

## Development of Mathematical Physics 1 Module Based on Problem Based Instruction

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### Abstract

Mathematical Physics I is one of the courses that train students to think critically and creatively in the learning process. Therefore in this research developed a teaching material in the form of modules based on Problem Based Instruction (PBI). The module began with introduce students to a contextual problem that later ended with the presentation and analysis of student work. This type of research is the development of research using a stage model of Plomp, namely: (1) preliminary research, (2) prototyping phase, and (3) assessment phase. The research subjects involved lecturers and students from two campuses, namely Universitas Negeri Padang and STKIP PGRI West Sumatra. The research data was obtained through the validation sheet of modules that look at the feasibility module by module construction, content and the language used. Item analysis was conducted by using qualitative and quantitative analysis. Based on the results of the validation, results showed that the modules are very valid and ready for trial eligibility to students. Modules that are designed are categorized as very valid with a value of 84.66 and very practical with a practical value of 83.05. This result indicate that development of Mathematical Physics I module based on the Problem Based Instruction learning model can be used by students and lectures in learning process.

**Keywords:** Mathematical Physics I; Module; Problem Based Instruction; and Validity

### INTRODUCTION

Mathematical Physics course is a compulsory subject that provides the basics of mathematical analysis to solve physics problems. This course is presented in six credits distributed in the second half semester (Mathematical Physics I) and the third semester (Mathematical Physics II). Mathematical Physics Course I is a prerequisite of some advanced physics course in the Physics Education Study Program.

The real conditions that occur seem to be hard enough for the students. In the second semester the students are still in the process of adjustment to learning systems in higher education, while the subject Mathematical Physics

I requires students to think critically in mastering two concepts that give the concepts of physics and mathematics. One of the obstacles faced by students is the students' lack of understanding about source books. Judging from the available source book has not been in accordance with the needs and design of lectures to be composed of lecturers. Then book the resources presented in the language of instruction in English so the motivation of students to learn material becomes low. This situation causes the difficulty for students to be able to master a textbook well, so the impact on the understanding of concepts and student results. Therefore it is strongly needed a teaching materials to help the students in understanding the material. Teaching materials is a set of materials arranged in a systematic, so it needs to be designed and reviewed in advance with the aim of competencies to be achieved in the learning process, as well as the function is to provide the

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widest opportunity for students to learn independently (Amilia, Andriani, & Zulherman, 2016). The existence of teaching materials that are applied in the learning process is expected to help students to actively learn independently and can easily understand the learning concepts presented.

In addition to the lack of teaching materials, the time constraints in the course also become one of the obstacles. Students need more time to master the concepts of physics and applied physics in contextual issues. Solving the problems of physics is required mathematical concepts in solving these problems theoretically that requires students to think critically, creatively and innovatively. The concept is a new tangible notions that may arise as a result of thought, including the definition, understanding, special character, the essence, the core or the content and so on (Doyan & Sukmantara, 2014). Therefore students should be able to master the concept of a given material. Mastery of the concept in question in this research is the ability of students to understand the concept in Mathematical Physics I subject both theoretical concepts and their application in daily life. Good mastery of concepts can help students be more active in learning

Learning is a process of a systematic development of the various components which include various components, that is lecturers, learning tools, teaching materials, students, and strategies in learning (Yanti & Meriko, 2014). A lecturer should have four basic competencies, namely competency pedagogic, professional, social, and personality. The pedagogic competences for physics teachers are, among others, knowing the characteristics of and identifying student's learning difficulties in physics. Professional competences for physics teachers are developing, selecting, and processing physics instructional materials creatively in accordance with student's developmental level (Sinaga, Suhandi, & Liliyasi, 2014). Lecturers must be able to develop teaching materials that are in accordance with the level of student development. Students are expected to be able to explore all the potentials that can develop the capacity to think

properly so improve students' understanding of the material supplied. The ability to think is one of the capital should be owned by the students as a preparation to face the development of science and technology today (Dwijananti & Yulianti, 2010). By development the thinking skills students will have a very important role in improving the quality of human resources. Likewise on the standard of higher education learning processes that require problem solving competencies for graduates (Kemenristekdikti, 2015). The critical thinking skills of students who are trained in higher education are expected to produce graduates who can contribute to the improvement of human resources in society and in solving problems that arise in everyday life.

To help realize it all, it is necessary to reform the learning process in higher education, including applying learning methods that can spur students to be active and have a critical mindset. One of the methods that can help students to develop their thinking pattern is Problem Based Instruction or PBI learning model. PBI is a learning model that presents an active student learning condition and involves students in problem solving through the stages of the scientific method (Fatwa, Septian, & Inayah, 2019). Research-based physics learning with scientific approach is expected to improve the students' competence mastering the concepts of physics, scientific processing skills, and having the scientific attitude (Usmeldi, 2016). Learning activities that are productive, active, creative, effective, and fun to do among other things by creating processes problem based instruction (Winarsih, Sajidan, & Prayitno, 2014).

The teaching materials developed in this research are in the form of modules by integrating the PBI method into the module. This is done to help the lecture and facilitate students in understanding the concepts and be able to learn independently. PB is a learning process that begins with presenting an authentic and meaningful problem to students so that students can carry out investigations and find solutions to problems by themselves (Yuniarti, 2015). The learning process using module is able to provide

opportunities for students to be able to learn independently, provide opportunities to interact and learn with the peers they choose, self-confidence, respect, self-discipline, and motivation to always be better (Ellianawati & Wahyuni, 2012). Application of the PBI model into the device learning that is used, can create learning that allows students to be able to learn actively and fun (Diani, 2015). The PBI learning model consists of several phases, including (1) Student orientation to problems, (2) Organizing students to learn, (3) Guiding individual and group investigations, (4) Developing and presenting work, and (5) Analyzing and evaluating problem solving processes (Halimah, Danawijaya, & Mulyana, 2014).

PBI is a learning model that uses real-world problems as a context for students to learn about ways of thinking and problem-solving skills, as well as to acquire essential knowledge and concepts from the subject matter. Learn this can encourage students to find reasons to the correct solution and encourage students to build, construct and defend argumentative solutions correct (Fakhriyah, Sumaji, & Roysa, 2016). This learning method can help students to be more active and independent in the learning process, not only in finding problems, but also being active and independent in analyzing and then solving these problems, as well as making a conclusion from the problem solving carried out.

This study is a preliminary research and development (R&D method). Research development is a process to develop and validate the products are used in education. The products developed can be either new or enhance existing products, which can be accounted for. Here the researchers developed a new product in the form of PBI based module that aims to help the lecture course on Mathematical Physics Mathematical Physics I. Module of Mathematical Physics I assists students in independent study and hone their skills in solving any problems that are given, in this case a critical thinking process of students is needed. Therefore, the process of critical thinking trained to students will shape their

tendency to thoroughly consider a problem arising from experience so that they are able to make the right decisions (Nisa, Jatmiko, & Koestiari, 2018). Module can provide feedback so that students know the shortcomings and immediately make improvements, improvements can be made because the module provides sufficient opportunity to find their own weaknesses based on the evaluation provided (Lasmiyati & Harta, 2014). With the key answers given, student's motivation in finding the truth of any given problem will increase.

Based on the problems and facts presented, it can be stated that there are still obstacles in the process of understanding students' concepts during the Mathematical Physics I course, such as the lack of source books and student activity in finding and understanding existing concepts. This study aims to develop a learning module by applying the PBI learning model. The benefit of this research is that students can use the Mathematical Physics I module based on the PBI learning model so that students are motivated to be more active in finding and solving existing problems independently. As a result, students can understand the concepts of the Mathematical Physics I course easily. In addition to understanding concepts that can be understood easily, students can also apply the concepts they have learned to solve mathematical physics problems presented in the form of questions. In addition to developing the Mathematical Physics I module based on the PBI learning model, this research was also conducted to improve students' critical thinking skills in solving problems during the Mathematical Physics I learning process.

## METHOD

Research method used is Research and Development developed by Plomp (2007) which refers to the development of a learning device model using the following stages: (1) preliminary research, (2) prototyping stage, and (3) assessment stage. According to Tessmer (1998) in

research and development, a formative stage evaluation was also carried out which included self-evaluation, prototyping (expert review, one-to-one and small group), and field tests. These two opinions are incorporated in the design for the development of this Mathematical Physics module. The research subjects consisted of two lecturers and students from two different campuses, namely 20 students from Universitas Negeri Padang and 20 students from STKIP PGRI West Sumatra. Research data were collected through filling out questionnaires by lecturers and student. Data analysis was carried out with quantitative and qualitative techniques.

The main discussion in this research is the design and realization phase (prototyping phase) which discusses validation by experts. Step-by-step of design of the module development above can be described as follows :

### **Preliminary research**

The activities carried out at the stage of preliminary investigations is conducting a preliminary analysis or identify the problem by analyzing the condition of the student that includes the ability and willingness to learn, a needs analysis and of concepts or content analysis, and assessment of the necessary literature in learning.

### **Prototyping phase**

The step is a stage of formulation / design of the module. This draft guidance refers to the development of teaching materials issued by the Education Ministry. The module is a self-teaching material (print or software) are arranged in a systematic and attractive. Furthermore, at this stage formative evaluation that includes self evaluation, prototyping (expert reviews, one-to-one and small group), as well as field test were done.

The review of the modules that have been designed, assessment and evaluation by experts is carried out at the expert review stage. The experts are examining the content, construct, and the language of each prototype. Advices from the experts will be used to revise the modules developed. Feedback and suggestions from the experts (validator) of the designs that have been

written on a sheet made of validation as a material revision and stated if this design was valid or not. In this validation sheet contains expert feedback about the construction, the feasibility of the content, and the language component of the module that has been given. This validation activities undertaken to obtain feedback on the overall content of the material contained in the module design.

The validity of the contents shows that learning developed based on the curriculum is appropriate with the material being taught. Then, language validity is related to the use of appropriate language roles on the instrument. Construct validity demonstrated internal consistency between the components of the model. Then, the design validation activities also assess the design of the module is aimed to look at the suitability of the learning model PBI to shape the design of the modules developed. The main part which is validated conformance learning outcomes, indicators, the truth of the concepts and language used.

Validation module using the validation sheet given to experts and practitioners in the field of education according to the study. While practicality is carried out to see student response questionnaires and lecturer response questionnaires related to the practicality of using the modules that have been made.

Analysis validation is performed by using a Likert scale with the following provisions: not good = 1, good enough = 2, good = 3, and excellent = 4.

The calculation of the final value of the validation and practicality results expressed in scale (0-100) was performed using the Equation (1) by Riduwan (2013).

$$p = \frac{f}{n} x 100\% \quad (1)$$

where  $p$  is the value of validity,  $f$  is obtained score and  $n$  is score maximum.

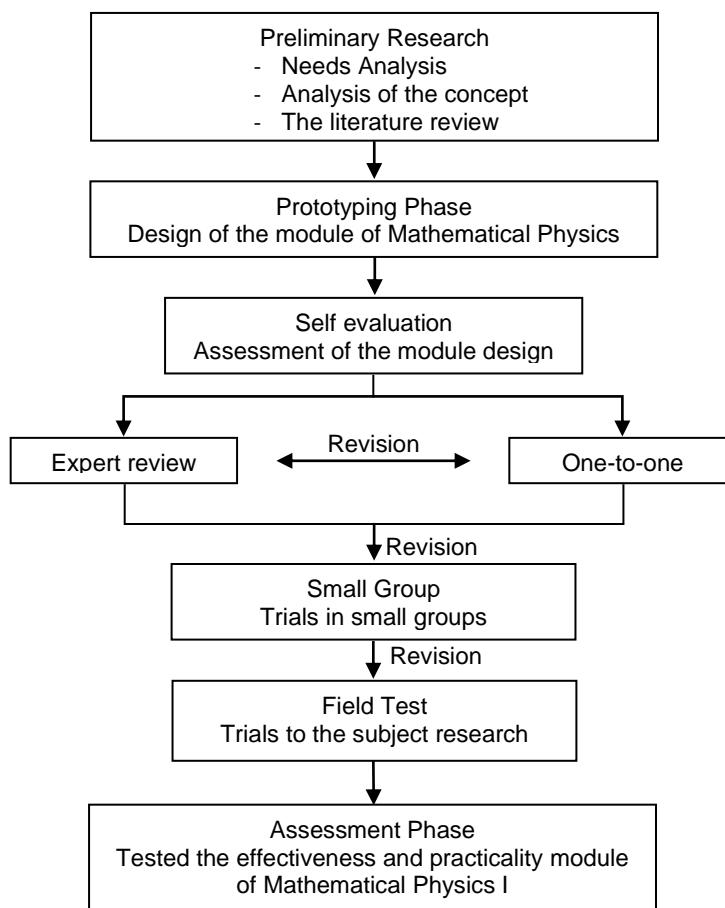
The category of module validity based on the final score obtained according to Riduwan (2013) is shown in Table 1.

**Table 1.** Categories of Module Validity

Interval	Categories
0 – 20	Very invalid
21 – 40	Invalid
41 – 60	Less valid
61 – 80	Valid
81 – 100	Very valid

**Assessment Phase**

The next phase is carried out to test the practicalities of the level and effectiveness of the module so that it is understood that if the module can be used to achieve a practical purpose in improving the quality and achievement of students. Generally, the steps of this research can be seen from the conceptual framework in Figure 1 .



**Figure 1.** Research Flow

**RESULT AND DISCUSSION**

The validation of the module done after designing module guided from teaching materials created by the Education Ministry. In the design of teaching materials pass through several steps, among others: (1) assessing the suitability of the material that will be presented in teaching materials with the achievement of learning had been developed previously, (2) determine the

depth of content and scope of teaching materials, (3) determine the purpose of teaching materials, (4) determine the type of treatment to be given to teaching materials, (5) determine the source of learning materials. Once the design phase is complete modules developed further evaluation and assessment by experts and peers. The experts assess the validation of content, construct, and language. The main part which is validated learning outcomes suitability, truth concepts and language used. Feedback from the validator is

used to fix and revise the modules developed until the resulting module is valid. The validation phase begins with an analysis and assessment of experts consisting of three lecturers. Validation is done by

experts in the field of expertise of Physics and Physics Education. Here is an example of a module that has been validated by experts.

**BILANGAN KOMPLEKS** FISIKA MATEMATIKA I

Membimbing penyelidikan individu maupun kelompok

Mahasiswa mengumpulkan informasi untuk mendapatkan pemecahan masalah dan dosen memfasilitasi mahasiswa

**PENGERTIAN BILANGAN KOMPLEKS**

Konsep bilangan kompleks muncul untuk mengakomodasi nilai akar suku bilangan negatif. Ditinjau persamaan kuadrat dalam  $z$  berikut :

$$az^2 + bz + c = 0$$

dengan  $a, b$  dan  $c$  variabel bebas. Penyelesaian persamaan kuadrat di atas adalah

$$z_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Jika diskriminan  $D = b^2 - 4ac$  bernilai negatif, maka dua nilai  $z$  mengandung akar bilangan negatif. Ketika  $D < 0$  maka kita mengenal bilangan baru yang disebut dengan *bilangan imajiner* dengan didefinisikan nilai  $\sqrt{-1} = i$  sehingga  $i^2 = -1$ , jika

$$\sqrt{-16} = 4i$$

$$\sqrt{-3} = i\sqrt{3}$$

Adalah contoh bilangan imajiner  
Tetapi  $\sqrt{-2}\sqrt{-8} = i\sqrt{2}i\sqrt{8} = -4$  adalah contoh bilangan real.

*Contoh bil real yg lebih sederhana*

**Contoh soal**

Cariilah akar-akar Untuk contoh persamaan kuadrat berikut :

$$z^2 - 2z + 2 = 0$$

Penyelesaian  
maka akar-akarnya adalah :

$$z = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$z = \frac{2 \pm \sqrt{4 - 8}}{2}$$

$$z = \frac{2 \pm 2i}{2}$$

$$z = 1 \pm i$$

istilah bilangan kompleks digunakan untuk menunjukkan set bilangan real, imajiner atau gabungan keduanya, seperti  $1 \pm i$ . Maka  $1 + 5, 17i, 4$  mewakili contoh-contoh bilangan kompleks.

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(a)

**BILANGAN KOMPLEKS** FISIKA MATEMATIKA I

**A. PENGERTIAN BILANGAN KOMPLEKS**

Konsep bilangan kompleks muncul untuk mengakomodasi nilai akar dari bilangan negatif. Ditinjau persamaan kuadrat dalam  $z$  berikut :

$$az^2 + bz + c = 0$$

dengan  $a, b$  dan  $c$  variabel bebas. Penyelesaian persamaan kuadrat di atas adalah

$$z_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Jika diskriminan  $D = b^2 - 4ac$  bernilai negatif, maka dua nilai  $z$  mengandung akar bilangan negatif. Ketika  $D < 0$  maka kita mengenal bilangan baru yang disebut dengan *bilangan imajiner* dengan didefinisikan nilai

*maka*

$$i^2 = -1$$

Contoh bilangan imajiner

$$\sqrt{-16} = 4i$$

$$\sqrt{-3} = i\sqrt{3}$$

Contoh bilangan real

$$2i + 6$$

dimana 6 merupakan bilangan real

**Contoh soal**

Cariilah akar-akar Untuk contoh persamaan kuadrat berikut :

$$z^2 - 2z + 2 = 0$$

Penyelesaian  
maka akar-akarnya adalah :

$$z = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$z = \frac{2 \pm \sqrt{4 - 8}}{2}$$

$$z = \frac{2 \pm 2i}{2}$$

$$z = 1 \pm i$$

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(b)

Figure 2 (a,b) The revised modules

Based on the Figure 2, the validators obtained advices from the developed module. The advices and inputs from the validators is used as a

reference in improving the module and developing a better module. The advice given by the validator can be seen in detail in Table 2.

Table 2. Assessment Validation Module First Stage

Validation	Validator	Assesment (%)	Conclusion	Suggestion
feasibility of construction	RW	80	Feasible and need repairment	Add a list of references
	YH	89	Feasible to repair	Explain instruction should be done by students
	HL	64	Feasible and need repairment	Fix the display to make it more attractive
	Average	78		
Eligibility contents	RW	77	Feasible to repair	In the phase of orientation on the issue should be given more contextual phenomenon

Validation	Validator	Assesment (%)	Conclusion	Suggestion
Language compoments	YH	94	Feasible to repair	Each phase needs to be clarified instruction appropriate syntax
	HL	67	Feasible and need repairment	Try to approach the concept of a simpler description
	Average	79		
	RW	84	Feasible without repair	
	YH	84	Feasible to repair	1. Some of the sentences should be simplified to facilitate the reader 2. Notice of writing sentences 3. Pay attention to the writing of punctuation
	HL	75	Feasible to repair	Adjust the order of the language standard
	Average	81		

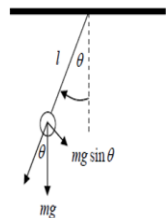
Table 2 describes the suggestions that need to be revised to the module. Validator advice on the feasibility of the construction of the contents of the module is to give an explanation for the instruction should be done by the student so that the student becomes easier to understand in the study modules. In addition, the validator also advises that the module should be equipped with a list of references.

In the feasibility section of the content of the module, the validator advises that in the orientation phase on the problem, the problem is given in the form of physical phenomena in daily life so that learning becomes contextual. Another suggestion given by the validator that the material presented in the form of a simple description so that the student becomes easier to understand the concept of Mathematical Physics I. Suggestion of validators to the components in the module

language is the language used to adjust the order of the standard language and the use of correct punctuation.

Based on the results of the first module validation, an improvement was made to the feasibility of construction, content, and language of the module. In the construction section there are improvements where each of the stages of implementation of the PBI-based module is given an explanation of what to do by students. With this explanation, the process of concept discovery by students becomes more focused. Furthermore, in the content section, the problems are given more contextual where the students analyze the solution of the given problem with their own knowledge. The problems given are things that are commonly found in everyday life, as seen in the Figure 3.

Dalam fisika dasar kita mempelajari getaran harmonis sederhana salah satunya adalah persoalan bandul sederhana yang disimpangkan dan akan mengalami gerak periodik ketika dilepaskan akibat gaya gravitasi yang bertindak sebagai gaya pemulih seperti yang diperlihatkan pada Gambar 1 untuk bandul bermassa  $m$  dengan panjang tali  $l$ . Bagaimanakah penyelesaian persamaannya dengan penggunaan deret untuk memperoleh hasil kuantitatif dalam persoalan bandul sederhana tersebut



Gambar 1. Bandul sederhana

(a)

Dalam fisika dasar kita mempelajari getaran harmonis sederhana, salah satunya adalah persoalan bandul sederhana yang disimpangkan. Sama halnya dengan ayunan dalam permainan anak-anak yang ditarik dan mengalami gerak periodik ketika dilepaskan akibat gaya gravitasi yang bertindak sebagai gaya pemulih seperti yang diperlihatkan pada Gambar 1 untuk beban anak bermassa  $m$  dengan panjang tali ayunan  $l$ . Bagaimanakah penyelesaian persamaannya dengan penggunaan deret untuk memperoleh hasil kuantitatif dalam persoalan ayunan sederhana tersebut?



Gambar 1. Ayunan anak

(b)

**Figure 3.** Examples of improvements that have been made

The problem given begins with an example of everyday life in the form of a swing game as shown in Figure 3. Then from the example students have to find the answer to the given problem using an infinite series to produce an equation. Giving examples related to everyday life phenomena can make it easier for students to understand concepts. One of the efforts that can be done to make it easier for students to understand the concepts of learning faced by students is to provide learning that exposes students to the problems of everyday student life, so that student learning is more meaningful

(Hidayat, Kade, & Haeruddin, 2013). Furthermore, the module is presented in a simpler language structure so that it is easily understood by students.

Based on the results of the first validation by experts and peers on Table 2, it can be concluded that modules are reasonable to use but it still needs revisions. Then the researchers revise module based on input from the validator to obtain a module that is actually valid for use. Once the module is given back to the validator to do a second validation. Results from a second validation can be seen in Table 3.

**Table 3.** Assessment Module Validation Stage Two

Validation	Validator	Assesment (%)	Conclusion
Feasibility of Construction	RW	82	Very valid
	YH	90	
	HL	80	
	Average	<b>84</b>	
Eligibility Contents	RW	83	Very valid
	YH	94	
	HL	81	
	Average	<b>86</b>	
Language Components	RW	84	Very valid
	YH	85	
	HL	82	
	Average	<b>84</b>	



Based on Table 3, it can be seen that the results of module validation are 84 with very valid categories. The results of this assessment indicate that the module has met the requirements for construction, the content includes conformity to the curriculum, knowledge structure, actuality, and the breadth of material and language. The modules developed according to the existing topics depend on the learning achievements that have been formulated. This revised module will then be tested on the object of research. This is done to see the practicality of the module in improving students' understanding of the Mathematical Physics I course. The high validity results indicate that the Mathematical Physics I module based on the PBI learning model developed can be trusted. According to Hayati & Lailatussaadah (2016) if the value of the validity of the instrument is high, then the instrument can be trusted and valid.

Practicality is the usability level of the Mathematical Physics I prototype module by lecturers and students, namely carrying out lectures using revised modules based on validator assessments. The practicality of the module is seen from the extent to which lecturers and students can use the module in Mathematical Physics I courses that have been compiled. To see whether the module that has been compiled is practical to use or vice versa, the module is tested on students. Module testing was carried out on two campuses, on the research campus of STKIP PGRI West Sumatra and on the partner campuses of the Universitas Negeri Padang as a broad trial. The practicality of the module can be seen from the practicality questionnaire in the form of a student response questionnaire and a lecturer response questionnaire given. Lecturers and students filled out a practicality questionnaire, and analyzed it so that the practical level of the modules used could be identified. Based on the modules that have been distributed, it is known that the use of PBI-based learning modules is very practical to use in Mathematical Physics I lectures. The results of the module practicality analysis by the lecturers can be seen in the Table 4.

**Table 4.** Results of Module Practicality by Lecturers

Lecturer	Total (%)	Average (%)	Conclusion
HD	83:5	85:4	Very Practical
HL	87:3		

The results of the practicality of the modules in Table 4 are the lecturers' responses to the developed modules which are very practical with an average percentage value of 85.4%. Based on the analysis of the lecturer response questionnaire data, it is known that the use of PBI-based modules makes it easier for lecturers to carry out Mathematical Physics I lectures. In addition, the Mathematical Physics I module can build communication between lecturers and students and help lecturers in overcoming time constraints in lectures. The Mathematical Physics I module also helps lecturers in guiding students to understand the relationship between the concepts of Physics and Mathematics so as to form students to think critically and creatively. Data for practicality is also seen from the student response questionnaire. While the data on practicality results by students can be seen in Table 5.

**Table 5.** Results of Module Practicality by Students

Students	Total (%)	Average (%)	Conclusion
STKIP PGRI West Sumatra	83 : 5	80 : 7	Very Practical
Universitas Negeri Padang	77 : 8		

The results of data processing of the practicality assessment module of Mathematical Physics I by students where the student's response to the module of Mathematical Physics I in the lecture in this study is in the very practical category with an average percentage value of 80.7%. Thus PBI-based physics learning is practically used by lecturers and to improve students' critical thinking abilities.

Based on the practical value data of the module obtained from lecturers and students, it can be stated that the Mathematical Physics I module based on the PBI learning model can be categorized as very practical, so it can be trusted and is suitable for use during the Mathematical Physics I learning process. According to Menrisal, Yunus, & Rahmadini (2019) that the higher the practicality value of a product, the more feasible the product is to be used in the learning process.

Use of PBI-based modules can improve students' critical thinking skills. This is also shown by the results of research from Ulfa (2020) where the development of physics modules using the PBI

learning model can improve students' problem solving abilities. Increased critical thinking skills in students can guide students in solving and solving an existing problem.

## CONCLUSION

Based on the results of research and discussion can be concluded that the development of a learning module based on PBI is suitable for use in lectures of Mathematical Physics I. The results of module validation carried out by experts obtained that the average construction feasibility, content feasibility, and language feasibility in the developed module were categorized as very valid with the percentage of validity being 84.67%. This means that the modules developed based on the PBI method according to the experts can be tested and are ready to be implemented to students. Furthermore, the practical results of the modules are seen from the responses of lecturers and students to the developed modules. The lecturer response was very practical with an average proportion value of 85.4%. Meanwhile, the student response questionnaire to the module is in the very practical category with an average percentage value of 80.7%.

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