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STEM-based mathematics learning module with PBL model in improving higher-order thinking skills

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***Abstract*:**
The development of STEM-based mathematics learning modules that are systematically arranged using the PBL (Problem-Based Learning) model is one way to train students' higher-order thinking skills (HOTS). This study aims to describe the process, validity, and practicality of the developed mathematics learning module and determine the students' higher-order thinking skills after using the mathematics learning module using the development research type. This STEM-based mathematics learning module with the PBL model was developed referring to the ADDIE development model, which consists of 5 stages, namely: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. The math learning module focuses on statistical material on the size of data concentration given to class VIII students at UPT SMPN 9 Gresik, as many as 31 students. Implementation begins with analyzing the results of instrument validation by validators, then analyzing student response questionnaires filled out by students after using the learning module and through higher-order thinking skills tests. Based on the results of the development process, it can be concluded that students still have difficulty working on higher-order thinking skills at the initial stage, namely the analysis stage. Designing and making modules are carried out at the design stage and development stages. At the implementation stage, the module was tested and declared feasible by the validator. The last stage is the evaluation stage, namely analyzing the data that has been obtained. The results of the validation of this math learning module are in the very valid category, with an average total validity (RTV) value of 4.16 by the three validators. The math learning module was also declared practical in theory with an average score of B, with the provision that it could be used with minor revisions. Practically, it gets an average score of 77.64% in the category of higher-order thinking skills, 19 students in the very good category, 7 students in the good category, and 5 students in the moderate category. Thus, The STEM-based mathematics learning module using the PBL model could been said to be well used to improve students' mathematical understanding and higher-order thinking.

Keywords: HOTS; Learning Module; Mathematics; STEM-PBL-based.

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Introduction

Mathematics is a subject that is always taught at every level of education. One of the reasons math is taught at every level of education is because math is handy for solving problems in everyday life. Darhim also stated that mathematics teaches the ability to do quantitative calculations and trains the way of thinking, especially in forming the ability to analyze, create, evaluate, and problem-solve. According to Saraswati and Agustika, math subjects provide the ability to think logically, critically, systematically, analytically, and effectively work skills. From some of these opinions, it can be concluded that mathematics not only teaches about counting but also trains thinking skills in solving problems (Manik & Ngurah, 2020).

Thinking ability is an important thing that needs to be developed in mathematics lessons. These abilities are divided into two types: low-level and high-level thinking skills. Low-level thinking skills include the ability to remember, understand, and apply, while high-level thinking skills include the ability to analyze, evaluate, and create (Abidin & Tohir, 2019). In this case, students are required to have the ability to think in each level of thinking in the cognitive domain to be able to solve or solve varied problems. Therefore, an important ability that students must have when studying mathematics is the ability to think at a higher level. Higher-level thinking skills are thinking skills that can relate new information to information that has been obtained and then connect the information to solve problems or find solutions to a situation to be solved (Heong et al., 2011). Budiarta said that high-level thinking skills are complex thinking skills that include parsing material, criticizing, and creating solutions to problem-solving (Budiarta et al., 2018).

Higher-order thinking is very important for students. Students who have high-level thinking skills will find the mathematics learning process more meaningful because students do not just memorize formulas and then apply them. Still, students are also able to solve new problems using these formulas. The development of various fields, such as education, science, and technology, characterizes the 21st century. Pratiwi et al., in their research, stated that 21st-century education must reflect 4C skills, namely Critical thinking, Communication, Creative thinking, and Collaboration, where these abilities are also aspects of higher-order thinking skills (Pratiwi, 2019). Facts in the field show that students' higher-order thinking skills in Indonesia are still relatively low. It can be seen that when students work on problems different from the examples given, they will ask questions and feel confused when solving them. In addition, the teacher's method of teaching mathematics is limited to explaining, writing, giving example problems, and giving exercise problems that are the same as the example problems. In this case, it can be said that one of the factors causing low higher-order thinking skills is that students are not accustomed to working on higher-order thinking problems.

Furthermore, from the results of the PISA (Program for International Student Assessment) in 2018, which were attended by 78 countries, Indonesian students ranked unsatisfactory, namely 72nd in literacy and mathematics and 70th in science (Ndiung & Jediut, 2020). In the ability to solve PISA questions consisting of 6 levels, according to Astawan, almost all Indonesian students are only able at level 3, while other countries have reached levels 4, 5, and 6 (Astawan et al., 2021). Based on the results of research conducted by Amalia and Pujiastuti, it shows that from a maximum score of 100%, the average student's level of analysis ability reaches 33.33%, the level of evaluating reaches 44.44%, and the level of creating is 0% (Amalia & Pujiastuti, 2020). Based on this percentage, it shows that students' higher-level thinking skills are still low.

There are many approaches and models in learning that can be used to improve students' higher-order thinking skills. One approach that can be applied is the STEM approach. According to Mulyani, the STEM approach is an approach that combines four disciplines at once, namely science, technology, engineering, and mathematics, with an educational process that focuses on solving problems in everyday life (Mulyani, 2019). Sartika, in her research, stated that STEM-based education is an approach that is used in the 2013 curriculum because it has the same goal of developing aspects of attitude, knowledge, and skills (Dewi Sartika, 2019). STEM is a form of future learning that is needed to face the challenges of changing times because the main focus of STEM is to form human resources who can think critically, logically, systematically, and reason so that they will be able to face global challenges (Choirunisah et al., 2022). In this case, the STEM-based learning approach will help students to develop higher-order thinking skills.

In addition, the application of STEM is usually supported by problem-based learning models, one of which is the Problem-Based Learning (PBL) learning model. PBL is a learning model that uses real problems as something that students must learn to train high-level thinking skills in problem-solving (Suratno. Kamid. Sinabung, 2020). According to Ariani et al., the STEM approach with the PBL model is a learning that is integrated with science, technology, engineering, and mathematics to improve students' thinking skills through the process of solving real-life problems (Nurhayati et al., 2019). In this case, problem-based learning will trigger students to think. The use of STEM-based approaches with PBL models is expected to train students' higher-order thinking skills. Previous research has proven that STEM-based learning with the PBL Model was successful in improving students' higher-order thinking skills (Nuryanto & Yuliardi, 2023). Thus, in this study, STEM-based learning with the PBL model will be tried in mathematics. The selection of the correct learning method will affect students' higher-order thinking skills. Still, in addition to the methods used, students' higher-order thinking skills will not be achieved by themselves without the efforts and facilities available. One of the facilities that can be used is the learning module. The modules are teaching materials that are arranged systematically and interestingly, including content, material, methods, and evaluation, which students can use to learn independently (Mukhlis et al., 2023). According to Suastika and Rahmawati, modules are an essential component because they can assist students in obtaining critical information on the subject matter (Suastika & Rahmawati, 2019). Thus, by using learning modules, it is hoped that it can make it easier for students to understand the material and can be used for independent learning.

Research Methods

The type of research used in this article is development research. Development research is research conducted to develop a product. In this study, researchers developed a mathematics learning module on statistics material focusing on mean, median, and mode using the STEM approach with the PBL model for class VIII SMP / MTs. The research and development model used in this research is the ADDIE development model, which consists of five stages, namely Analysis, Design, Development, Implementation, and Evaluation, which are carried out procedurally (Anam et al., 2022). The following shows the ADDIE model development scheme.

Picture 1. The ADDIE model development scheme

The procedure for the developed module uses the ADDIE development model as follows:

1. Analysis
   This stage is the first stage in this development model, which is conducted by conducting curriculum analysis activities used in education units. Student analysis is used to determine the characteristics of students who are used as subjects for module implementation. Analyzing learning materials created as teaching module content and identifying gaps as a way to explore the challenges teachers and students encounter while implementing learning.

2. Design
   Next is to make a module design or module framework that is developed based on the analysis of the problems that have been done before. This stage aims to determine the formulation of success measures to be achieved.

3. Development
   The development stage is crucial because the product developed will be executed at this stage. The first step is to create the display, material content, and validation of the developed product, which are also carried out at this stage. The validation process uses validation instruments, practicality questionnaires, and test sheets. The product produced is a STEM-based math learning module with the PBL model.

4. Implementation
   The application of the math learning module that has been developed is then tested to get feedback related to learning objectives, content, and also the response of the developed module. The implementation was carried out at UPT SMPN 9 Gresik to class VIII students in the 2022/2023 school year. In addition, this application also aims to see students' higher-order thinking skills.

5. Evaluate
   The last stage is to evaluate, which aims to monitor and evaluate the module that has been tested as a whole, including the results of the higher-order thinking ability test and the results of student responses.

Results and Discussions

The ADDIE development model procedurally consists of the Analysis, Design, Development, Implementation, and Evaluation Stages. The following table shows the stages of the ADDIE Model development in the STEM-based mathematics learning module with the PBL Model in detail.

Table 1. Module Development Activity Stages

Concepts		Activity	information
Analysis	Identification causes of problems in learning and plans to be implemented in developing learning modules	1. Analyzing the curriculum 2. Analyzing learning materials 3. Analyzing Students 4. Identifying Student Gaps	Analysis Summary
Design	Verify the desired results based on previous analysis and determine what forms, types, and strategies will be implemented.	1. Planning the outline of the learning module 2. Designing instruments	Brief Design
Development	Develop and validate learning resources and develop the necessary supporting materials and strategies.	1. Creating learning modules 2. Validation of modules and assessment instruments 3. Revision of learning modules	Mathematics Learning Module
Implement	Preparation of the learning environment and implementation of learning by involving students	1. Implementation of learning modules 2. Students' high-level thinking ability test 3. Student response questionnaire filling	Student test results and responses
Evaluate	Assessing the quality of products and learning processes	1. Assessment and evaluation 2. Make recommendations	Evaluation plan

The details that have been applied in the table above are then analyzed in more detail in several stages below.

A. Analysis Stage

This stage is used to analyze the needs required in the development of learning modules. The stages of analysis are curriculum analysis, student analysis, material analysis, and identification of gaps obtained through interviews with teachers at UPT SMPN 9 Gresik and observations made by researchers. UPT SMPN 9 Gresik is a school that uses the 2013 curriculum for grades VIII and IX. At this stage, researchers analyze the essential competencies and indicators that students must achieve. The module to be developed contains statistical material that is limited to the sub-chapter of single data centralization measures (mean, median, and mode) in grade VIII even semester in the development of STEM-based mathematics learning modules with the PBL model to train students' high-level thinking skills.

At this stage, student analysis was also carried out, and the result was that only some students were active in learning mathematics. Other findings showed that many students found it challenging to solve mathematics problems, especially HOTS problems that require high-level thinking skills. Students can only solve ordinary issues that are usually found in school textbooks. Next, analyze learning materials. Analysis of learning materials is a stage to determine, detail, and systematically organize what materials are relevant to be taught related to STEM (Science, Technology, Engineering, and Mathematics). Learning materials developed by giving students problems with PBL steps to train students' high-level thinking skills are limited to statistical materials with sub-chapters of mean, median, and mode.

This gap analysis was conducted to determine the fundamental problems underlying the need to develop STEM-based learning modules with the PBL model to train students' high-level thinking skills. After conducting interviews with grade VIII mathematics teachers at UPT SMPN 9 Gresik, researchers obtained information about the limitations of learning resources used by students and the lack of activities for students to practice high-level thinking. The books they use are also only textbooks obtained from the school. It makes students have low motivation to learn mathematics.

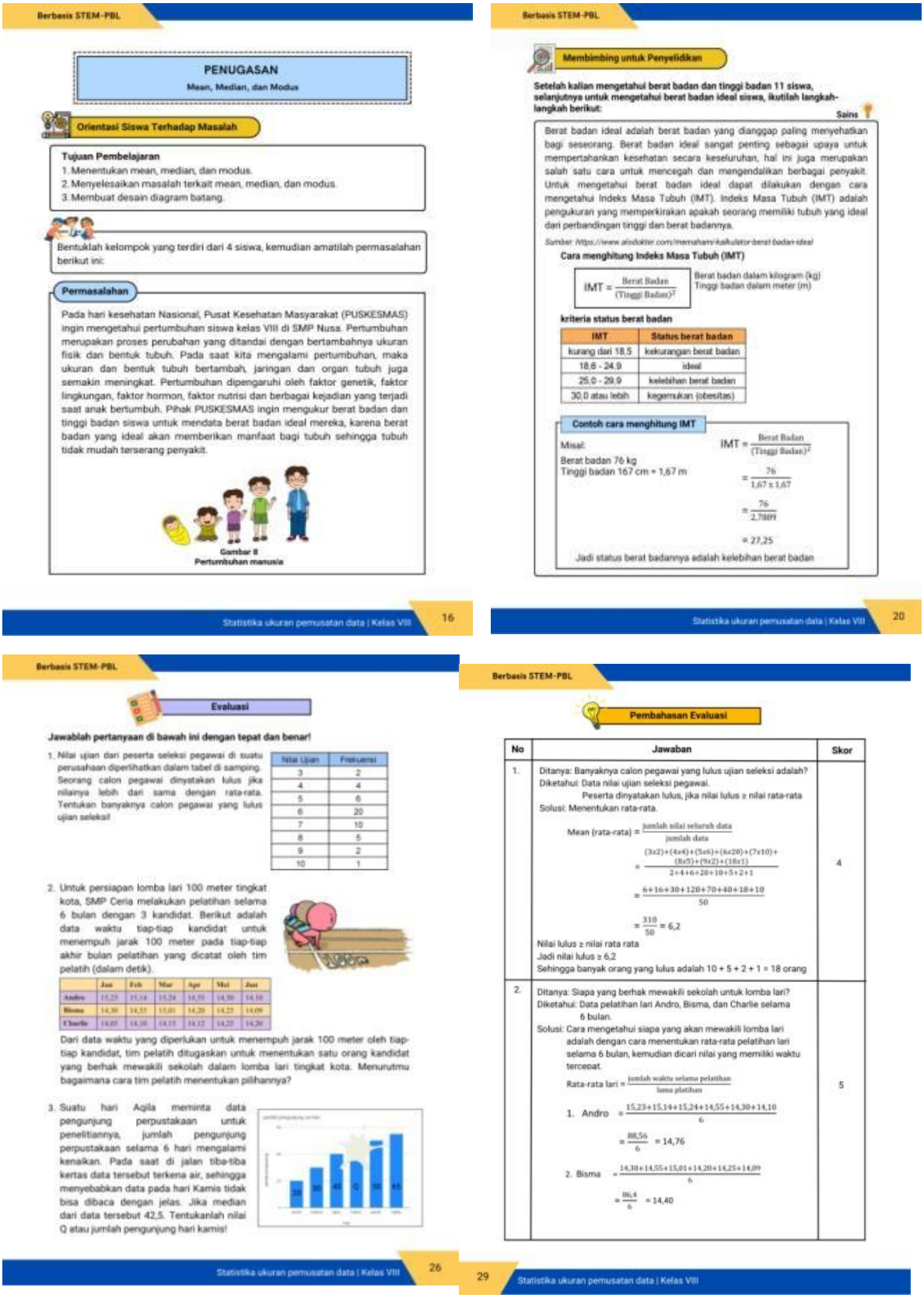
B. Design Stage

The developed learning module adjusts to the core competency standards and essential competencies based on the 2013 curriculum. The STEM-based mathematics learning module with the PBL model on statistics material is a printed module with A5 size. The product design for developing the learning module consists of a cover, title page, foreword, table of contents, module description, module usage instructions, core competencies, and essential competencies, learning achievement indicators, concept maps, materials, assignments, summaries, evaluations, feedback, evaluation discussions, bibliographies, and author profiles. At this stage, the design of research instruments was also carried out, consisting of validation sheets, student response questionnaire sheets, and high-level thinking ability test sheets for students.

C. Development Stage

At this stage, the researcher realized and validated the STEM-based mathematics learning module with the PBL model to train this high-level thinking ability. The researcher discovered the previously created learning module design into an authentic product using the Canva application. The following shows the details of the developed mathematics learning module.

Picture 2. Introduction of Learning Module



Picture 3. Content of Learning Module

The image above shows that the developed module contains elements of the module, starting from the cover, instructions, materials, sample questions, practice questions, and discussions. To view the complete learning module, please go through the following link: https://online.fliphtml5.com/unibsitubondo/xknt/. The learning module that has been developed has been validated by several experts and has been revised based on notes from several validators.

Table 2. Validation Result of Mathematics Learning Module

No	Assesment Aspect	Validator 1	Validator 2	Validator 3	Average Category	Average Total Validity	Description
1	Feasibility of Presentation	3.75	4	4.25	4	4.16	Very Valid
2	Language Feasibility	4	4	5	4.33		
3	Content feasibility	4	4	4.42	4.14		

Arikunto said that there are three aspects of assessment: presentation feasibility, content feasibility, and language feasibility. In addition, there are four categories in the total validity average, ranging from invalid, less valid, valid, and very valid (Arikunto, 2012). Table 2 above shows that three expert validators tested the validity of the module. These validators gave a value of 4 for the feasibility of presentation, 4.33 for language feasibility, and 4.42 for content feasibility. Thus, the total validity average of the developed learning module is 4.16, and the result was Very Valid.

In addition to validity, practicality and effectiveness are indicators of success in the development of learning modules. The results of the data analysis of the practicality of the development of mathematics learning modules are shown in Table 3 below.

Table 3. Results of Theoretical Practicality of Mathematics Learning modules

No	Validator	Final Grade	Average	Category	Description
1	Validator 1	78.67	83.11	B	It can be used with minor revision
2	Validator 2	80.00			
3	Validator 3	90.67			

Based on the table of theoretical practicality results on the mathematics learning module above, it is known that validator 1 gave a score of 78.67, validator 2 of 80.00, and validator 3 of 90.67. The average of these assessments is 83.11, and they are in category B, which means that they can be used with minor revisions. Furthermore, the results of student responses also include indicators of the practicality of developing a mathematics learning module. In this case, it will be explained in detail during the implementation stage. The following shows in detail the revisions that have been made: https://online.fliphtml5.com/unibsitubondo/fzxe/.

D. Implementation and Evaluation Stage

After the STEM-based mathematics learning module with the PBL model was revised and the product was declared valid and practical by the validator, the researcher then conducted a trial in class VIII-C UPT SMPN 9 Gresik. This module was applied to 31 students. Analysis of student responses is shown in the table below.

Table 4. Practicality results (student responses) of the mathematics learning module

No.	Statement	Total Value	%NR
1	The appearance of this STEM-PBL-based mathematics learning module is attractive.	99	79.84%
2	This STEM-PBL-based mathematics learning module makes me more enthusiastic about learning mathematics.	96	77.42%
3	By using STEM-PBL-based mathematics learning modules, learning mathematics is not dull.	95	76.61%
4	This STEM-PBL-based mathematics learning module helps me master mathematics lessons, especially statistics material (mean, median, and mode).	93	75%
5	The presence of motivational words in the STEM-PBL-based mathematics learning module has an impact on my attitude and learning outcomes.	96	77.42%
6	This STEM-PBL-based mathematics learning module is something new for me, and it adds to my experience.	96	77.42%
7	I do not feel burdened by using this STEM-PBL-based mathematics learning module.	99	79.84%
8	The instructions in this STEM-PBL-based mathematics learning module are easy for me to understand.	91	73.39%
9	This STEM-PBL-based mathematics learning module is easy for me to understand.	93	75%
10	This STEM-PBL-based mathematics learning module can help me determine my concepts.	89	71.78%
11	The delivery of materials and assignments in this STEM-PBL-based mathematics learning module is related to improving my higher-order thinking.	91	73.39%
12	This STEM-PBL-based mathematics learning module contains an evaluation test that can test how far my understanding of statistics material (mean, median, and mode) is.	98	79.03%
13	The language used in this STEM-PBL-based mathematics learning module is simple and easy to understand.	98	79.03%
14	The sentences and paragraphs used in this STEM-PBL-based mathematics learning module are clear and easy to understand.	102	82.26%
15	The letters used are simple and easy to understand.	108	87.10%
	Average		**77.64%**

The table above shows that the responses given by students regarding the developed learning module are at 77.64%. It means that the students' responses are good. Overall, the indicators of the practicality of developing a mathematics learning module, namely theoretical practicality of 83.11, which states that it can be used with

minor revisions, and practical practicality through student responses of 77.64%, which means that student responses are good. Thus, the practicality of the mathematics learning module that has been developed is declared Practical. These results are in line with Meityastuti's research, which states that the STEM-based PBL model learning device was declared feasible and practical to use (Meityastuti & Wijaya, 2022).

The effectiveness of developing mathematics learning media is shown by analyzing the results of students' high-level thinking ability tests. In addition, there is also a percentage of students' high-level thinking skills.

Table 5. Percentage of Students' High-Level Thinking Skills

Category	Score Interval	Frequency	Percentage (%)
Very good	Student score ≥ 80	19 students	61.29%
Good	60 ≤ Student score < 80	7 students	22.58%
Enough	40 ≤ Student score < 60	5 students	16.13%
Not enough	20 ≤ Student score < 40	-	-
Amount		31 students	100%

Based on the table above, there are 19 students with a percentage of 61.29% included in the category of having a very good level of high-level thinking skills, 7 students with a percentage of 22.58% included in the category of having a good level of high-level thinking skills, and 5 students with a percentage of 16.13% included in the category of having a sufficient level of high-level thinking skills. Thus, it can be said that the STEM-based learning module with the PBL model can train students' high-level thinking skills because 19 students have a very good category and 7 students have a good category. Likewise, Kurniawati has conducted research, and the results show that modules with STEM-PBL were practical in learning activities (Kurniawati & Ummah, 2023). Based on the results of the research and discussion previously described, it can be concluded that the learning module developed is said to be valid, practical, and effective in improving students' higher-order thinking.

Conclusions and Suggestions

The process of developing a STEM-based mathematics learning module with a PBL model to train high-level thinking skills using ADDIE development shows that (a) curriculum analysis, the curriculum used in the school used for the study is the 2013 curriculum for grades VIII and IX, (b) student analysis, in this case only some students are active in learning and many students still have difficulty in solving high-level thinking skills questions, (c) analysis of learning materials, the material used is statistics that focuses on the measure of data centralization, and (d) gap analysis, in this case the school used for the study only uses one learning source, namely textbooks obtained from the school. The STEM-based mathematics learning module with the PBL model to train students' high-level thinking skills received a total average score of 4.16 from the validators and was categorized as very valid. The STEM-based mathematics learning

module with the PBL model to train students' high-level thinking skills that were developed met the practical aspects in theory with a final score of B from the three validators with the category can be used with slight revisions, and sensible in practice with the percentage of student responses of 77.64%. Based on the results of the students' high-level thinking skills test, it was found that 19 students were in the very good category, 7 students in the good category, and 5 students in the sufficient category. Thus, The STEM-based mathematics learning module using the PBL model could been said to be well used to improve students' mathematical understanding and higher-order thinking.

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