Volume 6, Nomor 1, Juni 2022
Numerical: Jurnal Matematika dan Pendidikan Matematika
http://journal.iaimnumetrolampung.ac.id/index.php/numerical
DOI:https://doi.org/10.25217/numerical.v6i1.

Improving Mathematical Critical Thinking Ability With Learning Modules Using Brain-Based Learning Models

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Article Info
Article History
Received: 25-05-2022
Revised: 06-06-2022
Accepted: 07-06-2022
Keywords:
Brain-Based Learning Models;
Mathematical Critical Thinking Ability;
Modules

Abstract
The quality of mathematics learning is influenced by good teaching material and can facilitate students to be active in knowledge and improve mathematical critical thinking skills. Mathematical critical thinking skills focus on activities in analyzing a more specific idea. Developing a learning module using a brain-based learning model is necessary to improve mathematical critical thinking skills. This study aims to determine the characteristics of the learning module using a brain-based learning model that is valid, practical, and effective. This type of research is development research using the Plomp model, which consists of three stages, namely the preliminary, development, and assessment stages. The module uses a Brain-based learning model for class X Senior High School (SMA). The instruments used are validation sheets, observation sheets, questionnaires, interviews, and tests. The results showed that the learning module using the brain-based learning model for class X SMA was valid, practical, and effective. The validity of the module reaches 78.6. In contrast, the practicality of the module is 91.67%. In terms of effectiveness, it can be seen from students' average mathematical critical thinking ability test results, namely from 52.2 to 88.1.

INTRODUCTION

Mathematics plays a vital role in aspects of life to foster and form quality human beings. Knowledge of mathematics is necessary to master because it is needed in everyday life [1]–[3]. Rohmaha [4] states that learning mathematics plays a role in developing students' logical, critical, analytical, and systematic thinking skills. Good mathematics learning in schools is learning that can make students competent in the field study by the expected learning objectives. Permendikbud Number 59 of 2014 concerning high school mathematics teaching purposes. One of them is to require students to be actively involved in learning so that problem-solving abilities become more developed. Based on problem-solving ability in mathematics, a student must have one of the higher-order thinking skills [5]–[7]. One of the higher-order thinking skills required in the 2013 curriculum learning is critical thinking skills.

This critical thinking ability focuses on analyzing more specific ideas and carefully distinguishing, selecting, and identifying a perfect direction. In mathematics, critical thinking ability is the ability to involve prior knowledge, mathematical reasoning, and use cognitive strategies in proving, generalizing, and evaluating mathematical situations, known as thoughtful ways [8], [9]. Based on the facts found in several public high schools in Padang City, students' mathematical

Print ISSN: 2580-3573, Online ISSN: 2580-2437

critical thinking skills are still relatively low. Based on the initial test of essential skills of thinking given to several public high schools in Padang City, information was obtained that students' critical thinking skills were still relatively low. It refers to the criteria for necessary thinking skills (KBK), namely:

Table 1. Critical Thinking Ability Level Criteria [10]

Interpretation (%)	Category
$81,25 \leq X \leq 100$	Very high
$71,5 \leq X < 81,25$	High
$62,5 \leq X < 71,5$	Currently
$43,75 \leq X < 62,5$	Low
$0 \leq X < 43,75$	Very low

The recapitulation of the assessment of critical thinking ability trials conducted in two schools obtained an average score of 52.2. Suppose you refer to table 1. Then it is still classified as a low category. It is necessary to optimize the mathematics learning process to improve students' mathematical critical thinking skills. However, this is partly because learning during COVID-19 did not run properly, affecting students' mathematical achievement, especially in necessary thinking skills. In line with research conducted by Zakaria [11] said, the existence of covid-19 resulted in the learning process being carried out online, where many students did not like learning mathematics online, so it increasingly impacted students' low mathematical critical thinking skills.

In response to the above problems, a learning module is needed that can facilitate students to improve their mathematical critical thinking skills. The module to be developed is in the form of a mathematics module. A module is one of the teaching materials that can support the learning process, especially critical thinking skills. The developed module must have unique characteristics and characteristics in use. The module is one of the teaching materials that can be an alternative and designed systematically with language that students easily understand. The author also analyzes the teaching materials used in class X mathematics. The teaching materials have not seen a learning process that provokes student activity and does not contain indicators of students' mathematical critical thinking abilities. Developing quality and exciting learning modules is needed to improve students' mathematical thinking skills.

According to Wiska [12], in his research, it was found that active learning activities in mathematics subjects can improve students' critical thinking skills. Learning modules that apply learning models can also enhance students' thinking skills in mathematics, one of which is the Brain-Based Learning model. The brain-Based Learning model is one of the learning models that can create learning oriented towards empowering the brains and minds of students, to develop critical thinking skills. The specialty of this Brain-Based Learning model is that it does not only use the brain to learn but learns how the brain works so that we can maximize the work of the brain for learning and we can improve the quality of learning at its maximum level.

The learning begins with displaying a mind map, which directs and guides students to solve various problems so that it will spur students' critical thinking processes. This brain-based learning model has several learning stages, namely the first Pre-Exposure Stage. This stage is a preparation stage that can provide a framework for new learning and begins to prepare the students' brains with possible connections. This stage gives the brain a review of the new knowledge before digging

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further. The second stage of the preparation, at this stage, is a phase in creating curiosity or pleasure. This is similar to "setting anticipatory conditions" but goes further in preparing for learning—the third stage of initiation and acquisition at the location of initiation and acquisition. The teacher divides the students into several groups. Students join their group of friends. Then the teacher gives a module to each group, and students study the module before filling it out. After that, students discuss filling out the exercises in the module with their group friends.

The fourth stage is elaboration. Students present the results of group discussions in front of the class while other participants pay attention, express opinions, or ask questions. Next, the Fifth is the Incubation and Memory Entry Stage. Students stretch during the incubation and memory entry-stage while watching videos that can motivate them to learn. In addition, educators also provide simple practice questions in the form of understanding inquiries related to the material that the teacher has just studied. The sixth stage is Verification and Confidence Checking. At the verification and confidence checking stage, educators provide practice questions at a more complicated level. Next, the last stage is the Seventh, namely Integration and Celebration. At this stage, the educators conclude the material that has just been studied. This Brain-Based Learning model is more oriented to efforts to empower the brain potential of students. This means that in this Brain-Based Learning, the emphasis is on the student center or focuses more on students' activeness in learning in the classroom.

The application of the brain-based learning model in learning is supported by modules designed based on the brain-based learning model's stages. Before students use this module, educators guide students to be able to understand and solve problems both in discussion and independently. This activity hopes that students' mathematical abilities can be improved, especially in increasing mathematical critical thinking skills. The research aimed to determine the achievement of the application of learning modules using the brain-based learning model in enhancing students' mathematical necessary thinking skills in class X MIPA SMA.

METHOD

The development research uses brain-based learning model modules to improve students' mathematical critical thinking skills. The research subjects were students of class X MIPA SMAN 1 Padang. The module development phase refers to the Plomp development model, which has three stages: preliminary research, prototyping, and assessment. [13]. The purpose of the primary research stage is to emphasize content validity, where needs analysis, curriculum analysis, concept analysis, and analysis of student characteristics are carried out here. The instruments used at this stage are interview guidelines, student questionnaires, curriculum and concept analysis, and observation sheets.

The development phase (prototyping phased) focuses on consistency (product validity), prioritizes product practicality, and gradually leads to effectiveness. This stage consists of several prototypes, namely prototype 1 (Validity Test). This stage is carried out self-evaluation (self-evaluation) and expert assessment (expert review) to test the validity of the module that has been designed. The second prototype 2 (practical test with one-to-one evaluation) was given to 3 students. Three of the third prototype was tested with a small group evaluation (small group) assigned to 6 students. The research instrument used was in the form of a self-evaluation sheet and a module validation sheet.

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In the small group evaluation stage, activities are focused on evaluating the quality of the products produced in the one-to-one evaluation stage. The assessment was carried out to determine whether the resulting learning module was in line with expectations, practical, and effective for improving students' mathematical critical thinking skills. The module's effectiveness carried out a final test of essential thinking skills for six students.

RESULTS AND DISCUSSION

Based on the research that has been done with three stages of development, the module that uses the brain-based learning model obtains the following results:

1. Initial Investigation Stage (Preliminary Study)

Activities carried out at this stage begin with analyzing needs, curriculum analysis, concept analysis, and student analysis. In the needs analysis activity, information was collected about the compulsory mathematics learning process at SMAN 1 Padang through interviews with mathematics educators who stated that students' mathematical critical thinking skills were still low, especially on indicators of analyzing and evaluating, observing the process of learning activities used in the learning process. Curriculum analysis is carried out to examine the curriculum used. Based on the study, it is known that learning is based on the 2013 curriculum: KD 3.7 and KD 3.8 regarding trigonometric ratios, which are divided into six meetings.

Next is the concept analysis. Based on the concept analysis, the trigonometric ratio material is chosen because, in the process, learning with brain-based learning models can be used to improve critical thinking skills. Fourth is the analysis of students. Based on the results of student analysis, after an initial test of essential mathematical skills of thinking is still in the low category, students tend to want teaching materials or learning resources that are easy to understand and more enjoyable to improve their mathematical critical thinking skills.

2. Prototype Development Stage

After obtaining the results at the initial investigation stage, the next step will be to design a learning module that uses a brain-based learning model to improve mathematical critical thinking skills. The module design is made with a standard size, namely A4. The writing on the module generally uses Comic Sans with size 12. As for the characteristics of the module that uses the brain-based learning model to be developed, it can be seen in the following module components:

Figure 1. Front and Back Cover Design

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The module cover is designed using the Corel Draw 2021 program. This cover is made in front of two parts: the front and the back. The product design for the development of the module consists of a cover module, a module profile, a glossary, and instructions for using the module by the stages of the brain-based learning model.

Next, a self-assessment is carried out on the resulting product. At this stage, the researcher checks the typing errors, punctuation marks, the suitability of the material, and the suitability of the problems listed in the lesson plans with a listed module. Furthermore, the revised product was prepared to be validated by five experts at the expert review stage, consisting of 3 mathematics education lecturers, one educational technology lecturer, and one language lecturer. The results obtained at the expert review stage for the module validity test results are as follows:

Table 2. Overall Module Validity Results

No	Rated aspect	Validity Index	Category
1	Presentation	3.57	Very valid
2	Content eligibility	3.49	Very valid
3	Language	3.75	Very valid
4	Graphics	3.25	Valid
Average validity index		3.52	Very Valid

Based on Table 2, the module's assessment by three mathematics education experts, 1 Indonesian language expert, and one education technology expert. It was declared very valid with an average validity index value of 3.52.

After carrying out the validation process, the following stage is a one-to-one evaluation, which aims to observe a problem found in the module using a brain-based learning model. This activity was tested on three students with different ability levels. This activity was carried out from February 14, 2022 - to February 19, 2022. After the module using the brain-based learning model was repaired based on one-to-one evaluation, this stage can be said to be prototype 3, which was then carried out in small group evaluations.

A trial was conducted at the small group evaluation stage on six students selected based on different ability levels. Learning is carried out with core activities using the brain-based learning model stages. In implementing the small group evaluation stage, the researcher acts as an educator who teaches using the steps of the brain-based learning model according to the lesson plans and modules. The following is an example of the results of one student's answer at the verification and checking stage of confidence in activity module 3.

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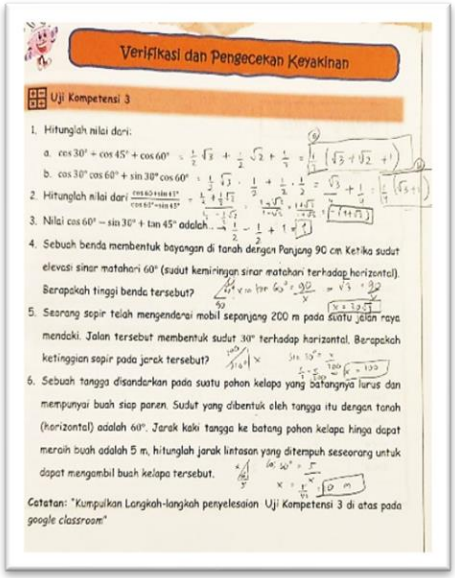
Verifikasi dan Pengecekan Keyakinan

Uji Kompetensi 3

1. Hitunglah nilai dari:
   a. $\cos 30° + \cos 45° + \cos 60°$
   b. $\cos 30° \cos 60° + \sin 30° \cos 60°$
2. Hitunglah nilai dari $\frac{\cos 60° + \sin 45°}{\cos 60° - \sin 45°}$
3. Nilai $\cos 60° - \sin 30° + \tan 45°$ adalah ...
4. Sebuah benda membentuk bayangan di tanah dengan Panjang 90 cm. Ketika sudut elevasi sinar matahari 60° (sudut kemiringan sinar matahari terhadap horizontal). Berapakah tinggi benda tersebut?
5. Seorang sopir telah mengendarai mobil sepanjang 200 m pada suatu jalan raya mendaki. Jalan tersebut membentuk sudut 30° terhadap horizontal. Berapakah ketinggian sopir pada jarak tersebut?
6. Sebuah tangga disandarkan pada suatu pohon kelapa yang batangnya lurus dan mempunyai buah siap panen. Sudut yang dibentuk oleh tangga itu dengan tanah (horizontal) adalah 60°. Jarak kaki tangga ke batang pohon kelapa hinga dapat meraih buah adalah 5 m, hitunglah jarak lintasan yang ditempuh seseorang untuk dapat mengambil buah kelapa tersebut.

Catatan: "Kumpulkan Langkah-langkah penyelesaian Uji Kompetensi 3 di atas pada *google classroom*"

Figure 2. Verification and Confidence Check Stage Worksheet

At this stage, interviews were also conducted with the six students. The interview results stated that the overall module used was easy to understand and was good, both in terms of writing, materials, and the selection of designs on the module. In addition to conducting interviews, students were also asked to fill out a student response questionnaire regarding the practicality of using the module. An average of 84.83% was obtained with efficient criteria. In addition to students, a practicality questionnaire was given to mathematics educators in class X MIPA SMAN 1 Padang. The results obtained were 91.67% for modules with efficient criteria. Based on the practicality questionnaire, the module filled out by educators for the mathematics learning module using the brain-based learning model is very practical.

Brain-based learning modules can improve students' mathematical critical thinking skills. This is assessed based on indicators of essential skills of thinking, namely interpretation, analysis, evaluation, and inference. This is evaluated by looking at the student's response to the question; namely, the student can write what is known and asked from the question correctly and completely, then the student can make a mathematical model of the problem given correctly and give a correct, complete explanation. Furthermore, students can also use the right and proper strategies in doing calculations, and students can also make valid conclusions according to the context of the problem.

3. Assessment Phase

The assessment stage was carried out in a small group (small group evaluation), which was carried out in February 2022. After being revised based on input at the one-to-one stage, the learning module was tested on a limited basis in class X MIPA SMAN 1 Padang. At this stage, the practicality and effectiveness of the compulsory mathematics learning modules that were developed were seen. The module's usefulness is seen from the analysis of interviews with educators and questionnaires filled out by students as users of the learning module. At the same time, the effectiveness is seen in the final test of students' critical thinking skills. Following are the results of the analysis of each instrument.

a. Educator Interview Results

Based on the results of interviews with educators, it can be concluded that the learning module is evident in the use of pictures and writing. The sentences given do not use double

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meanings. The level of service of the module is easy to understand and use, then at the level of practicality of the learning module. Educators assess that the lesson plans and modules are practical to improve students' critical thinking skills.

b. The results of the student's practicality questionnaire

Based on the results of the recapitulation of the module practicality questionnaire by students, it was found that the average value of the module practicality questionnaire was 85.83% in the practical category. This indicates that the learning module developed is practical.

c. The results of the educator's practicality questionnaire

Based on the results of the questionnaire response of educators to the practicality of the module that uses brain-based learning as a whole is 91.67% with efficient criteria, so it can be concluded that the mathematics learning module that uses the brain-based learning model is declared to be practical and can be used well by students. in learning.

In addition to the practicality test, at the small group evaluation stage, an effectiveness test was also carried out, which aims to determine mathematical critical thinking skills after studying with a module that uses a brain-based learning model consisting of 5 questions, the results of the final test can be seen in Table 3 below:

Table 3. Mathematical Critical Thinking Ability Test Results

Name	Indicator				Score (%)	Information
	Interpretation	analysis	evaluation	inference		
AFA	90	100	100	100	97.5	Complete
LA	100	100	100	90	97.5	Complete
AF	90	100	85	90	91.2	Complete
APK	100	100	100	100	100	Complete
AAA	100	90	100	90	95	Complete
BKH	80	90	90	90	87.5	Complete
Average	93.3	96.7	95.8	93.3	94.8	

Small group students had completed with an average score of 94.8%, so at this stage, it can be concluded that learning modules using brain-based learning models to improve mathematical critical thinking skills are adequate.

The following is the documentation of students answering the mathematical critical thinking ability test questions in Figure 3 below:

Figure 3. Students Working on Mathematical Critical Thinking Ability Test Questions

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The learning outcomes obtained in this study were in the form of a description test of 5 questions. This test is conducted to assess the students' mathematical critical thinking skills after learning to use a brain-based learning model module. Based on the data analysis of the six students who have completed, the following is an example of the answer of one of the students in completing the mathematical critical thinking ability test.

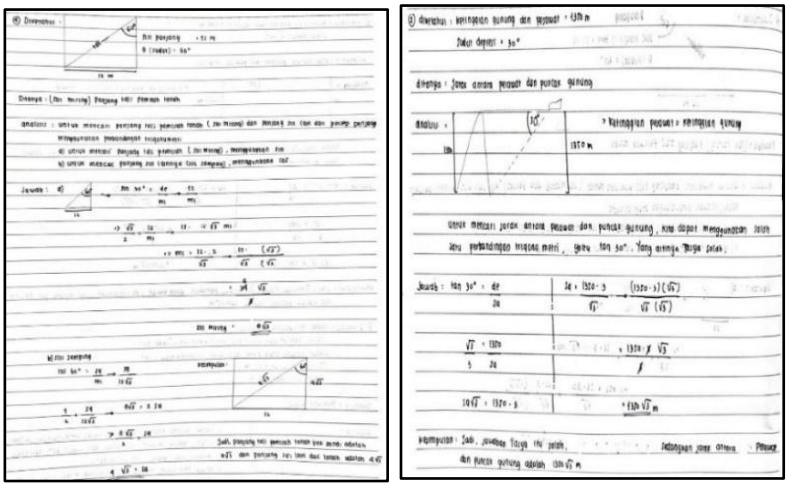

Figure 4. Example of one of the student's answers in Mathematical Critical Thinking Ability

When compared with the initial critical thinking ability test, which has an average value of 52.2 compared to the last mathematical critical thinking ability test given to students, it is found that the average percentage score is 94.8. It can be seen that there are differences in the level of mathematical critical thinking skills of students who learn to use the lecture method with students who learn to use brain-based learning models. So, referring to table 1 above, it can be seen that the results of the students' mathematical critical thinking ability test results, which were initially low, increased to the very high category.

Based on the analysis results, it was found that the learning module using the brain-based learning model increased mathematical critical thinking abilities. Several things that cause students' necessary thinking skills in implementing the Brain-Based Learning learning model to rise higher are students who are more actively involved in the learning process, discussing each other, exchanging information, and being more flexible and focused in carrying out learning activities in the classroom. Students do not feel pressured to understand the lessons delivered.

Some of the sensory support provided in learning also improves students' critical thinking skills, such as playing classical instruments while students are discussing, giving worksheets printed in bright colors, using attractive colored pens when taking notes, and pauses for drinking. This is the opinion of Nahdi (2015), who states that in learning that applies the Brain-Based Learning model, students are more actively involved in education, such as actively discussing and being active in project activities contained in student worksheets. These activities trigger increased skills. Students possess critical thinking.

Based on the analysis of the research results and the theory that is used as a reference, it can be concluded that there are differences in students' critical thinking skills in classes that implement the Brain-Based Learning model compared to the control class that is accustomed to being subjected to the DI model while studying with class teachers. In this research, the answer can be found. Namely, the implementation of the BBL learning model affects the critical thinking skills

Print ISSN: 2580-3573, Online ISSN: 2580-2437

of senior high school students. These results are relevant to the effects of Lusiana's research [14]; Permana [15]; Gladys [16]; Orengwu Okatahi [17], that students' necessary thinking skills in classes given physics learning with the Brain-Based Learning learning model are significantly different when compared to types offered physics learning using conventional methods, with the effect size category being moderate. Classes given physics learning with the BBL model have higher critical thinking skills than classes that use traditional methods.

Furthermore, Maryati [18] also stated that after being subjected to the Brain-Based Learning learning model, there was an increase in students' critical thinking skills. In addition, the results of this study are also relevant to Wiantara [19] and Hari Utomo [20] that there are differences in the critical thinking skills of students who are subjected to the implementation of the Brain-Based Learning learning model compared to the control class which is not subject to the Brain-Based Learning learning model. These differences indicate that students' critical thinking skills in the experimental class are higher than those in the control class.

CONCLUSIONS AND SUGGESTIONS

The learning module that uses the brain-based learning model developed in class X MIPA SMA for KD trigonometric ratios is declared valid, practical, and effective. Based on the validation results by five experts, the results obtained 3.52 with very reasonable criteria. After passing the small group process and the mathematical critical thinking ability test, the results showed that the learning module using the brain-based learning model for the trigonometric ratio material was effective, as seen from the average value and the percentage of completeness of students who took the mathematical critical thinking ability test. It is recommended that other researchers develop learning modules using a brain-based learning model for different materials and try it out on several discussion topics so that the resulting product is better.

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Print ISSN: 2580-3573, Online ISSN: 2580-2437