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Development of Problem-Based Learning Mathematical Module with STEM Approach to Improve Problem-Solving Ability and Self Efficacy

Eliana Putri Setiawati[a,*], Arief Agoestanto[a]

[a]*Mathematics Department, Universitas Negeri Semarang, Sekaran Campus,Gunungpati, Semarang, 50229, Indonesia*

** E-mail address: elianaputri@students.unnes.ac.id*

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Abstract

The aim of this research was to produce problem-based learning mathematical modules with STEM approach with a valid, practical and effective in improving problem-solving ability and self efficacy. This study used a Research and Development (RnD) with a 4-D development model. The 4-D development process stage consists of Define, Design, Develop, and Disseminate. This research did not reach the disseminate stage due to time constraints. Based on the results of the research, it was found that the problem-based learning mathematical modules with STEM approach that was developed met the criteria, namely, (1) validity with a percentage of 88% with very valid criteria, (2) practicality with a percentage of 91.5% with very strong criteria. practical, (3) effective in increasing problem-solving ability with an n-gain result of 0.64 with medium criteria, (4) effective in increasing self-efficacy with an n-gain result of 0.575 with medium criteria.

1. Introduction

Developments that occur in the 21st century affect the dynamics of education today. Education is one of the most important things in life. According to Harahap & Surya (2017), mathematics is a science that is given at all levels of education in Indonesia, namely Elementary School (ES), Junior High School (JHS), High School (SHS) and College. Mathematics is one of the basic sciences that is not only needed to study mathematics further, but is also needed to study other sciences (Syahrir, & Susilawati, 2015).

Learning is a process of interacting students with their environment effectively and efficiently which consists of several components, a very important component, namely learning objectives (Fatikhah & Izzati, 2015). According to the National Council of Teachers of Mathematics or NCTM (2000), the purpose of learning mathematics is to improve problem solving abilities, reasoning and proof abilities, communication ability, the ability to make connections and the ability to representation (representation). Thus, problem-solving ability is one of the abilities that is very necessary in learning mathematics and needs to be possessed by students.

Mathematical problem solving abilities are very important for students. According to NCTM (2000), problem-solving ability cannot be separated from learning because problem-solving is part of learning mathematics. According to Hendriana & Soemarmo as quoted by Agustami, Aprida, & Pramita (2021), problem solving is important in learning mathematics, even steps in problem solving are part of learning mathematics. The importance of problem-solving ability can also be seen in the basic competencies contained in the content standards in Permendikbud Number 64 of 2013. These basic competencies state that students are expected to be able to demonstrate a logical, critical, analytical, careful and thorough attitude, responsible, responsive, and not easily give up in solving problems (Kemendikbud, 2013). Based on this description, it can be concluded that problem solving is an important part of learning mathematics

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According to Mahuda (2017), problem solving ability is the ability of students to solve a problem based on the aspect of identifying the problem, developing a settlement plan, solving problems and looking back at the results. Based on the observation results, the problem solving abilities of students at SMA NU Hasyim Asy'ari Kudus are still not optimal. This statement is reinforced by the results of students' answers when given a problem-solving ability test in class X. The problem-solving ability test was given to 15 class X students of SMA NU Hasyim Asy'ari Kudus. Of the 15 students, only 4 students scored ≥65, while the other 11 children scored below 65. Based on the results of the students' answers they were still unable to understand in identifying what was known and what was asked correctly, making a settlement plan and review the results obtained. Therefore, students' mathematical problem solving abilities need to be developed so that students can solve problems in everyday life related to mathematics.

In addition to the importance of cognitive abilities, it is also necessary to have affective abilities that must be possessed by students. Attitude is one of the teacher's assessments of learning. One of the affective abilities that students must have is self-efficacy (Yunida et al., 2016). According to Bandura (1997), self-efficacy is a person's belief about the extent to which he estimates his own ability to carry out tasks to achieve the desired results. In addition, with self-efficacy students will be confident in their own abilities so that students become optimistic in solving the problems given. So, increasing self-efficacy needs to be considered as a supporting component in students' problem-solving abilities. Based on the results of observations made by researchers on class X students of SMA NU Hasyim Asy'ari Kudus, it was found that the self-efficacy of students was still low. This was obtained by the researcher after giving a self-efficacy questionnaire which contained several statement items to 15 students in class XI at SMA NU Hasyim Asy'ari Kudus.

Based on the results of the questionnaire, it was found that most students did not feel challenged to solve questions with difficult categories, students believed that when they studied, they could solve the questions given, students did not try to solve problems independently when the questions were difficult, students prefer to solve easy math problems, students also feel pressured if the questions given do not match their expectations and students will immediately give up when they cannot solve the problem.

One important element for achieving learning effectiveness is the existence of learning resources (Sudaryati et al., 2017). The availability of good learning resources can help students to improve their knowledge, ability and attitudes (Diana et al., 2018). Based on observations that researchers carried out at NU Hasyim Asy'ari Kudus High School for the 2021/2022 academic year, in learning mathematics the method used is the lecture method, while the learning resource used in learning is student worksheet. Based on the results of observations, it is suspected that the student worksheet used in learning has not been able to help students to learn independently and the examples of questions and answers contained in the student worksheet have not been able to help students understand learning material and the problem solving abilities and self-efficacy of students have not been optimal.

Students who have difficulty learning mathematics actually lie in the use of learning media or teaching materials used (Kurnasari et al., 2018). These factors can cause students to be lazy to study mathematics at home or at school. One effort that can be done is to add teaching materials that support the learning process of students. The recommended learning resources for learning are modules. The existence of the module is expected to help students' learning activities. According to Astiti et al. (2014) a learning approach using modules can help students to learn independently according to their respective learning acceleration. In essence, modules are teaching materials that contain a series of learning experiences that are systematically arranged so that students can achieve their learning goals (Dewi & Lestari, 2020).

The approach to events in everyday life is very suitable to be used as an innovation in compiling modules so that students can easily understand them. Innovation in developing modules is needed, one of the modules that can provide innovation in mathematics is a problem-based learning module. Problem-based learning modules are problem-oriented modules as a starting point for learning (Iriani et al., 2019). Applying the right learning model can help students to actively participate in learning. According to Masri (2018), a learning model that can improve students' problem-solving ability and self efficacy is problem-based learning. Based on the opinion above, Problem Based Learning is an innovative learning model that has the characteristics that there are real problems to help students apply the knowledge they already have to solve a problem and can improve problem-solving ability and self efficacy.

Problems in Problem Based Learning can be combined with science, technology, engineering and mathematics (STEM) (Farwati et al., 2017). The application of a problem-based learning model with a STEM approach can improve critical thinking ability and problem solving (Putri et al., 2021). According

to Yolantia et al. (2021), the application of problem-based learning modules can increase students' self-efficacy. According to Dachi & Perdana (2021), students self-efficacy can also be increased with the STEM learning approach. Therefore, one of the efforts to make learning more interesting and to increase problem-solving abilities and self-efficacy is to use problem-based learning mathematical modules with STEM approach.

Based on the description above, the author conducted a study entitled "Development of Problem-Based Learning Mathematical Modules with STEM (Science, Technology, Engineering, and Mathematics) Approaches to Improve Problem-Solving Ability and Self Efficacy". This research was conducted with the aim of producing a product in the form of a problem-based learning mathematical modules with STEM approach.that can improve students problem-solving ability and self efficacy.

2. Methods

This type of research used a Research and Development (Rnd) research approach with a 4-D research and development procedure according to Thiagarajan with a 0ne-Group Pretest-Posttest Design research design. The four stages of the 4-D development process consist of Define, Design, Develop and Disseminate (Tiagarajan, 1994). This research did not reach the disseminate stage due to time constraints. The product produced in this development research was problem-based learning mathematical module with STEM approach to linear programming material for class XI high school students.

The define stage divided into several steps, namely initial analysis to determine problems in learning mathematics, student analysis to determine student characteristics which include problem solving abilities and self-efficacy, task analysis to detail tasks and material to be used in learning, namely linear program material, concept analysis is used to describe facts and identify concepts related to linear programming material, specifications of learning objectives are based on competency standards and basic competencies listed in the 2013 curriculum on linear programming, and the preparation of research instruments which are composed of learning devices, namely lesson plans and problem-based learning mathematical modules with STEM approach and data collection instruments, namely problem-solving ability test questions, response questionnaires, self-efficacy questionnaires along with their respective validation sheets and problem-based learning mathematical modules with STEM approach validation sheets.

The design stage used to design modules that will be used in learning linear programming material. At this stage the researcher designed the initial design of a problem-based learning mathematical modules with STEM approach, lesson plans, and data collection instruments which were then validated by the validator.

The develop stage carried out by validating the modules and data collection instruments by the validator which consists of two mathematics lecturers and one mathematics teacher and making revisions based on suggestions and comments from the validator. The problem-based learning mathematical modules with STEM approach that has been developed was tested in mathematics learning carried out at Hasyim Asy'ari NU High School. The module trial was carried out in class XI with 25 students. Mathematics teachers and students were given a response questionnaire to the problem-based learning mathematical modules with STEM approach to find out the practicality of the module. In addition, to find out the effectiveness of the module on problem solving abilities students are given pretest and posttest questions which will then be tested for learning completeness in the mean and proportions, paired sample t tests and n-gain tests. Meanwhile, to find out the effectiveness of the module on self-efficacy, students are given a self-efficacy questionnaire, which will then be tested for n-gain to determine the increase in self-efficacy.

2.1. Modul Validity

The validation of this module based on three aspects, namely content, presentation and language aspects. The percentage of validation score results by the validator is analyzed based on the validity criteria of the module and research instruments as follows.

Table 1. Modul Validity Criteria

Validity Percentage	Validity Classification
$80\% < P \leq 100\%$	Very Valid
$60\% < P \leq 80\%$	Valid
$40\% < P \leq 60\%$	Quite Valid
$20\% < P \leq 40\%$	Invalid
$0\% < P \leq 20\%$	Very Invalid

(Table sources: Ernawati & Sukardiyono (2017))

2.2. Validation of Problem Solving Test Questions

The validation of problem solving test questions based on three aspects, namely material, construction and language aspects. The percentage of validation results by the validator was analyzed based on the validity criteria of the module and research instruments adapted from Ernawati & Sukardiyono (2017).

After the pretest and posttest questions have been revised according to the suggestions and comments from the validator, they can be tested on students.

2.3. Validation of Self Efficacy Questionnaires

The validation of self-efficacy questionnaires based on three aspects, namely material, construction and language aspects. The percentage of validation results by the validator was analyzed based on the validity criteria of the module and research instruments adapted from Ernawati & Sukardiyono (2017).

2.4. Validation of Students Response Questionnaires

Validation of student response questionnaires based on three aspects, namely material, construction and language aspects. The percentage of validation results by the validator was analyzed based on the validity criteria of the module and research instruments adapted from Ernawati & Sukardiyono (2017).

2.5. Validation of The Teacher Response Questionnaire

Teacher questionnaire validation based on three aspects, namely material, construction and language aspects. The percentage of validation results by the validator was analyzed based on the validity criteria of the module and research instruments adapted from Ernawati & Sukardiyono (2017).

2.6. Module Practicality

The results of filling out the teacher and student response questionnaires were analyzed based on practicality criteria according to Kartini & Putra (2020) as follows:

Table 2. Module Practicality Criteria

Practical Percentage	Practical Classification
$80\% < P \leq 100\%$	Very Practical
$60\% < P \leq 80\%$	Practical
$40\% < P \leq 60\%$	Quite Practical
$20\% < P \leq 40\%$	Impractical
$0\% < P \leq 20\%$	Very Impractical

(Table Sources: Kartini & Putra (2020))

2.7. Module Effectiveness

To find out whether there is an increase in problem-solving ability and self-efficacy of students before and after using the problem-based learning mathematical modules with STEM approach, a mean and proportion learning mastery test is carried out as well as a paired t-test. Meanwhile, the n-gain test is used to determine the increase in problem-solving ability and self-efficacy after using the problem-based learning mathematical modules with STEM approach. The results of the acquisition of the n-gain value were analyzed based on the criteria for the average n-gain score according to Hake (1999) as follows.

Table 3. *N-Gain* Score Criteria

N-Gain Value	*N-Gain Classification*
$0.7 < \langle g \rangle \leq 1.00$	High
$0.3 < \langle g \rangle \leq 0.7$	Medium
$0 < \langle g \rangle \leq 0.3$	Low

(Table Sources: Hake (1999))

3. Results & Discussions

The result of this research is a product in the form of a problem-based learning mathematical modules with STEM approach to material for class XI high school linear programming. The resulting module is used to improve students' problem-solving ability and self-efficacy. This research and development procedure refers to the 4-D research and development procedure. The following are the results of the development of each stage:

3.1. Define

The define stage is divided into several steps. An explanation of the steps in the define stage are as follows:

3.1.1 Front-end Analysis

In the initial analysis stage of this study, researchers made observations at school to find out the problems experienced in learning mathematics at SMA NU Hasyim Asy'ari. In addition, researchers also conducted interviews with mathematics teachers. Some of the results of observations and interviews are as follows: (1) the curriculum used is the 2013 curriculum, (2) the teaching materials used are only worksheets, (3) the methods used are lectures and assignments, (4) the presentation of the material is delivered coherently, (5) the media used are whiteboards and markers, (6) the learning process places more emphasis on teacher centered.

3.1.2 Learner Analysis

Students are not enthusiastic in learning mathematics, do not do the practice questions given by the teacher and immediately give up when they cannot complete the practice questions. Based on this description, it can be said that students' self-efficacy is still low. Students' problem-solving abilities are also not optimal, this can be seen from the results of students' answers when given a problem-solving ability test. Students who achieve minimum learning mastery standard only 36% of one class.

Based on the description above, a problem-based learning mathematical modules with STEM approach.

3.1.3 Task Analysis

The material used in this research is linear programming material for class XI high school students.

3.1.4 Concept Analysis

Concepts related to linear programming material are arranged in detail and systematically to form a concept map.

3.1.5 Spesifying Instructional Objectives

The formulation of learning objectives is based on the competency standards and basic competencies listed in the 2013 curriculum regarding linear programming.

3.1.6 Preparation of Research Instruments

The research instruments compiled consisted of learning tools and data collection instruments. Learning tools consist of lesson plans and problem-based learning mathematical modules with STEM approach. While the data collection instruments consisted of response questionnaires and their validation sheets, pretest and posttest problem-solving ability test questions along with their validation sheets, initial and final self-efficacy questionnaires and their validation sheets, and problem-based learning mathematical modules with STEM approach validity assessment sheets.

3.2. Design

At the design stage, the researcher designed the initial design of a problem-based learning mathematical modules with STEM approach, lesson plans and data collection instruments which were then validated by the validator.

3.2.1 Module Format Selection

The format used in designing modules uses the Canva application for making cover designs and module backgrounds as well as the Microsoft Word 2016 application for making material.

3.2.2 Initial Design of The Module

Some of the content contained in the module includes: competency standards, basic competencies, Indicators, concept maps, problems in everyday life arranged integrated with STEM, student worksheet, summaries, practice questions, bibliography, answer keys, glossary and author profile.

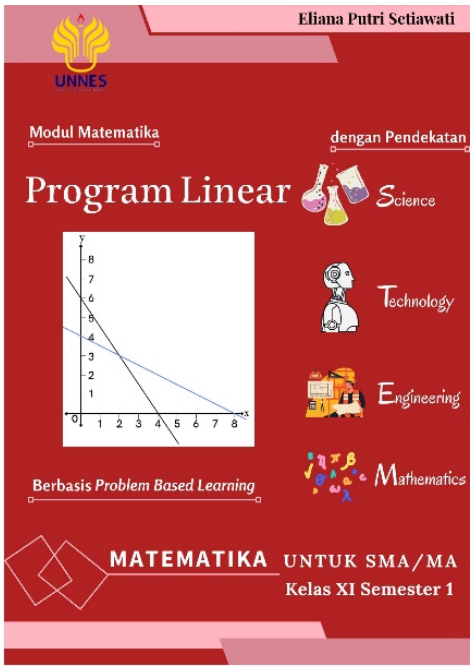

Figure 1. Module Cover

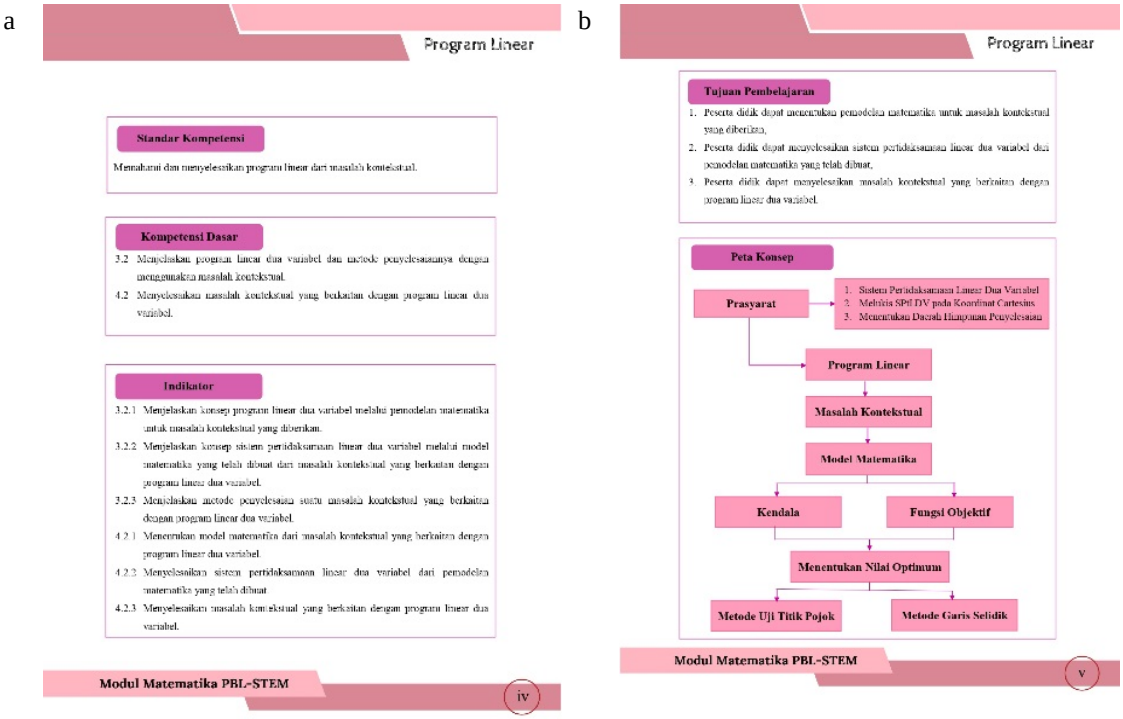

Figure 2. (a) Competency Standards, Basic Competencies, Indicator; (b) Objectives and Concept Maps

a b

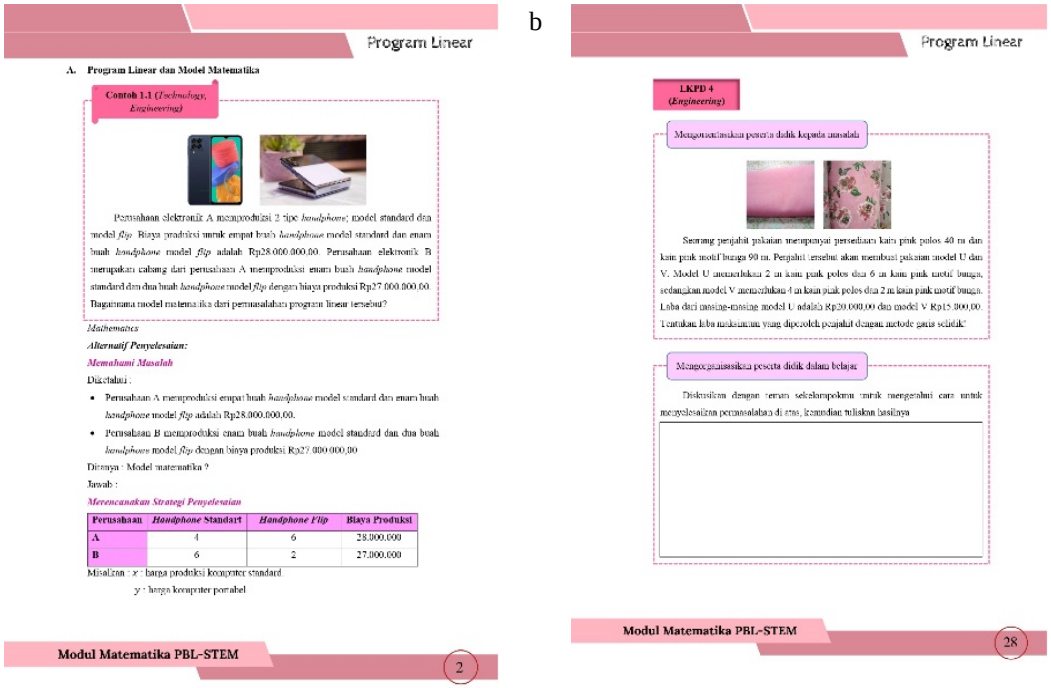

Figure 3. (a) Examples of problem in everyday life integrated with STEM; (b) Student worksheet integrated *problem based learning*

Figure 4. References

3.3. Develop

The data collection modules and instruments that have been validated and have gone through the revision stage were tested on class XI students at SMA NU Hasyim Asy'ari.

3.3.1 Validation by validators

3.3.1.1 Module Validation Results

Based on the validation results of the problem-based learning mathematical modules with STEM approach by the validator, it was found that the validity score of the problem-based learning mathematical modules with STEM approach from validator 1 was 86% with very valid criteria, the validity score of validator 2 was 85% with very valid criteria valid, the validity score of validator 3 is 92% with very valid criteria, and a combined validity score of 88% with very valid criteria so that problem-based learning mathematical modules with STEM approach can be used in learning.

3.3.1.2 Validation Results of Problem Solving Test

Based on the validation results of the problem solving test questions by the validator, it was found that the validity score of the problem solving test questions from validator 1 was 89% with very valid criteria, the validity score from validator 2 was 84% with very valid criteria, the validity score from validator 3 was 98% with very valid criteria, and a combined validity score of 90% with very valid criteria so that problem solving test questions can be used to measure students' problem solving abilities.

3.3.1.3 Validation Results of the Self Efficacy Questionnaire

Based on the results of the self-efficacy questionnaire validation by the validator, it was found that the validity score of the self-efficacy questionnaire from validator 1 was 94% with very valid criteria, the validity score from validator 2 was 100% with very valid criteria, the validity score from validator 3 was 94% with the criteria very valid, and a combined validity score of 96% with very valid criteria so that self-efficacy questionnaires can be used to measure student self-efficacy

3.3.1.4 Validation Results of the Student Response Questionnaires

Based on the validation results of student response questionnaires by the validator, it was found that the validity score of the student response questionnaire from validator 1 was 94% with very valid criteria, the validity score from validator 2 was 97% with very valid criteria, the validity score from validator 3 was 97% with very valid criteria, and a combined validity score of 96% with very valid criteria so that student response questionnaires can be used to measure students' responses to problem-based learning mathematical modules with STEM approach.

3.3.1.5 Validation Results of the Teacher Response Questionnaires

Based on the validation results of the teacher's response questionnaire by the validator, it was found that the validity score of the teacher's response questionnaire from validator 1 was 91% with very valid criteria, the validity score from validator 2 was 91% with very valid criteria, the validity score from validator 3 was 97% with the criteria very valid, and a combined validity score of 93% with very valid criteria so that the teacher response questionnaire can be used to measure teacher responses to problem-based learning mathematical modules with STEM approach.

3.3.2 Revision I Based on Suggestions and Comments From The Validator

After going through the validation stage by the validator and making improvements to the modules and data collection instruments, the problem-based learning mathematical modules with STEM approach. and instruments is feasible for further trials.

3.3.3 Test Questions Test Problem Solving Abilities

The following are the results of the analysis of problem-solving ability test questions.

Table 4. Results of Problem Solving Ability Test

Item Number	Validity	Reliability	Different Power	Difficulty Level
1	90% (Very Valid)	0.87 (Reliable)	0.43 (Good)	0.53 (Medium)
2			0.42 (Good)	0.39 (Medium)
3			0.42 (Good)	0.64 (Medium)
4			0.43 (Good)	0.42 (Medium)

3.3.4 Revision II

The second revision stage was carried out based on the results obtained from the problem solving ability test questions. The results of the test of the problem-solving ability test have shown validity with very valid criteria, high reliability, good discriminating power and a medium level of difficulty. Because the problem solving ability test questions are valid and reliable, the problem solving ability test questions can be used for operational field trials.

3.3.5 Operational Field Testing

Operational field trials were used to determine the effectiveness and practicality of problem-based learning mathematical modules with STEM approach. The results of operational field trials are as follows:

3.3.5.1 Problem Solving Skill

Based on the output of the SPSS normality test, the pretest results obtained sig = 0.2> 0.05, then H_0 was accepted and the SPSS output results of the normality test, posttest results obtained sig = 0.149> 0.05, then H_0 was accepted. So, the results of the pretest and posttest of students' problem solving abilities are normally distributed. Based on the results of the SPSS homogeneity test output, it was found that the value was sig = 0.205> 0.05, so H_0 was accepted. So, the results of the pretest and posttest of students' problem solving abilities have the same (homogeneous) variance.

Based on the results of the SPSS output of the individual learning mastery test, the value was sig = 0.000 <0.05, so H_0 was rejected. So, the average problem-solving ability of students is >64.5 or the problem-solving ability of students has reached the minimum learning mastery standard. Based on the output of the SPSS learning mastery test in proportion, the value sig = 0.000 <0.05, then H_0 is rejected. So, the proportion of the number of students who have scores above 65 is more than 79.5% so that the problem solving abilities of students reach the minimum learning mastery standard in proportion.

Based on the results of the SPSS output of the paired sample t test, the value of sig = 0.000 <0.05 is obtained, so H_0 is rejected. So, there are differences in the value of learning outcomes in pretest and posttest problem solving abilities using problem-based learning mathematical modules with STEM approach. Based on the results of the n-gain calculation, the value of $\langle g \rangle$ = 0.64 is obtained with moderate criteria. So, students' problem-solving abilities increased in the moderate category after using the problem-based learning mathematical modules with STEM approach.

The following is the recapitulation of students' problem-solving ability improvement using n-gain.

Table 5. Recapitulation of Students' N-Gain Test Results

***N-Gain* Value**	***N-Gain* Classification**	**Lots of Learners**	**Percentage**
$0.7 < \langle g \rangle \leq 1.00$	High	10	40%
$0.3 < \langle g \rangle \leq 0.7$	Medium	14	56%
$0.0 < \langle g \rangle \leq 0.3$	Low	1	4%

3.3.5.2 *Self Efficacy*

Based on the results of the n-gain calculation, the value of $\langle g \rangle$ = 0.575 is obtained with moderate criteria. So, students' self-efficacy increases in the moderate category after using the problem-based learning mathematical modules with STEM approach.

The following is the recapitulation of students' problem-solving ability improvement using n-gain.

Table 6. Recapitulation of Students' *N-Gain* Test Results

***N-Gain* Value**	***N-Gain* Classification**	**Lots of Learners**	**Percentage**
$0.7 < \langle g \rangle \leq 1.00$	High	2	8%
$0.3 < \langle g \rangle \leq 0.7$	Medium	23	92%
$0.0 < \langle g \rangle \leq 0.3$	Low	0	0%

3.3.6 Module Practical Results

The following is the recapitulation of teacher and student response questionnaires to find out the practicality of problem-based learning mathematical modules with STEM approach.

Table 7. Recapitulation of Module Practical Results

Response Questionnaire	Percentage Average	Criteria
Teacher Response Questionnaire	91%	Very Practical
Students Response Questionnaire	92%	Very Practical
Combine Average	**91.5%**	**Very Practical**

From the table above, it is obtained that the average combined practicality of the module is 91.5% with very practical criteria. So, the problem-based learning mathematical modules with STEM approach has very practical criteria.

Based on the results of the analysis that has been carried out, the results obtained are that the development of problem-based learning mathematical modules with STEM approach can improve students' problem-solving abilities and self-efficacy in the medium category. In addition, the development of problem-based learning mathematical modules with STEM approach has met the valid, practical and effective criteria in improving students' problem-solving abilities and self-efficacy. This research is in line with research conducted by Finariyati et al. (2020), the results of his research are that the mathematics module meets the criteria of being effective in improving problem solving ability. Based on research conducted by Nurintya & Agoestanto (2022), teaching materials with STEM nuances have a 99.09% percentage result with very valid criteria so they can be used in learning mathematics.

Problems in everyday life are suitable as innovations in compiling modules to improve problem-solving ability and self-efficacy. This is in line with research conducted by Yolantia et al. (2021), the results of his research are that the use of problem based learning modules has an influence on student learning outcomes and self-efficacy. Problems in problem based learning can be combined with science, technology, engineering and mathematics (STEM) (Farwati et al., 2017). Based on research conducted by Putri et al. (2021), problem solving abilities increase after using the problem based learning module with the STEM approach. Meanwhile, according to Dachi & Perdana (2021), the STEM approach can also increase students' self-efficacy.

Based on the description above, it was found that the use of problem-based learning mathematical modules with STEM approach was effective in increasing students' problem-solving abilities and self-efficacy. Based on research conducted by As'ari (2019), the results of his research are that the developed module can be used if it meets valid, practical and effective criteria. Because problem-based learning mathematical modules with STEM approach developed has met the valid, practical and effective criteria, the module can be used in learning mathematics.

4. Conclusion

The problem-based learning mathematical modules with STEM approach developed in this study has met the valid, practical and effective criteria. Based on the results of the analysis of the validity of problem-based learning mathematical modules with STEM approach, a combined validation score of 88% with very valid criteria was obtained. Based on the results of the practicality analysis of problem-based learning mathematical modules with STEM approach, a combined score of 91.5% was obtained with very valid criteria. The problem-based learning mathematical modules with STEM approach is categorized as effective enough to improve students' problem-solving abilities. This conclusion was obtained based on the results of the mean and proportion learning mastery test, paired t test, and n-gain test obtained a value of 0.64 with medium criteria or in other words an increase in students' problem solving abilities after using problem-based learning mathematical modules with STEM approach is in the medium category. In addition, problem-based learning mathematical modules with STEM approach are categorized as quite effective for increasing student self-efficacy. This conclusion was obtained based on the n-gain test results obtained by a value of 0.575 with medium criteria or in other words an increase in students' self-efficacy after using the problem-based learning mathematical modules with STEM approach is in the medium category.

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