Based on the results of the normality test, the sign value > 0.05, the data has a normal distribution. Homogeneity test 0.510 > 0.05, homogeneous data has the same variation. Then continued with the independent sample t-test to determine the difference in the use of modules in the control and experimental classes. The independent sample t-test test shows that the sign value is 0.000 < 0.05, so there is a significant difference between the use of the PjBL-STEM module in improving creative thinking skills.

Based on the description above, the PjBL-STEM module can be used to improve students' creative thinking skills. The module is a media that is often used by teachers. This is because the module is a teaching material which contains material and activities that can be carried out by students independently and which have been arranged systematically. Integration of PjBL-STEM based module development will also have a positive impact on learning. The advantages of the PjBL-STEM model can increase student learning activities because students are required to actively complete a project and apply it in everyday life (Rochim et al., 2021).

According to Anjarwati et al. (2022), the integration of the STEAM-Project Based Learning approach can train students to face challenges, plan and solve problems, and respond to the problems they face. This can train students to think of creative and innovative ideas/ideas in solving their problems. In line with

research Mamahit et al. (2020), the use of the STEM integrated project model (PjBL-STEM) can support active learning in the classroom by providing opportunities to produce products of discovery and improve creative thinking skills.

Conclusion

The development of a PjBL-STEM-based module aims to enable students to identify problems, provide creative ideas and design a product. With the integration of PJBL-STEM, it helps students identify, analyze, and solve problems in everyday life. Thus, researchers developed a PJBL-STEM-based science learning module device to improve students' creative thinking skills. The development of PjBL-STEM based modules can be said to be proven effective in improving students' creative thinking skills, with an average increase in N-gain of 0.57. The t-test results showed a significant difference between the experimental class using the PjBL-STEM module and the control class, with a significance value of 0.000. The results of validation expert by material validation (0.89), media (0.90) and language (0.86) with a very high category. The practicality by science teacher (96%) and readability by students (90%), so the module is suitable for use. Development with the PjBL-STEM model can also improve students' creative thinking skills in terms of the N-Gain Score of 0.57 in the quite effective category. The development of the PjBL-STEM module can be an innovation in learning in schools to support 21st century skills for students. The PjBL-STEM module related to everyday life makes it easier for students to solve and find solutions to the problems they face by using creative and critical thinking patterns.

Acknowledgments
The researcher would like to thank the Principal of SMP Negeri 2 Toroh, teachers and staff, especially the science teacher, and all grade VII students who have provided the opportunity and helped in the research process of developing the PjBL-STEM module to improve creative thinking skills in classroom learning.

Author Contributions
All authors contributed to writing this article.

Funding
No external funding.

Conflicts of Interest
No conflict interest.

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