



## Development of Mathematical Logic Practicum Module Based on PhET Simulation to Improve Students' Reasoning Ability

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### Abstract

This study aims to produce a mathematical logic practicum module based on a PhET simulation to improve students rational, practical, and effective reasoning skills. This research is a resrarch development of Borg and Gall with 7 stages. Valid products are seen from the results of expert validation, practical products are seen from the results of the questionnaire, while effective products are seen from the results of trials. The results of the validation of the experts obtained very valid criteria with a mean of 88,72%. The results of the student response questionnaire obtained results of 90,16%, with very practical criteria. The test results obtained the Sig. (2-tailed) paired t test is 0,000 less than 0,05, which means that there are differences in students' mathematical reasoning abilities after using a development product in the form of a mathematical logic practicum module based on PhET simulation. It can be concluded that the mathematical logic practicum module based on PhET simulation is feasible to be used as a manual for mathematical logic practicum and can improve students reasoning abilities.

### Abstrak

Penelitian ini bertujuan untuk menghasilkan modul praktikum logika matematika berbasis PhET simulation untuk meningkatkan kemampuan penalaran mahasiswa yang valid, praktis, dan efektif. Penelitian ini adalah penelitian pengembangan Borg and Gall dengan 7 tahap. Produk valid dilihat dari hasil validasi ahli, produk praktis dilihat dari hasil angket, sedangkan produk efektif dilihat dari hasil uji coba. Hasil validasi para ahli memperoleh kriteria sangat valid dengan rerata 88,72%. Hasil angket respon mahasiswa memperoleh hasil sebesar 90,16% dengan kriteria sangat praktis. Hasil uji coba memperoleh nilai Sig. (2-tailed) uji t Paired adalah 0,000 lebih kecil dari 0,05 yang artinya terdapat kemampuan penalaran matematis mahasiswa sesudah menggunakan produk pengembangan berupa modul praktikum logika matematika berbasis PhET simulation. Dapat disimpulkan modul praktikum logika matematika berbasis PhET simulation layak digunakan sebagai panduan praktikum logika matematika dan dapat meningkatkan kemampuan penalaran mahasiswa.

Keywords: Mathematical Reasoning Ability; Math Logic; Practicum Module; PhET Simulation.

### INTRODUCTION

Mathematical logic is one of the lecture materials that students at the IKIP PGRI

Pontianak Mathematics Education Study Program must learn. In addition to being taught in the classroom, this logic material is also practiced. Logic is a part of

mathematics that is obligatory and important for students to know because it can train abstract thinking power, train logical thinking, and train students in reasoning. Surjasumantri in (Hidayati, 2013) states that logic is a science and the ability to reason, think correctly. Logic deals with arguments (statements), which study methods and principles to show the validity (valid or not) of an argument, especially those developed through the use of mathematical methods and mathematical symbols (Mirati, 2013; Novianti, 2015). Even though this logic has been studied in high school, in fact, there are still many students who experience difficulties, especially in the reasoning process. Therefore, mathematical logic emphasizes students' mathematical reasoning abilities.

The mathematical ability standards was the reasoning that students must have (Kusumawardani, Wardono, & Kartono, 2018; Lestari & Andinny, 2020; Putra & Sari, 2016) Mathematical reasoning skills needed by students in analyzing, assuming logically, explaining and concluding ideas in new situations (Modifi, Amiripour, & Bijan-zadeh, 2012). Reasoning is a thought in solving problems so that the resulting statements have conclusions that are not based on logic with unlimited evidence (Rosita, 2014).

Several studies on mathematical reasoning abilities include: 1) (Anshori, Hamdani, & Yani, 2018) stated that students have not been able to meet the indicators of mathematical reasoning abilities, 2) (Suprihatin, Maya, & Senjayawati, 2018) stated that students' mathematical reasoning was still low, and 3) (Hidayatullah, Sulianto, & Azizah, 2019) stated that the overall percentage of students' mathematical reasoning abilities was 55% in moderate criteria. This also happens to students, when pre-observation is carried out there are 37,04% of students can solve

reasoning problems (Oktaviana & Harjadi, 2020). To support mathematical logic related to student reasoning, a module that supports students during practicum is required.

Practicum is a learning activity that aims to allow students to test and apply theory using laboratory facilities and outside the laboratory (Khamidah et al., 2014). (Ariningsih, Nawawi, & Hartono, 2014) also explained that the learning process accompanied by the experimental method can make students involved themselves where students can directly observe, analyze, prove and draw conclusions on an object. Thus, through the practicum process, the knowledge obtained by students will last longer by conducting their experiments than the knowledge obtained from books or information provided by others. So that experimental activities can be carried out well, one of which requires teaching materials in the form of practicum guides. The practicum guide is expected to be able to direct students to do the correct practicum in conducting experiments.

The teaching material for this practicum guide is often called a practicum module. Modules are very much needed in practicum activities, apart from being a practical guide, modules can also be designed to direct students to be able to work with scientific steps. Module teaching materials must be arranged systematically and attractively so that students can learn independently. (Furqan, Yusrizal, & Saminan, 2016) learning modules are teaching materials that contain materials, methods, and evaluations with a systematic and interesting arrangement that can be used independently to achieve competence. Also, (Asyhar, 2010) modules are printed teaching materials that are equipped with their own learning instructions so that they can be used inde-

pendently. Practical module teaching materials are learning programs that are structured systematically, and refer to measurable learning objectives to achieve learning objectives (Sa'idah & Yulistianti, 2018).

Based on the observations made, information was obtained that the practicum module used so far was monotonous which did not hone students' reasoning abilities because students only immediately made props according to those presented in the practicum module. The practicum module is incomplete and students tend to only follow what is written in the guidebook and the learning becomes less meaningful. For that, it is necessary to develop practicum modules that can improve students' mathematical reasoning abilities. Also, researchers used a PhET simulation in the developed practicum module.

PhET is a learning simulation that is used for the learning process both in class and individually in the fields of physics, biology, chemistry, and mathematics (Perkins et al., 2006). PhET simulation emphasizes the relationship between real-life phenomena and the underlying science, supports interactive and constructive approaches, provides feedback, and provides a creative workplace (Finkelstein, Adams, Keller, Perkins, & Wieman, 2006). The considerations that underlie the use of PhET simulations include: (1) PhET simulation is an interactive learning model that can provide opportunities for students to study material at any time, can be repeated until they understand the concept, guide and upload to experience the learning process independently, understand natural phenomena through scientific activities, and imitate the work of scientists in finding invisible mathematical facts, concepts, laws, or principles, (2) students, in general, have computer/laptop facilities to access the PhET simulation

program through the internet, and (3) the success of research results on learning physics materials through computer simulations in improving concept understanding (Ingerman, Linder, Marshall, & Booth, 2012; McKagan et al., 2008).

PhET simulations are provided to help students understand unimaginable mathematical concepts. This simulation makes it easier for students to learn mathematical logic concepts more deeply without having to do experiments in the laboratory. Through the PhET simulation, students are expected to have a better understanding of the material being taught (Wieman, Adams, Loeblein, & Perkins, 2010). Several studies that use the PhET simulation include: 1) (Fithriani, Halim, & Khaldun, 2016) with the results of the study that there is an increase in critical thinking skills in students who get learning with PhET simulation media, (2) (Mursalin, 2013) concluded that the model PhET simulations assisted by worksheets can be used to remediate and minimize misconceptions of prospective physics teacher students on the topic of electrical circuits, (3) (Wiravanjava, 2017) stated that the application of the experimental methods using PhET simulations has an effect on critical thinking skills and student learning outcomes. However, the difference between the researcher and the previous research is that the researcher uses the PhET simulation for mathematics material and improves students' reasoning skills.

Simulation can make students involved in the virtual world so that they can apply their knowledge, abilities, and thoughts. Besides, simulations can guide students to build their reasoning skills and are also able to describe something that is not visible and attract students' interest to be involved in practicum activities. The PhET simulation needs to be applied to

students during practicum because it emphasizes the formation of skills to acquire knowledge and communicate it. Based on this description, this study aims to develop a mathematical logic practicum module based on a PhET simulation to improve the reasoning skills of students at the IKIP PGRI Pontianak.

## METHOD

This research is a research and development. Research and development of a mathematical logic practicum module based on a PhET simulation It uses the development model Borg and Gall which consists of 10 steps but deep This research only performs 7 steps, namely potentials and problems, data collection, product design, design validation, design revision, product testing, and product revision because the trial sample coverage is limited to only one place.

Potentials and problems are steps to identify problems that occur before development is carried out. Data collection is a step to collect data regarding the creation of a mathematical logic practicum module based on a PhET simulation. Data were collected from previous studies and preliminary observations in several students where the research was conducted. The product design is a step in designing a mathematical logic practicum module based on a PhET simulation which will be used in the implementation of practicum at IKIP PGRI Pontianak.

In the design validation, three validators were validated, namely the lecturers of the IKIP PGRI Pontianak so that input, evaluation, and revision of the practicum guidelines that had been designed were obtained. In the design revision, improvements were made to the mathematical logic practicum module based on a PhET simulation based on input from the validators. After the product is valid, the

product trial step is continued. The trial was conducted to analyze students' mathematical reasoning abilities after using a mathematical logic practicum module based on a PhET simulation. Trials are also carried out to revise the practicum module if there are various weaknesses in use during the practicum. The trial was carried out at IKIP PGRI Pontianak in the implementation of practicum with 27 class B semester I students as subjects. Furthermore, product revision is a product improvement step if during the trial there is input from students and lecturers.

The instruments used in this study were (1) validation sheet both material and media used to determine the validity level of the practicum module being developed; (2) the student response questionnaire was used to determine the level of practicality after using this practicum module which was filled in by 27 students who were the research subjects; and (3) test questions that measure students' mathematical reasoning abilities in the form of pretest and posttest which are used to determine the level of effectiveness of this practicum module. Given the pretest and posttest questions due to measuring the improvement after using this practicum module. The mathematical reasoning ability test questions are given in the form of 4 essays which contain indicators of mathematical reasoning abilities.

The results of the validity and practicality of the mathematical logic practicum module based on the PhET simulation can be seen in Table 1.

Table 1. Validity and Practicality of theProduct

Assessment (Validity, Practicality)	Value Scale	Rating Percentage (%)
Very Valid /Practical	5	85 <average ≤ 100
Valid/Practical	4	65 <average ≤ 85
Quite Valid/Practical	3	50 <average ≤ 65
Invalid/Practical	2	35 <average ≤ 50
Very Invalid/Practical	1	20 <average ≤ 35

This product is valid if the percentage of the mean value of the validator > 65% and the product is practical if the percentage of the average student response is > 65% (Oktaviana, Prihatin, & Fahrizar, 2020). As for effectiveness, it was carried out by t-test *paired samples* with SPSS to check the mean difference between the pretest and posttest where if there is a difference it is said to be effective and if there is no difference it is said to be ineffective.

## RESULTS AND DISCUSSION

### Results

Description of the development of a mathematical logic practicum module based on a PhET simulation to improve the reasoning ability of students at the IKIP PGRI Pontianak from potential and problem steps to product revision steps are described as follows.

The problem that was obtained during the observation was that the practicum module used so far was monotonous which did not hone students' reasoning abilities because students only immediately made props according to those presented in the practicum module. The practicum module is incomplete and is in the form of a cookbook so that students tend to only follow what is written in the guidebook and learning becomes less meaningful. Besides, a practicum module is needed that can facilitate students to study independently, can be opened repeatedly, and improves student reasoning. For this reason, it is necessary to develop a practicum module that can facilitate students' mathematical reasoning abilities using the PhET simulation.

The data collection is carried out in making a mathematical logic practicum module based on the PhET simulation, which is looking for materials related to

PhET simulation to be added to the practicum module.

In product design, a mathematical logic practicum module based on a PhET simulation is designed. Broadly speaking, this practicum module consists of 1) color and pictorial cover pages, 2) Foreword, 3) Table of Contents, 4) Contents consisting of an introduction, introduction to PhET simulation, and practicum content which includes practicum activities with 8 activities, and 5) Bibliography.

Validation is used to determine the validity of the practicum module. Validation was carried out by 3 experts. Each expert became a media expert and material expert. This means that the three validators assess and provide suggestions on what to improve from the practicum module and assess whether the practicum module is valid or not. The following are the results of the practicum module assessment in Table 2.

Table 2. Expert Assessment Results Expert

No	Name	Average	Criteria
1.	Validator I	88.08%	Very Valid
2.	Validator II	87.69%	Very Valid
3.	Validator III	90.38%	Very Valid

Based on Table 2, the validity results obtained in very valid criteria. Besides, researchers also make improvements to the practicum module so that it produces a new revised practicum module.

The revision in question is an improvement of the product developed based on input, suggestions, or comments from the validators so that the mathematical logic practicum module based on the PhET simulation can be used for research purposes, can be used as a student practicum guide during practicum implementation, as well as train students in improving their abilities. mathematical reasoning. The revised results are as follows: (1) Revision of the cover. According to validator I, the cover should be made attractive, not too ordinary, while after revision, the cover is made more attractive and adapted to the application used. The results before and after the revision can

be seen in Figure 2.

Based on Figure 2, the researcher improves the cover of the practicum module by making it more attractive and colorful and adding an image that shows the activities to be carried out based on suggestions from validator I. Next (2) revisions related to the addition of the display image PhET simulation. According to validator II, preferably on the introduction of simulation PhET in the lab first step given activity image display PhET simulation while after the revision, given the image display PhET simulation so that students more easily operate the application Phet. The results before and after the revision can be seen in Figure 3.

MODUL PRAKTIKUM LOGIKA MATEMATIKA BERBASIS PHET  
SIMULATION



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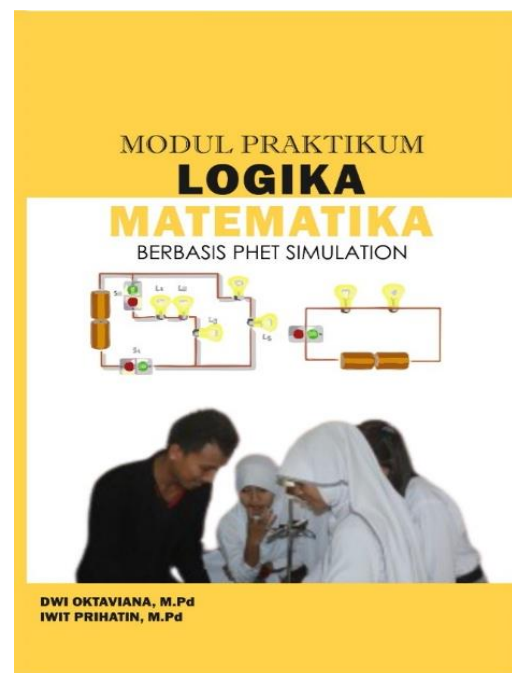


Figure 2. Revision of Cover (left = before revision, right = after revision)



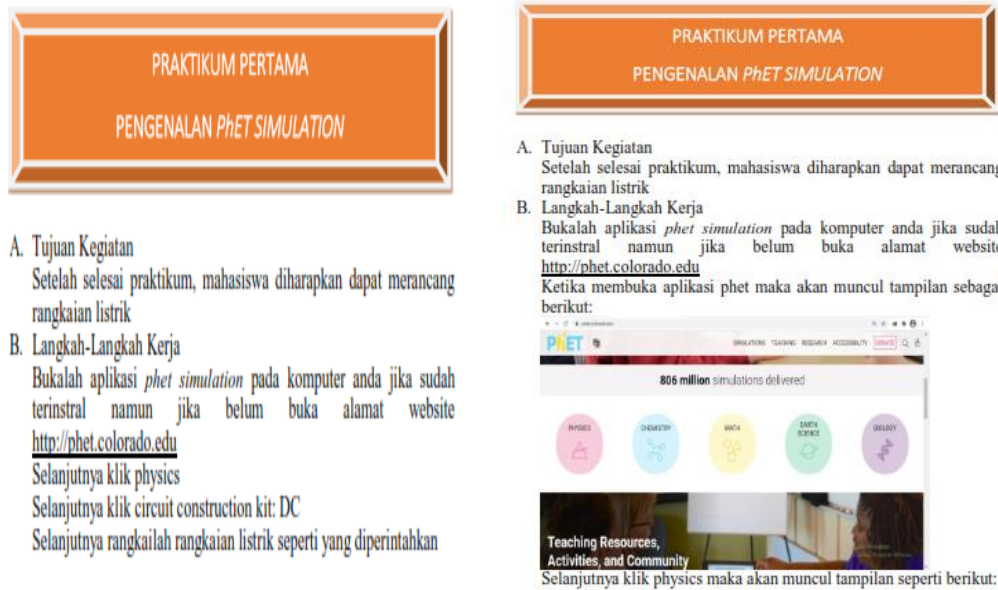


Figure 3. Improved Image of Phet Simulation Display (left = before revision, right = after revision)

Based on Figure 3, the researcher added a PhET simulation display image based on suggestions from validator II. Furthermore (3) revisions related to the addition of introductory theory to each practicum. According to validator II, introductory theory should be added to each practicum,

while after revision, an introductory theory is given in each practicum so that students know the initial theory in each practicum activity. The results before and after the revision can be seen in Figure 4.

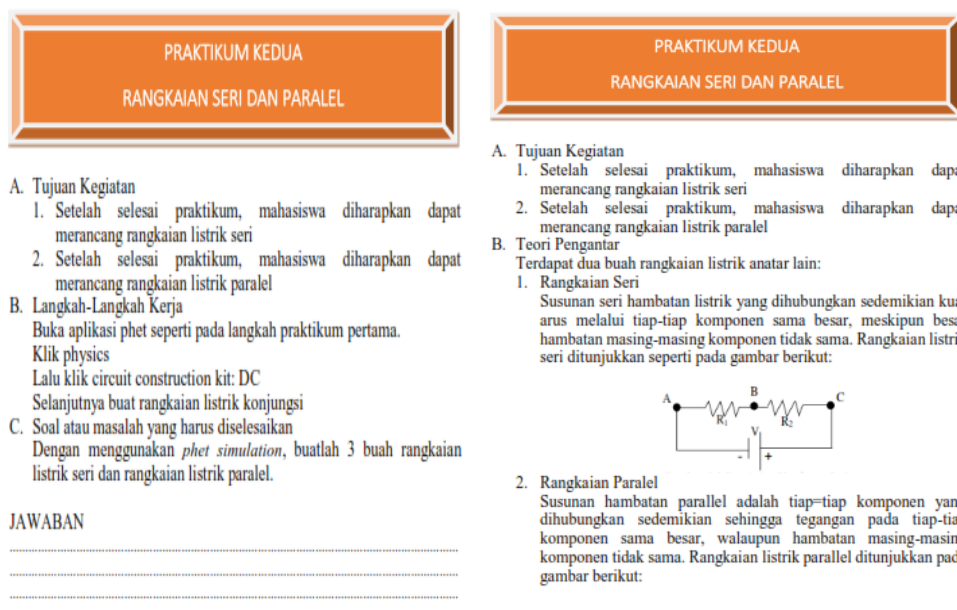


Figure 4. Improvements to Addition of Introductory Theory (left = before revision, right = after revision)

Based on Figure 4, the researcher adds an introductory theory to each practicum activity based on suggestions from validator II. Finally (4) revisions related to the addition of introductory theory to each practicum. According to validator III, it is better if the answer sheets for questions or problems that must be resolved be made more focused according to the question orders, while after revision, the worksheets are described based on the question orders so that students are more focused in solving problems. The results before and after the revision can be seen in Figure 5.

Based on Figure 5, the researcher made the answer sheet more focused according to the question command based on suggestions from validator III.

The trial was carried out in the mathematics laboratory of IKIP PGRI Pontianak, especially for the semester I students. First, the lecturer gave questions pretest to students to find out the students' initial reasoning before being given a practicum. Furthermore, the lecturer gave practicum to students by practicing the practicum module based on the PhET simulation on mathematical reasoning

skills for 8 meetings. Students seemed very enthusiastic about participating in the practicum, students experimented by assembling an electric circuit through a PhET simulation. Students conduct their experiments in assembling electrical circuits. Students in assembling electrical circuits use reasoning abilities because the electrical circuits that are assembled must be able to light up according to the concept. Then, the lecturer gave questions posttest to students at the end of the practicum to determine the increase in students' mathematical reasoning abilities after being given a practicum using a practicum module based on the PhET simulation. Besides, the researcher provides a response questionnaire to all students to assess the modules that have been used. The questionnaire functions to assess the practicality of the practicum module based on the PhET simulation of students' mathematical reasoning abilities.

After that, the questionnaire was calculated to get the percentage value for practicality. The results obtained are 90.16% and are classified as very practical. This means that the practicum module for

<p>C. Soal atau masalah yang harus diselesaikan Dengan menggunakan <i>phet simulation</i>, buatlah rangkaian listrik konjungsi kemudian uraikan cara kerjanya untuk membuktikan konsep dari pernyataan majemuk konjungsi kemudian simpulkan hasil percobaan kalian.</p> <p style="text-align: center;">JAWABAN</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p>	<p>D. Soal atau masalah yang harus diselesaikan Dengan menggunakan <i>phet simulation</i>, buatlah rangkaian listrik konjungsi kemudian uraikan cara kerjanya untuk membuktikan konsep dari pernyataan majemuk konjungsi kemudian simpulkan hasil percobaan kalian.</p> <p style="text-align: center;">JAWABAN</p> <p>1. Gambar Rangkaian Listrik Konjungsi</p> <div style="border: 1px solid black; width: 200px; height: 100px; margin: 0 auto;"></div> <p>2. Deskripsi Penggunaan Rangkaian Listrik Konjungsi</p> <p>.....</p> <p>.....</p> <p>.....</p>
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Figure 5. Correction of the Problem Answer Sheet (left = before revision, right = after revision)



mathematical logic based on PhET simulation on students' mathematical reasoning abilities is practical to use. The results of the pretest and posttest work are used to determine the effectiveness of this practicum module. The results obtained are by conducting hypothesis testing to determine whether there is an increase in students' mathematical reasoning abilities after using development products in the form of a practicum module for mathematics logic courses and sets using PhET simulation. Previously, the calculation of normality testing was carried out on the mathematical reasoning ability data pretest and posttest. Based on the calculation, the Asymp. Sig. (2-tailed) significance value is 0.156 and 0.127 is greater than 0.05. So by the basis of decision making in the Kolmogorov-Smirnov normality test, it can be concluded that the data is normally distributed. Thus, the assumptions or normality requirements in the t-test have been met. Furthermore, hypothesis testing is carried out to see whether there is a difference between the two means. The results of hypothesis testing can be seen in Table 3 below.

Table 3. Hypothesis Test Results

	t	df	Sig. (2-tailed)
Pair 1 Pretest - Posttest	-20.934	26	.000

Based on Table 3 shows that by performing the Paired t-test, the Sig. (2-tailed) is 0.000 smaller than 0.05, which means that there is a difference between the pretest and posttest values so that this PhET simulation-based mathematical logic practicum module is effectively used for mathematical reasoning abilities. This happens because students who initially had difficulty in solving questions containing reasoning indicators after practicing this practicum module, students were able to solve questions containing these

indicators. Through experiments and practices carried out by students independently, it causes an increase in students' mathematical reasoning abilities.

After testing the product, this practicum module is ready to be packaged into the final product. The practicum lecturer at the trial site did not provide any suggestions. He only thought that this module made it easier for students to do experiments and could help students to improve their mathematical reasoning skills. Thus, this practicum module can be printed again and used as the final product.

## Discussion

The research results indicate that the evaluation of the validator in this practicum module states that it is good as seen from the whole. From the test results of the mathematical logic practicum module based on the PhET simulation, interesting findings include that during the experiment, students interacted very much with lecturers and other students, student activities in practicum were very enthusiastic and enthusiastic in finding mathematical logic concepts using reasoning because this module was equipped PhET simulation which can involve students in real life and generate concepts.

The mathematical logic practicum module based on the PhET simulation allows students to easily understand the concepts of mathematical logic through electrical circuits, which is an effective module in improving students' reasoning abilities. This is in line with research (Prihatiningtyas, Prastowo, & Jatmiko, 2013) which states that high school physics learning on the subject of dynamic electricity using PhET simulation media and simple kits can run effectively, where students are generally interested in the con-

tent, media, and learning methods/models. Also supported by research (Saregar, 2016) states that quantum physics learning by utilizing PhET simulation media has a positive impact on student learning outcomes. Besides, research (Wasiran, 2017) states that the development of teaching materials in the form of practicum guides is very effective in its use for the learning process.

## CLOSING

### Conclusion

Based on the results of the research and discussion, it can be concluded that the development of a mathematical logic practicum module based on the PhET simulation to improve students' reasoning abilities obtained very valid with an average of 88,72%, very practical with an average of 90,16%, and effective where there is a difference between the two averages.

### Suggestions

The suggestions that can be given based on the results of this study are that further research is expected to develop a practicum module using other applications that support mathematics learning.

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