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Electronic Module Using Problem-Based Learning for Set Theory: Practicality Assessment and Initial Effects on Mathematics

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Abstrak

Penelitian ini bertujuan untuk menelaah kegunaan modul digital pada pokok bahasan himpunan yang dirancang berlandaskan pembelajaran berbasis masalah (PBL) guna menunjang kecakapan representasi matematis para mahasiswa. Penelitian ini tergolong dalam jenis penyelidikan dan pengembangan (Research and Development/R&D) dengan menerapkan pola pengembangan ADDIE yang mencakup lima fase, yakni Analisis, Perancangan, Pengembangan, Penerapan, dan Penilaian. Subjek penelitian ini adalah 30 mahasiswa tingkat satu pada semester ganjil, yang secara langsung berperan sebagai pengguna modul dalam proses pembelajaran. Pengumpulan data mengenai kepraktisan dilakukan dengan menggunakan instrumen berupa angket kepraktisan. Hasil analisis data menunjukkan bahwa bahan ajar digital yang mengadopsi pendekatan pembelajaran berbasis masalah pada topik himpunan tergolong dalam klasifikasi amat praktis. Hasil N-Gain menunjukkan bahwa kemampuan representasi kelas berada pada kategori sedang. Temuan ini mengindikasikan bahwa modul yang dikembangkan tidak hanya mudah digunakan dan dipahami oleh mahasiswa, tetapi juga mampu mendukung keterlibatan aktif mahasiswa dalam pembelajaran matematika berbasis masalah.
Kata Kunci: Modul Elektronik; Kemampuan Representasi Matematis; Praktikalitas; Problem-Based Learning

Abstract

This investigation endeavors to scrutinize the functional applicability of an electronically crafted module concerning set theory, meticulously architected upon the tenets of problem-oriented pedagogy (POP), with the principal objective of augmenting learners' proficiency in mathematical articulation. The inquiry is methodologically situated within the paradigm of investigative elaboration (I&E), employing the ADDIE architectural framework encompassing five sequential phases: analytical scrutiny, schematic formulation, constructive assembly, practical deployment, and evaluative assessment. The participants encompassed thirty neophyte scholars during the inaugural odd academic term, who served as direct beneficiaries of the instructional implement throughout the pedagogical process. An evaluative questionnaire was deployed. Analytical scrutiny of the accumulated metrics reveals that the problem-oriented electronic module pertaining to set theory achieved within the classification of superlative practicality. The normalized gain indices demonstrate that the representational competencies residing within the intermediate stratum. This empirical evidence substantiates that the formulated module is not merely facile in utilization and cognition for scholars but also efficacious in fostering dynamic engagement within problem-centric mathematical tutelage.
Keywords: Electronic Module; Mathematical Representation Abilities; Practicality; Problem Based Learning

I. INTRODUCTION

Modules designed by lecturers can help students achieve learning success (Gunawan, Sukmana, & Sumartini, 2024). However, over time, learning has evolved into online learning. This learning can be supported by teaching materials in the form of modules designed online, commonly referred to as digital modules.

Electronic modules are didactic materials that cover a single subject, are organized systematically and based on the curriculum, and are presented through electronic devices such as computers or gadgets. Electronic modules can also be defined as a set of digital teaching tools that are assembled sequentially for self-directed learning purposes (Ermawati et al., 2022). Electronic modules are included in the variety of ICT-based learning media and are a component of e-learning, the use of which relies on advances in information and communication technology (Imaningtyas et al., 2016; Ramayanthi et al., 2015; Rahayu, Aima, & Juwita, 2023).

The ease of using, preparing, interpreting, or obtaining results from an evaluation instrument is called practicality (Dimyati & Mudjiono, 2013; Husniah & Azka, 2022). Alfianika (2016) states that practicality is an examination to determine whether a tool can be categorized as practical, easy to use, or uncomplicated. Practicality testing is carried out with the aim of ensuring that practical media can be used and easily understood. It also helps teachers and accelerates student understanding during the learning process (Gunawan et al., 2023). Practicality is another way to measure how well a medium performs after use. According to Nieveen in Nuryadi (2019), the perspective of educators and students who assess that the resulting product is simple to use reflects the aspect of usefulness. Therefore, practicality is a quality that shows that users of learning media can use it easily, which in this study are lecturers and students.

The selection of set theory as the focus of electronic module development is based on its role as a key foundation in discrete mathematics and algebra. However, this material often poses conceptual challenges for students, especially in representing the relationships between sets visually (Venn diagrams) and symbolically (mathematical notation). Preliminary studies show that conventional teaching materials are unable to accommodate the interactive needs required to understand these abstract concepts (Manihuruk & Sutabri, 2024). In fact, mathematical representation skills—including visual, symbolic, and verbal representation—are key to understanding set theory.

Although there have been many studies on electronic modules, there have been no studies that specifically integrate Problem-Based Learning (PBL) with electronic modules for set theory material in the context of improving mathematical representation skills. The PBL approach was chosen because of its ability to encourage multidimensional representation activities (Susilawati, 2013; Rinaldi & Afriansyah, 2019), for example by converting real problems into Venn diagrams and mathematical notation. PBL-based electronic modules can facilitate this process through interactive features such as drag-and-drop set simulations and step-by-step exercises, which are not possible in

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printed modules (Yuniastuti & Khoiron, 2021). This combination not only addresses the research gap but also integrates the advantages of PBL in training problem-solving skills with the flexibility of visualization from e-modules, resulting in a more holistic mathematical representation.

II. METHOD

This study is an exploration and development (R&D) by applying the ADDIE paradigm (Analysis, Design, Development, Implementation, Evaluation). The Implementation stage is the main focus to test the practicality of the electronic module based on Problem-Based Learning (PBL) on set theory material and its initial impact on students' mathematical representation abilities. The research design uses a quasi-experimental approach with a pretest-posttest control group pattern, involving 30 students as the experimental class using electronic modules and 30 students as the control class with conventional learning. Control variables include students' academic backgrounds (odd semester, first level) to minimize bias.

The research instrument consists of two types: (1) a practicality questionnaire (20 items) with a 1–5 Likert scale covering aspects of material readability, ease of navigation (usability), and learning support effectiveness. This instrument has been validated by two mathematics experts (Content Validity Ratio > 0.75) and shows high reliability (Cronbach's Alpha $\alpha = 0.89$); (2) a mathematical representation ability test in the form of essay questions based on visual, symbolic, and verbal indicators, which has also undergone expert validation and limited testing ($\alpha = 0.82$).

The implementation process lasted for 4 weeks (8 sessions @90 minutes). In the experimental class, students were involved in module introduction, PBL-based contextual problem discussions, and interactive task completion (quizzes/simulations), while the control class used conventional lecture and exercise methods. The data were analyzed using two approaches: (1) practicality was calculated based on the percentage of questionnaire scores, and (2) effectiveness was measured using the N-Gain test. The practicality criteria for the electronic module can be seen in Table 1.

Table 1.
Criteria for Practicality

Ideal Percentage (%)	Criteria
80≤V≤100	Very Practical
60≤V<80	Practical
40≤V<60	Quite Practical
20≤V<40	Less Practical

Analysis of students' mathematical representation abilities using the N-Gain test. The N-Gain calculation categories can be seen in Table 2.

Table 2.
N-Gain Value Category

Value	Category
g≥0,7	High
0,3≤g≤0,7	Moderate
g<0,3	Low

III. RESULT AND DISCUSSION

The process of collecting responses from lecturers and students regarding the electronic module was carried out using an assessment questionnaire. This questionnaire was systematically designed to evaluate various important aspects of the

electronic module, such as visual design quality, ease of navigation, interactivity, and clarity of material presentation. Each aspect was assessed based on user perception to determine how well the module could support classroom learning activities. It contains the findings of the study and analysis. If the research is in the form of Research and Development (R&D), then it is mandatory to display the final product results, especially material related to the research topic.

Data collection through questionnaires was conducted to obtain an objective picture from two different perspectives, namely from the perspective of students and lecturers. The student perspective is important because they are the direct users of the electronic module, so their responses reflect their real experiences in interacting with the module. Meanwhile, the lecturer perspective is needed to assess the extent to which this module can facilitate effective learning, in terms of content, pedagogy, and suitability for problem-based learning.

By analyzing questionnaire data from both lecturers and students simultaneously, this study can produce a comprehensive picture of the practicality of electronic modules. Practicality here includes the extent to which the module is easy to use, aids the learning process, and provides added value in improving student understanding. The module is considered practical by both user groups, meaning that it can be viewed as an effective learning tool and can be recommended for wider use.

The practicality test was conducted by involving lecturers and students in the experimental class. This test aimed to measure the usability and ease of use of electronic modules in real learning situations. Based on the assessment results obtained from lecturers, the problem-based learning-based electronic module on sets received a practicality percentage of 85.33%, which was categorized as "Very Practical." This assessment shows that the electronic module is considered to have high practicality and is easy to implement in teaching and learning activities in the classroom. In addition to the lecturers' assessment, the practicality test also involved 30 students in the experimental class. Of the total participants, a large number of students gave ratings based on the criterion "Very Practical," indicating that the module was considered effective and easy to use. The percentage of students who rated the module as practical ranged from 76% to 98%, with an average score of 86%. This average falls into the "Very Practical" category. A digital module that has been proven to be applicable means that the product is easy to use in teaching and learning activities or in a series of activities carried out by its users (Muhsinin & Fatmawati, 2020). These results indicate that the module is not only easy to use, but also facilitates a more interactive and flexible understanding of the concept of circles.

These findings are in line with research by Widodo & Kartikasari (2017), which shows that the use of digital modules based on interactive features can strengthen students' motivation and proactive involvement in the process of mastering mathematics. Teaching materials developed by combining dynamic images and interactive video recordings provide a more realistic learning experience, thereby

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reducing students' difficulties in digesting theoretical material (Munir, 2012). Furthermore, research by Novalia & Noer (2019) states that electronic modules are effective in increasing student focus and engagement because the material is presented in small units that are easy to digest and learn in a short time.

Representation skills were observed based on the results of initial and final tests given to students in the control group and experimental group. The assessment instruments tested referred to the parameters of quantitative representation skills. The evaluation was carried out on two groups as test samples, namely the experimental group and the comparison group. The mean value of the quantitative representation skills measurement results of the students can be observed according to the mean value of the initial and final test results, which are visualized in the Figure 1.

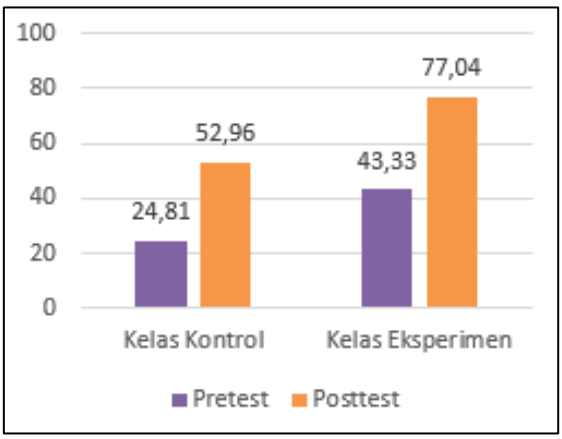

Figure 1. Average Mathematical Representation Ability Test Scores of Students

Based on the illustration presented, there appears to be significant academic progress in both learning groups, both in the experimental group and the control group. The experimental group, which utilized a digital module of combined problem-based learning materials, showed an increase in average scores of 32.71 points between the initial and final exams. Meanwhile, the control group, which underwent traditional teaching, also recorded an increase in scores, but only reached 28.15 points. This fact indicates that the application of digital modules combining problem-based learning materials contributes more to the academic progress of students than conventional teaching methods.

Table 3.
SPSS Results

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Mathematical Representation	Experiment	.260	30	<.001	.894	30	.006
	Control	.264	30	<.001	.877	30	.002

Referring to Table 3 of the SPSS results presented in the previous tabulation, it can be concluded that the learning achievement of students in the mathematics representation ability test in the experimental group showed a significance value (sig.) of less than 0.05. This fact indicates that the data from the final mathematics representation ability test in the experimental group did not meet the normality requirements. Not limited to the experimental group, the normality test results for the control group also show a significance value below 0.05. This means that the learning outcome data in the control group is also not normally distributed. The similarity of the distribution

characteristics in both groups proves that in both learning that utilizes problem-based learning digital modules and traditional learning, the data from the test of students' mathematical representation ability does not follow a normal distribution pattern.

Thus, referring to the results of the normality test on both groups, it can be concluded that the data from the final test of students' mathematical representation abilities are not normally distributed. Therefore, to test the difference in learning outcomes between the experimental group and the control group, the appropriate analysis method is to apply a non-parametric test such as the Mann-Whitney test. The application of this test allows for valid and reliable analysis results to be obtained even though the data does not meet the normality prerequisite.

Table 4.
Results of Comparison Test of Two Samples

	Value
Mann-Whitney U	98.500
Wilcoxon W	563.500
Z	-5.367
Asymp. Sig. (2-tailed)	<.001

Based on Table 4, it shown in the comparison table of the two samples above, it can be seen that the Asymp. Sig. (2-tailed) value of 0.001 is lower than 0.05, which indicates that H0 is rejected and Ha is accepted. The acceptance of Ha indicates that there is a significant difference between the average posttest scores of the experimental group and the average posttest scores of the control group. In line with the criteria outlined above, it can be concluded that the digital module of set theory material based on problem-based learning is effective in improving the mathematical representation capabilities of students.

Table 5.
N-Gain Normality Test of Mathematical Representation Ability

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
N-Gain	Experiment	.165	30	.036	.937	30	.077
	Control	.165	30	.035	.938	30	.081

Based on the SPSS table output above, the N-Gain results from the mathematical representation ability test of the experimental class have a significance level of sig. > 0.05. This indicates that the data is not normally distributed. Similarly, the control class also has a significance level of sig. > 0.05. This indicates that the data is not normally distributed.

Several components in the electronic modules are shown in Figure 1, Figure 2, and Figure 3.

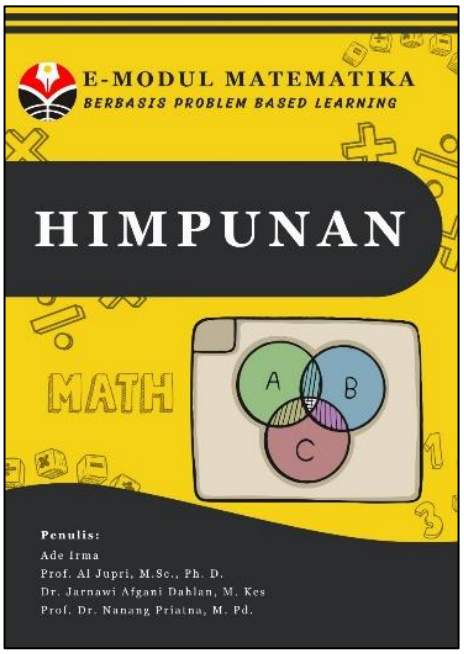

Figure 2. Cover

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Figure 2 shows the cover as the main page explaining the identity of the electronic module.

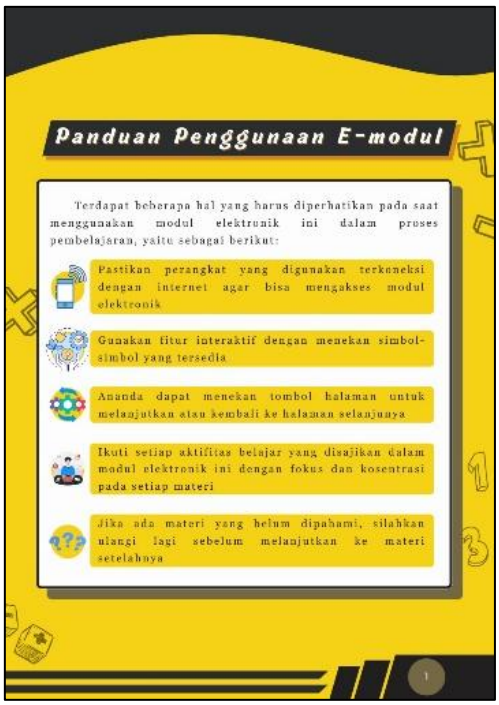

Figure 3. User Guide

Figure 3 explains the guidelines for using electronic modules so that students can use them more easily.

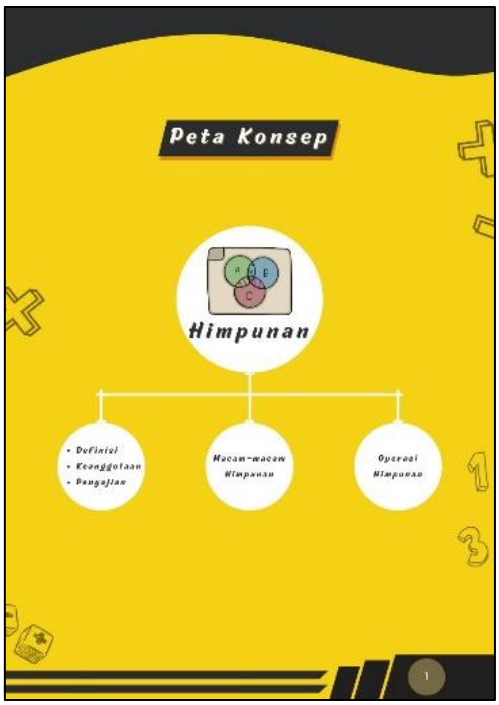

Figure 4. Concept Map

Figure 3 shows the materials in sequence, illustrated with a clear concept map.

After going through the validation stage, the problem-based learning-based electronic module was then tested for practicality to determine the extent to which the electronic module could be used effectively in supporting the learning process. The practicality test was conducted by involving lecturers and students in the experimental class. This test aimed to measure the usability and ease of use of the electronic module in real learning situations. Based on the assessment results obtained from lecturers, the electronic module for set theory based on problem-based learning received a practicality percentage of 85.33%, which was categorized as “Very Practical”. This assessment shows that the electronic module is considered to have high practicality and is easy to implement in teaching and learning activities in the classroom. In addition to the lecturers' assessment, the practicality test also involved 30 students in the experimental class. Of the total participants, a large number of students gave ratings based on the criterion “Very Practical,” indicating that the module was considered effective and easy to use. The percentage of students who rated it as practical ranged from 76% to 98%, with an average score of 86%. This average falls into the “Very Practical” category. An electronic module that has proven its practicality indicates that the product is easy to use in learning activities or in a series of activities carried out by its

users (Muhsinin & Fatmawati, 2020). These results indicate that the module is not only easy to use, but also facilitates a more interactive and flexible understanding of the concept of circles.

These findings are in line with research by Widodo & Kartikasari (2017), which shows that the use of interactive digital modules can foster motivation and active engagement among students in the mathematics teaching process. Modules developed by combining visual elements and dynamic displays provide a more realistic educational experience, thereby reducing students' difficulties in digesting abstract concepts (Munir, 2012). Furthermore, research by Novalia & Noer (2019) states that electronic modules are effective in increasing student focus and engagement because the material is presented in small units that are easy to digest and learn in a short time.

The difference in pretest scores between the experimental and control groups reached 18.52 points. This condition indicates that in the early stages of learning, the experimental group had a significant initial advantage. However, what is more interesting to note is the difference in posttest scores between the two classes, which reached 24.08 points. This widening gap indicates that the difference in learning effectiveness between the experimental and control groups became more apparent after the intervention was implemented. In other words, the problem-based learning electronic module not only maintained the initial advantage of the experimental class, but also increased overall learning achievement.

The combination of PBL and e-modules in set theory material has proven to be superior because the abstract nature of this material requires visual representation and interactivity. This module meets these needs through: (1) contextual PBL examples that relate sets to real-world problems, (2) drag-and-drop features for set operations, and (3) instant feedback for correcting representation errors.

Referring to the findings and progress that has been achieved, digital teaching materials on set concepts using a problem-based learning approach have proven to be able to strengthen the mathematical representation skills of college-level students.

IV. CONCLUSION

Based on the findings of the investigation, the digital module that adopts the Problem-Based Learning (PBL) approach in the topic of sets is considered highly functional according to the students' perceptions, with a usefulness score of 85.80%. Analysis of the questionnaire data reveals that this module meets the criteria of practicality in terms of material readability, ease of use, and applicability in learning. These findings reinforce the position of the module as a viable and easily implemented learning resource in higher education learning activities. However, claims regarding improvements in mathematical representation skills cannot be definitively concluded because this study focused on testing the practicality of the module, not its effectiveness through experimentation.

Based on these findings, it is recommended that this module be adopted

by lecturers as supporting teaching material for set theory. For further development, future research needs to expand the scope of the material to other mathematical topics and conduct effectiveness tests with a more rigorous design, such as randomized control trials, to measure the impact of the module on improving mathematical representation skills. In addition, integrating the module into the institution's learning platform can facilitate wider access for students and lecturers.

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