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Development of Mathematics E-Module to Improve Students' Mathematical Problem Solving Skills in Problem Based Learning Models

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Abstract

E-modules are electronic teaching materials that are designed practically and systematically to help students learn independently. The purpose of this study is to determine the validity, and practicality of the mathematics e-module of System of Linear Equations in Three Variables material, as well as to determine the magnitude of the increase in students' mathematical problem solving abilities. This research was a research and development (R&D) with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). Data collection techniques use observation, interviews, questionnaires, tests, and documentation. The instruments in this study are learning implementation observation sheet, expert validation questionnaires and student response, list of interview questions, mathematical problem solving ability test questions, as well as documentation of research activities. The results showed that 1) media expert validation of 3.87 with very valid criteria and material expert validation of 3.71 with very valid criteria; 2) student response questionnaire of 3.26 with very practical criteria; and 3) the occurrence of an increase in students' mathematical problem solving ability by 0.49 with moderate criteria.

1. Introduction

Education is a very important need as a means of forming the nation's next generation in anticipating the rapid development of science and technology (Fitria, et al., 2014). Mathematics is one of the disciplines studied by students from elementary to tertiary level, which can improve students' problem-solving skills and critical thinking skills in solving problems in everyday life and support the development of science and technology (Ulfah, 2019). The National Council of Teachers of Mathematics (NCTM) sets 5 standards of mathematical competence that students must have, namely problem-solving skills, communication skills, connection skills, reasoning abilities, and the ability to present ideas (Sormin & Sahara, 2019; Sulistyaningsih, et al., 2023). One of the competencies that will be achieved in the mathematics learning process in this study is the ability to solve students' mathematical problems.

Problem solving is one of the important cognitive abilities in mathematics. The ability to solve mathematical problems is needed by students, because in everyday life there are many problems related to mathematics (Novotná, et al., 2014). Therefore, in the process of learning mathematics it is very important to apply problem-solving skills for students (Sulistyaningsih, et al., 2023). However, the reality in the field shows that the learning process in schools has not been able to apply mathematical problem solving skills optimally. Mathematics learning that takes place often only conveys material concepts and memorizes pre-existing mathematical formulas without being associated with problems in everyday life, resulting in students experiencing difficulties when facing problems related to everyday life.

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Based on the results of an interview with one of the mathematics teachers at SMA Muhammadiyah 2 Bobotsari, it is known that students' mathematical problem solving skills are relatively low. This can be seen from the results of student tests on system of linear equations in three variables material which showed that only 36% of students completed out of 44 students. Low student learning outcomes are caused by students having difficulty in understanding questions that are different from the practice questions given by the teacher, especially questions in the form of stories, students also have difficulty in planning the strategies used to solve problems and often make calculation errors when solving problems. This shows that students do not re-examine their work, and immediately believe that their work is correct.

In addition, teachers also rarely use interesting teaching materials or learning media, so students get bored easily and their interest in learning decreases during the learning process. According to Komalasari *et al*., (2018), the use of teaching materials has a great influence on the success of a learning process. During the learning process, teachers only use textbooks and student worksheets provided by the school which are not necessarily in accordance with student learning needs. The textbooks and worksheets provided usually only contain material and sample questions that are still general and theoretical, so it will make it difficult for students to understand the questions, especially those in the form of stories. This is in line with Laksana & Wawe (2015) that there are still many teachers who only use worksheets or electronic teaching materials from the government that have not been in accordance with student needs. The teaching materials used must have interesting and practical content and presentation in order to increase student interest in learning and can be used by students anywhere and anytime independently. Based on this, researchers try to develop teaching materials in the form of electronic modules (e-modules).

E-module is a teaching material that is designed systematically based on a certain curriculum which is packaged in the form of the smallest learning unit and allows learning independently in a certain unit of time displayed using electronic devices such as computers or android (Fausih & Danang, 2014). Attractively designed to contain a series of well-coordinated activities related to material, learning activities, and evaluation, so that students are more focused, systematic, and can easily learn them to achieve the expected competencies in accordance with learning objectives (Telaumbanua, *et al*., 2017). E-modules will greatly help teachers and students in the learning process, where teachers will find it easier to deliver the material presented in the e-modules and students will also find it easier to understand the material presented in the e-modules (Sulistyaningsih, *et al*, 2023). E-modules can display text, images, animations and videos through electronic devices in the form of computers that can help students' learning process independently (Hamid & Alberida, 2021). So that e-modules can be equipped with videos to clarify the material delivered by the teacher, and can be used by students to learn independently without having to rely on the teacher, so that the role of the teacher is not too dominant from educator to facilitator and students' mathematical problem solving ability can increase optimally. In addition to being equipped with illustration videos for problem solving, the problems used in the e-module are problems associated with everyday life. Studentshave the opportunity to train themselves to learn independently, students can express ways of learning that are in accordance withtheir interests and interests, and students have the opportunity to test their own abilities by doing exercises provided in the e-module (Mulyasa in Azka, et al., 2019). In line with the results of research by Yuherni, et al., (2020), thatthe use of e-modules is very effective in learning mathematics which aims to improve the ability to solve mathematical problems. The e-module that the researcher will develop is packaged in the form of a flipbook.

Based on the description of the problem above, the purpose of this study is to develop a mathematics e-module system of linear equations in three variables material that is valid, practical, and can improve students' mathematical problem solving abilities.

2. Methods

This research was a research and development (RnD) using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). Research and development were step to develop new products or perfect existing products that can be accounted for (Sukmadinata, 2013). This research was conducted at SMA Muhammadiyah 2 Bobotsari. The population in this study was grade X students of SMA Muhammadiyah 2 Bobotsari. The sampling technique used simple random sampling. The sampling technique in this study used simple random sampling, which is a sampling technique that is carried out randomly without paying attention to all population strata (Sugiyono, 2019). The sample in this study was

26 students of class XI multimedia C as respondents of small group trials because they had studied system of linear equations in three variables material in class X, and 34 students of class X multimedia B as respondents of field trials. The object in this study is the mathematics e-module of system of linear equations in three variables material.

Data collection instruments through: 1) interviews with teachers; 2) observation of the learning process; 3) documentation; 4) media and material expert validation questionnaires to determine the validity of e-modules and questionnaires of student responses to the practicality of mathematics e-modules; and 5) problem solving tests to determine the effectiveness of mathematics e-modules in improving students' mathematical problem solving skills.

The data analysis technique used is qualitative descriptive. Initial data in the form of numbers (quantitative) is obtained from the results of the assessment of media and material expert validators, student response questionnaires, and pretest and posttest results which are then converted into data in the form of categories (qualitative). The criteria for validity and practicality of the e-module are presented in Table 1.

Table 1. E-module validity and practicality value conversion guidelines

Score Range	Criterion
$1.00 \leq mean\ (\bar{x}) < 1.75$	Not Good/Valid/Practical
$1.75 \leq mean\ (\bar{x}) < 2.50$	Less Good/Valid/Practical
$2.50 \leq mean\ (\bar{x}) < 3.25$	Good/Valid/Practical
$3.25 \leq mean\ (\bar{x}) \leq 4.00$	Very Good/Valid/Practical

(Table Source: Siswanto, et al., 2016)

The mathematics e-module is said to be valid after going through a validation test process by material experts and media experts with minimum good/valid criteria. The mathematics e-module is said to be practical if the results of the student response questionnaire receive a positive assessment with a minimum good/practical category. E-module mathematics is said to be effective in using if there is an increase in students' mathematical problem solving skills.

3. Results & Discussions

The development of this mathematics e-module is packaged in the form of a flipbook. The results of research and development of this mathematics e-module use the ADDIE model with the following steps.

3.1 Analysis Phase

At this stage, the researcher conducted a needs analysis to find out the potential problems that existed by conducting interviews with mathematics teachers and observing the learning process of grade X at SMA Muhammadiyah 2 Bobotsari. The problems obtained are as follows: 1) the teaching materials used by teachers are less attractive, namely worksheets packages and books provided by the school resulting in a lack of student interest in learning; and 2) low problem-solving ability of students, especially in solving story-shaped problems due to explanation of sample questions without any illustrations of problem solving audioly and visually. Then researchers get solutions to solve these problems by developing simple learning media that not only contain material, but there are video discussions on how to solve mathematical problems and are practical to use anywhere and anytime, namely in the form of mathematics e-modules that can interest students. Based on observations, students tend to be passive and less interested when learning mathematics because the teaching materials or learning media used are less interesting and difficult to understand. Students rely more on smart friends when they have difficulty doing individual and group assignments, resulting in low student learning outcomes.

The presentation of the material developed includes observing, questioning, discussing, reasoning, concluding and trying to solve problems with problem-solving steps according to Polya. The design of the practice questions made contains problems in the form of story problems that students must solve independently, so that through the mathematics e-module students practice a lot of problem solving problems regularly. To support good learning, learning media is needed that can support students to be able to solve mathematical problems independently and can be used anywhere and anytime. One of the right learning media is an innovative mathematics e-module to improve students' mathematical solving skills.

3.2 Design Phase

Figure 1. Design e – modules

At this stage researchers design e-modules using Microsoft word which is converted into PDF and then edited using flipbook applications so that links are obtained from the developed e-modules. The preparation of the e-module consists of several components, namely the title page, preface, table of contents, introduction, learning activities, final evaluation, glossary, answer key and bibliography. This stage is carried out for the manufacture of the initial design of the product in accordance with the selection of the format that has been chosen. The mathematics material chosen is system of linear equations in three variables class X high school material. The material is reviewed and adjusted to indicators of competency achievement so that what is delivered can achieve learning objectives. E-module mathematics is expected to present material that is easy to understand so that it can be used as a learning resource. This is in line with Nurrita (2018) who suggests that the use of media as a learning medium or learning resource can help teachers convey information to students, so as to achieve educational goals and better student learning outcomes. The material developed is in the form of providing contextual problems so that students can relate mathematics lessons to constructing material in students' daily lives (Islahiyah, et al., 2021).

The characteristics of this mathematics e-module are: 1) researchers present practice questions in the form of story problems so that students know the implementation of system of linear equations in three variables material in everyday life; 2) The e-module is equipped with a problem-solving illustration video; 3) e-modules are equipped with various questions (Purnomo and Suparman, 2020) so that students can practice and understand the material better; 4) E-modules are packaged in the form of flipbooks to make it easier for students to learn both during **class** hours and outside class hours without the need to bring books. Then the researcher compiled an instrument to assess the validity of the e-module for experts and questionnaires of student responses to the e-module for media users.

3.3 Development stage

At this stage the researcher makes the initial product of the e-module based on the design that has been determined at the design stage. Once the initial product is completed, the mathematics e-module is then validated by media experts and subject matter experts. Expert validation assessment aims to identify weaknesses and shortcomings of developed media by providing advice and opinions from validators, namely material experts and media experts (Lailiyah &; Rohayati, 2015). The validation of media experts in the development of mathematics e-modules was carried out by 3 media expert validators, namely 3 lecturers of the S1 Mathematics Education study program at the University of Muhammadiyah Semarang. The media expert validation sheet is in the form of a questionnaire which contains five aspects of

assessment, namely the display aspect of screen design, the aspect of ease of use, the aspect of consistency, the aspect of usability, and the graphic aspect. The results of the assessment of media expert validators are presented in Figure 2.

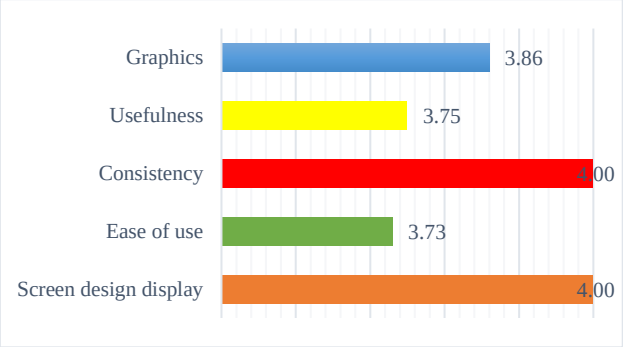

Figure 2. Media expert validation assessment results

Based on the validation assessment of media experts, a final score of 3.87 was obtained with very good/valid criteria. The appearance of the mathematics e-module must be attractive in order to arouse students' interest in learning. Supported by research by Resiana, et al., (2015) which states that the attractiveness of appearance greatly affects the learning process, the stronger the attractiveness of the media, the stronger the interest and motivation of student learning.

The validation of material experts in the development of this mathematics e-module was carried out by 3 validators of material experts, namely grade X high school mathematics teachers. The material expert validation sheet is in the form of a questionnaire which contains three aspects of assessment, namely the content aspect, the presentation aspect, and the language aspect. The results of the material expert validator assessment are presented in Figure 3.

Figure 3. Material expert validation results

Based on the expert validation assessment, the final score of 3.71 was obtained with very good / valid criteria. Based on the final assessment results of the expert validators, the mathematics e-module developed obtained an overall average score of 3.79 included in the very good / valid criteria, so it can be concluded that the mathematics e-module developed is valid to be used as a student learning medium, but it needs to be revised according to the advice given by expert validators before implementation. Supported by Nurrita (2018) research which states that the application of media in learning is considered very ideal because the learning process using learning media becomes easy and fun, so that students easily understand the subject matter taught.

Some of the suggestions given are: 1) the table of contents section is made automatic to easily find the desired subsection; 2) convert the video by scanning the barcode to the video click form so that it can be played immediately; 3) there is a discrepancy between the question and the answer key; and 4) there are typos in some words. Here's what the media looks like before and after the revision.

Figure 4. Video display *of barcode scan* before revision

Figure 5. Display of video clicks after revision

3.4 Implementation Phase

At this stage, researchers conduct small group trials to assess whether the product is still revised or can be used for field trials. The small group trial was carried out in class XI multimedia C SMA Muhammadiyah 2 Bobotsari with respondents as many as 26 students because they had received system of linear equations in three variables material in class X. Students accessed the mathematics e-module through a link shared via the WhatsApp application, then the researcher explained about the mathematics e-module that had been developed to the students. Furthermore, students are asked to try to operate and read the e-module independently. After the students tried independently, the researcher asked the students to fill out a student response questionnaire and provide suggestions or comments on the e-module.

Question trials are conducted to test the validity, reliability, level of difficulty and discriminating power of questions before being used to test the improvement of students' problem-solving skills in field trial classes. This trial was conducted in class XI multimedia C with respondents as many as 26 students. Validation questions are calculated using Microsoft Excel. Based on the results of the calculation of the validity of the question above, questions number 1 to 5 obtained validity values are at intervals $0.70 \leq 0.88 \leq 0.90$ with a significant rate of 5% and $r_{table} = 0.3739$ then the question is declared valid which is very good. The results of the calculation of the reliability of the questions are obtained $r_{11} = 0.77$ and $r_{table} = 0.3739$ so that $0.77 > 0.3739$ then the question is declared reliable. The level of difficulty is used to determine whether the criteria for an item are easy, medium or difficult. Based on the results of the calculation of the level of difficulty above, questions number 1 to 5 obtained a value for the level of difficulty in the interval $0.31 \leq 0.50 \leq 0.70$ with medium criteria. The differentiating power of the questions is used to distinguish high-ability students from low-ability students. The questions are categorized into four categories, namely very good, good, good enough, and not good. Questions with poor categories cannot be used (Sulistyaningsih, et al., 2023). Based on the results of the differentiating power calculation above, questions number 1 to 5 obtained the value of the differentiating power is in the interval $0.20 \leq 0.24 < 0.30$ with good enough criteria. The questions used in this study are questions that meet the criteria of valid, reliable, medium difficulty, and good distinguishing power. Based on the calculation of

validity, reliability, level of difficulty and differentiating power of the questions above, researchers took the questions used for research totaling 5 questions, namely questions number 1 to 5 for pretest and posttest.

Field trials were carried out in class X multimedia B SMA Muhammadiyah 2 Bobotsari with respondents as many as 34 students. The research was conducted through face-to-face learning at SMA Muhammadiyah 2 Bobotsari with 3 meetings. Students were asked to fill out a response questionnaire distributed by the researcher. The final result of the student's response is used as a determinant of the practicality of the mathematics e-module developed. This is in line with the research of Arini, et al., (2017) that student response questionnaires are used to measure the level of practicality of the learning media developed. The results of the student response questionnaire research are as follows.

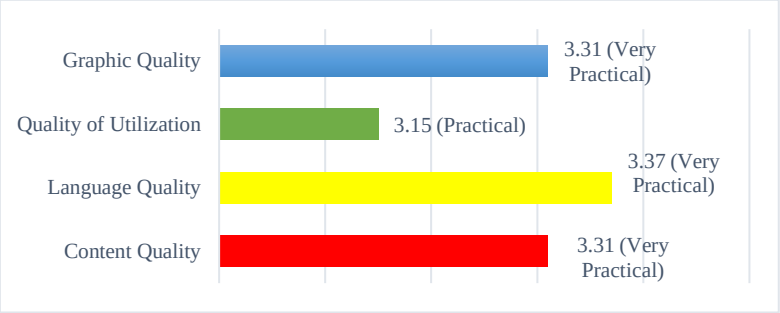

Figure 6. Results of student response questionnaire

Based on the recapitulation of the questionnaire assessment of student responses to the mathematics e-module used, the overall average score for the five aspects was 3.26, which is in the interval $3.25 \leq 3.26 \leq 4.00$ with very practical criteria. Mathematics e-modules are packaged as attractive as possible so that they are easy to understand and can attract students' interest in learning so that students are more excited during the learning process. This is supported by Audie (2019) in Maghfiroh (2021) which states that students tend to prefer learning media because it can increase student enthusiasm, motivation and interest in learning, and does not seem boring. This is in line with Munadi (2013) in Maghfiroh (2021) which states that learning media has the main function, namely as a learning medium that must be easily understood by students, so that the language used must be communicative and easy to understand. Based on the results of the student response questionnaire, it can be concluded that the mathematics e-module is very practical to use as a student learning medium.

The problem solving ability improvement test was carried out to determine whether there was an increase in students' mathematical problem solving ability after completing mathematics learning using the problem-based learning model assisted by the system of linear equations in three variables material mathematics e-module. Before carrying out learning using the mathematics e-module, students are asked to take a pretest to find out students' initial abilities regarding the system of linear equations in three variables material. After learning using the problem based learning model assisted by e-modules is completed, students are asked to do a posttest to find out the student's final ability after carrying out learning using the mathematics e-module.

This increase test is calculated by the N-Gain formula. Based on the calculation of the test for improving students' mathematical problem solving ability above, an average N-Gain value of 0.49 was obtained which was in the interval $0.30 \leq 0.49 \leq 0.70$ with medium criteria. So it can be concluded that there is an increase in the problem-solving ability of students in the field trial class classically with moderate criteria.

The developed e-module presents problem solving with problem-solving steps according to Polya and problem-solving indicators according to NCTM to assist students in improving mathematical problem-solving skills. In addition, the material in the e-module is presented in a coherent, clear, and uses problems that exist in everyday life to help students understand system of linear equations in three variables material.

The Problem Based Learning model is combined with e-module media which explores students' abilities to understand problems, plan solutions, carry out and determine solutions to each problem by providing real problems. The learning given to these students can provide a meaningful learning experience, where according to Yanti et al (2021) meaningful learning is learning that uses problems in students' daily lives. The use of e-modules with the Problem Based Learning model helps students to develop critical, creative and innovative thinking skills as well as student problem solving. Learning using the problem based

learning model assisted by e-modules is effective for problem solving abilities. In line with Sulistyaningsih (2023) that e-modules for Problem Based Learning have been developed by presenting problems and equipped with solution steps so that they can help students improve their problem solving abilities. The research results of Yuherni, et al., (2020), state that the use of e-modules is very effective in learning mathematics which aims to improve mathematical problem solving abilities. This is also supported by the research results of Ristiningsih, et al., (2021) and Rahmadila, et al., (2022) which state that learning using the problem based learning model assisted by e-modules is effective in improving the results of students' mathematical problem solving abilities.

3.5 Evaluation phase

Researchers evaluate in each process the stages are completed (formative) and at the end when the entire process has been carried out (summative). Evaluation carried out at the analysis stage is by limiting problems in research. Evaluation at the design stage is carried out on the design results to develop mathematical e-module products. The evaluation carried out at the development stage is the revision of the mathematics e-module according to suggestions or comments provided by validators, material experts and media experts. Evaluation at the implementation stage is carried out on the results of small group trials and field trials. The evaluation at the end is carried out to see again whether the mathematics e-module developed still needs to be revised or not.

The development of this e-module can still be carried out further by considering needs that can improve students' mathematical abilities. E-modules can be further developed, for example by providing animated visuals that attract more students' attention, adding more learning video features so that they can facilitate students' learning styles, and can also be developed for other materials and fields.

4. Conclusion

Based on the results of research and development that has been carried out, it can be concluded that: 1) the mathematics e-module of system of linear equations in three variables material meets the valid criteria with a final grade of 3.79 with very valid criteria; 2) the mathematics e-module of system of linear equations in three variables material meets the practical criteria with a final grade of 3.26 with very practical criteria; and 3) the mathematics e-module of system of linear equations in three variables material can improve students' problem-solving skills with an average N-Gain score of 0.49 in the medium category.

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