



Development of STEAM-Based Mathematics Teaching Materials on Direct and Inverse Proportion to Improve Mathematical Problem-Solving Ability and Self Regulated Learning

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Abstract

This research was research and development whose product was in the form of teaching materials based on STEAM (Science, Technology, Engineering, Art, and Mathematics). This research and development aims to analyze the feasibility and readability, as well as test the effectiveness of teaching materials in improving problem-solving abilities and Self Regulated Learning (SRL). The development stages include potentials and problems; data collection; product design; design validation and revision; product trials (readability tests) and revisions; trial implementation and revision; and then the final product. Furthermore, this study used a one-group pretest and posttest design, carried out at MTs Al-Utsmani with 37 class VIID students in the 2022/2023 academic year as respondents. The results of this study indicate that the developed STEAM-based teaching materials have a feasibility level of 92.82% with very feasible criteria; legibility level of 63.22% with easy-to-understand criteria; as well as effectively improve problem-solving abilities and SRL. This effectiveness is indicated by the average mathematical problem-solving abilities of students after using teaching materials is more than or equal to the Minimum Completeness Criteria, the mathematical problem-solving ability of students who achieve Minimum Completeness Criteria after using complete teaching materials in a classical manner with a proportion of at least 75%, Improvement of students' mathematical problem-solving abilities after using teaching materials is in the moderate minimal category, average SRL after using teaching materials are in the minimal moderate SRL categories, SRL that is in the minimal moderate SRL category while after using teaching materials complete in a classical manner with a proportion of at least 75%, improvement of SRL after using teaching materials is in the moderate minimal category.

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1. Introduction

National education is education based on Pancasila and the 1945 Constitution of the Republic of Indonesia, and is the right of every citizen to create quality individuals who are able to answer the challenges of an increasingly advanced era (Act of The Republic of Indonesia Number 20, 2003). The aim of national education is to develop abilities, shape character, dignity and educate the nation and develop the potential of students so that they become human beings who have faith, piety, noble character, knowledge, responsibility and are healthy, capable, creative, independent and democratic. In accordance with this law, Regulation of Government of The Republic of Indonesia Number 57 of 2021 Article 12 Paragraph 1 concerning National Education Standards states that the implementation of learning is carried out in an interactive, inspiring, fun, challenging learning atmosphere, motivating students to participate actively, and

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also provides sufficient opportunities for creativity, independence according to the talents, interests, and physical and psychological development of students. Based on the above it can be seen that education must be able to form qualified individuals, adapted to the challenges of the current era, properly organized and able to equip individuals to have good character.

In realizing individuals who have good character. The Indonesian Ministry of Education and Culture has determined the character values that must be possessed by Indonesian students, one of which is the SRL character. SRL itself is the attitude of not depending on other people and utilizing all knowledge, abilities, time to realize their hopes. Independent students have a good work ethic, tough, fighting spirit, professional, creative, courageous, and love to learn (Ministry of Education and Culture, 2017). However, not all Indonesian students currently have SRL characters. This is in accordance with research conducted by Robiana and Handoko (2020) which stated that the SRL of students at SMP N 3 Rajagaluh was still low, besides that research conducted by Early et al (2018) on class VIII students at SMP N 5 Brebes also stated that SRL of students is not optimal. Students who have low independence tend to just wait for the material or assignments given by the teacher without trying to find their own learning resources (Yulietri et al., 2015). One of the efforts that can be made to overcome this problem is to foster the character of independence through the formation of character in subjects, one of which is mathematics. This character formation can be done by facilitating students to be active both before learning, for example preparing for learning, during learning, or after learning, for example facilitating students to be able to repeat material again (Alperi, 2019). Apart from cultivating the character of independence, mathematics is also expected to be able to produce graduates who are in accordance with the developments of the 21st century so that they are in accordance with the notion of national education, so that they can compete globally and master technology and can welcome the era of the industrial revolution 4.0 (Haifaturrahmah et al., 2020). One of the important 21st century skills for students to master is the ability to solve mathematical problems. The ability to solve mathematical problems is very important because it forms the basis for solving mathematical and real-life problems (Destania & Riwayati, 2021). In fact, the problem-solving ability of students in Indonesia is still relatively low (Ulva et al., 2020). This low problem-solving ability can be seen from the results of the PISA (Program for International Student Assessment) and the National Examination. Indonesia's PISA average score in 2018 for mathematics only reached 379, below the OECD (Organization for Economic Co-operation and Development) average score of 487 (Ministry of Education and Culture, 2019a). In addition, MTs National Examination results in 2019 for mathematics also showed an average of 45.84 and the lowest among other subjects (Ministry of Education and Culture, 2019b).

The results of the 2019 National Examination for the low mathematics subject can also be seen at MTs Al-Utsmani, this school has a low average score of 41.19 with a percentage of mastery of the material for indicators of solving problem-inverse proportion of 27.50 and the indicator of solving problems about scale is 47.50 (Ministry of Education and Culture, 2019b). These results indicate that students' problem-solving abilities for material direct and inverse proportion are still relatively low. Furthermore, interviews with mathematics teachers stated that there was no habituation of questions in the form of problems given to students. In addition, the level of independence of students in learning is still relatively low, shown by the many students who only wait for instructions from the teacher in learning and doing assignments, are less active in learning, and there is no student initiative to look for other learning resources in the library. In addition, the 2013 curriculum mathematics teaching materials used in schools also have a limited number so that students only use worksheets that are sold on the market which only contain subject matter and practice questions that have not exposed students to real-world problems related to the material. Has not facilitated students to have the skills that must be possessed in this 21st century. To achieve this, learning aids are needed in the form of STEAM-based mathematics teaching materials. STEAM (Science, Technology, Engineering, Art, and Mathematics) is integrated learning, student-centered, and can foster problem-solving abilities (Yuliari et al. 2020). With the development of STEAM-based teaching materials, it is hoped that the mathematical problem-solving ability and SRL will increase. This research aims to analyze the feasibility and readability, as well as test the effectiveness of teaching materials in improving problem-solving abilities and Self Regulated Learning (SRL).

2. Method

This research used the research and development (R&D) method, as stated by Sugiyono (2016) that the research and development (R&D) method are a research method that creates a product while testing the effectiveness of the product. In this research and development, the product produced were STEAM-based teaching materials to improve problem-solving and SRL abilities, with stages covering potentials and problems, data collection, product design, design validation and design revision, product trial and revision, trial use and revisions, as well as the final product.

Data collection techniques used test and non-test methods. The test method consists of a gap test to determine the readability level of teaching materials, as well as a pretest and posttest to measure students' problem-solving abilities which have previously been tried out in a trial class. Meanwhile, the non-test method consists of a feasibility questionnaire for teaching materials to determine the validity of teaching materials and an SRL questionnaire to determine SRL students before and after using teaching materials. The SRL questionnaire and description test were given twice, namely before the lesson was held and after the lesson was held. The data obtained in this study are the results of design validation, the results of the readability test, the results of students' problem-solving ability tests, and the results of the SRL questionnaire.

The results of the design validation and the results of the readability test of teaching materials were analyzed using the percentage score formula (P) from Sudijono (2011). Furthermore, the value of the percentage score is reviewed for its eligibility level using the eligibility criteria from Sugiyono (2016). STEAM-based teaching materials are said to be valid or feasible if the score is more than 60%. Meanwhile, for the percentage score (P) on the readability of teaching materials the level of readability was reviewed using the readability criteria from Wahyuni et al. (2017). Teaching materials are said to be easy to understand if the percentage score is more than 60%, whereas if it is less than or equal to 40%, it is necessary to revise the product.

The effectiveness of teaching materials in improving problem-solving skills and SRL was analyzed using the average test, proportion test, paired sample t test, and n-gain test. Teaching materials are said to be effective in increasing problem-solving abilities and SRL if they meet the indicators of effectiveness. Effectiveness indicators in this study are 1) The average mathematical problem-solving ability of students after using teaching materials is more than or equal to the Minimum Completeness Criteria (Lestari et al., 2016). 2) The mathematical problem-solving ability of students who achieve Minimum Completeness Criteria after using complete teaching materials in a classical manner with a proportion of at least 75% (Lestari et al., 2016). 3) Improvement of students' mathematical problem-solving abilities after using teaching materials is in the moderate minimal category (Saputri et al., 2016). 4) Average SRL after using teaching materials are in the minimal moderate SRL category (Role et al., 2022; Maryati & Suryaningsih, 2021). 5) SRL that is in the minimal moderate SRL category while after using teaching materials complete in a classical manner with a proportion of at least 75% (Role et al., 2022). 6) Improvement of SRL after using teaching materials is in the moderate minimal category (Lestari et al., 2022). More details on the stages of developing STEAM-based teaching materials are presented in Figure 1 below.

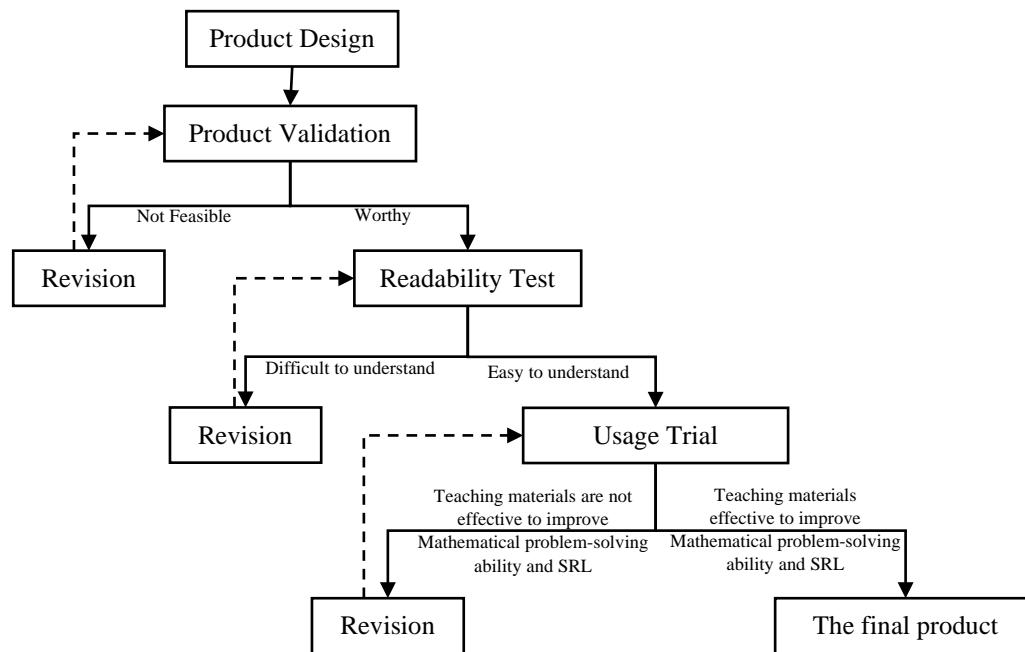


Figure 1. Teaching Materials Development Stage

3. Result and Discussions

3.1 Potential and Problems

The problem-solving ability of MTs Al-Utsmani students is still relatively low, this is shown from the results of the 2019 National Examination which is far below the average student absorption ability. In addition, SRL is also still relatively low, as seen from the many students who are less active, sleepy, and only study when asked by the teacher. One of the possible causes of this happening is the limited number of teaching materials for the 2013 curriculum in schools, so that students only use worksheets that are sold on the market. The worksheets does not yet facilitate students to have the skills needed in the 21st century in the form of problem-solving abilities, because it only contains brief material and exercises about concepts so that students are not yet familiar with questions in the form of problems that exist in the student's real world. Besides that, The worksheets also has an unattractive form because it is black and white and there are only a few pictures, which discourages students' willingness to learn which results in low SRL.

3.2 Data Collection

Data collection was in the form of core competencies, basic competencies, observation of books used in schools, interviews with teachers, and observations of textbooks and journals on the internet. From observations and interviews, information was obtained that the book used by teachers at school was the book "Math for SMP/MTs Class VII Semester 2" published by Erlangga, the 2016 revised edition, which was limited in number so students only used worksheets containing material and examples of questions about concept with a less attractive design. In addition, information was obtained that there was no habituation of questions in the form of problems given to students, students tended to only wait for instructions from the teacher in learning or doing assignments, and students were less active in learning. After that, observations were made on textbooks to add information about material direct and inverse proportion, including the book "Matematika SMP/MTs Kelas VII semester 2", "Modul 5 Perbandingan", "Modul 3 Asyiknya Berdagang Matematika Paket B Setara SMP/ MTs", and "Modul Pembelajaran Jarak Jauh Pada Masa Pandemi Covid-19 untuk Jenjang SMP Mata Pelajaran Matematika Kelas VII Semester Gasal" published by the Ministry of Education and Culture as well as several journals on problem solving skills.

3.3 Product Design

STEAM-based teaching materials are made using Microsoft Word 2016 and the help of the Canva application for cover pages, background designs, and the design of each sub-chapter title. The teaching materials use the basic colors of white and blue, A4 size according to ISO standards (Susanti and Astuti, 2020), the margins used are 4 cm for the top and inner sides and 3 cm for the bottom and outer sides of the book. This teaching material contains 75 pages, which at the beginning consist of covers, prefaces, table of contents, introduction (description of the use of teaching materials, descriptions of problem-solving abilities, learning models, competency standards, basic competencies, and competency achievement indicators, learning objectives, concept maps, material linkages with STEAM, motivation, and prerequisite questions). Next is the core part which contains material, practice questions, creative activities, summaries, games, competency tests, and answer keys.

Every problem in the teaching materials is associated with STEAM elements, this is intended so that students get used to using the abilities they have to be able to solve problems in real life, so that it will improve students' problem-solving skills. In addition, the integration of STEAM also makes this teaching material more interesting, students are faced with problems in the real world, not just memorizing concepts, equipped with attractive pictures and harmonious use of colors, this will certainly encourage curiosity and motivation students to learn so that it will increase the SRL. The creative activities in the teaching materials are intended so that students can also be creative according to their creativity but are still related to the material and STEAM. The competency test is intended so that students can measure, control, and evaluate their learning outcomes. The addition of games is intended so that students have motivation to learn independently because game activities are also related to material. The answer key is also intentionally displayed only the final results and not all of the solutions are displayed which is intended for students to find their own completion process so that students learn independently without relying on others. And finally, the final section, the final section consists of a glossary, bibliography, and back cover.

3.4 Design Validation and Design Improvement

Assessment of the feasibility level of this teaching material consists of 4 aspects, namely the feasibility of content, presentation, language, and graphics (BSNP, 2007). Validation was carried out by 5 validators consisting of 3 lecturers majoring in mathematics at UNNES and 2 mathematics teachers at SMP and MTs, with each validator providing comments and suggestions as a reference for improving teaching materials. Design improvements were made in several aspects such as an incomplete introductory section, material that did not yet lead to STEAM, material with minimal images, and so on. After being corrected several times, the teaching materials are appropriate in terms of feasibility. The results of the final design validation of STEAM-based teaching materials are presented in Table 1 below.

Table 1. Teaching Materials Feasibility Test Results

Aspects Analyzed	P	Criteria
Content eligibility	92.22	Very worth it
Presentation eligibility	93.64	Very worth it
language eligibility	89.33	Very worth it
Graphical eligibility	96.08	Very worth it

Based on the feasibility results above, it can be concluded that the STEAM-based teaching materials developed are very feasible so that they can be used as learning resources, according to Akmal & Asikin research (2022) which revealed that proper STEAM-based teaching materials can be used as learning resources for students. In addition, research conducted by Haifaturrahmah et al (2020) also states that product development in the form of proper STEAM-based worksheets can be used as a learning resource to support learning.

3.5 Product Trials (Readability of Teaching Materials) and Product Revisions

The readability test was carried out by giving a gap test to students who had obtained material on direct and inverse proportion, namely class VIII C students of MTs Al-Utsmani. Held on 4 September 2022 to 32 students. The score of the readability test results was obtained at 63.30 so that it can be concluded that the teaching materials are easy to understand. In accordance with research by Dewi & Arini (2018) which states that reading with a good readability test can increase learning interest, memory, and reading efficiency, as well as Pangesti et al. (2017) also stated that STEM-based teaching materials that have an easy-to-understand readability level are due to the use of appropriate language, sentences, grammar, and typography

so that these teaching materials are easily understood by students. At this stage no revisions were made to the teaching materials.

3.6 Test Implementation and Product Revision

This stage was attended by 37 students of class VII D MTs Al-Utsmani. At this stage it begins with the pretest, then continues with the learning process using STEAM-based teaching materials, and the last is the posttest. The pretest and posttest instruments for problem solving ability and SRL have been tested before with very high reliability criteria.

The pretest and posttest data obtained were then tested for normality using the Kolmogorov Smirnov test with the hypothesis used as follows.

H_0 : Pretest and posttest data of problem-solving ability and SRL are normally distributed

H_1 : Pretest and posttest data of problem-solving ability and SRL are not normally distributed

The criterion used for the hypothesis above is accept H_0 if value $Sig. > 0.05$ (Aulia et al., 2019). Based on the normality test, value $sig.$ pretest problem-solving ability is $0.098 > \alpha = 0.05$, $sig.$ posttest problem-solving ability is $0.079 > \alpha = 0.05$, $sig.$ SRL pretest is $0.200 > \alpha = 0.05$ and value $sig.$ posttest SRLs are $0.200 > \alpha = 0.05$. Based on this, it can be concluded that the pretest and posttest data of problem-solving ability and SRL are normally distributed.

Furthermore, the pretest and posttest data of problem-solving abilities and SRL were analyzed for homogeneity using the Lavene test, with the following hypothesis.

H_0 : Pretest and posttest data are homogeneous

H_1 : Pretest and posttest data are not homogeneous

The criterion used is accept H_0 if value $Sig > 0.05$ (Ramadhani & Amudi, 2020). Based on the homogeneity test, the value is obtained $Sig. = 0.073 > \alpha = 0.05$ on problem-solving ability data. This is meaningful H_0 accepted, which means that the pretest and posttest data of homogeneous problem-solving ability. In addition, obtained value $Sig. = 0.502 > \alpha = 0.05$ on SRL data. This is meaningful H_0 accepted, which means that the pretest and posttest SRL data are homogeneous.

The next step is to test its effectiveness. The first effectiveness test is the t test. The t test is used to determine whether the test results of students' problem-solving abilities are more than or equal to the Minimum Completeness Criteria. The results of the t test on the posttest data on problem-solving abilities, namely $t_{count} = 4.659 > 1.688 = t_{table}$, so H_0 rejected, meaning that the average problem-solving ability of students after using teaching materials is more than the Minimum Completeness Criteria.

The second effectiveness test is the z test. The z test is used to determine whether the test results of students' problem-solving abilities reach Minimum Completeness Criteria after using complete teaching materials in a classical manner with a proportion of at least 75% or not. The results of the z test on the posttest data of the ability to solve problems in this study are $z_{count} = 1.993 > 1.645 = z_{table}$, so H_0 rejected. This means that the proportion of students' problem-solving abilities that achieve Minimum Completeness Criteria after using teaching materials is more than 75%.

The third test for effectiveness is the paired sample t-test. The paired sample t-test is used to determine whether there are differences in problem-solving abilities between before and after using teaching materials. The results of the paired sample t-test data for pretest and posttest problem-solving abilities in this study were obtained $Sig(2 - tailed) < \alpha = 0.05$ on pretest and posttest problem-solving abilities. This is meaningful H_0 rejected, which means that there are differences in students' problem-solving abilities between before and after using teaching materials. Furthermore, to find out the magnitude of the increase in the value of the pretest-posttest problem-solving ability is calculated using the N-Gain formula. The N-Gain value is 0.52. This means that there is an increase in pretest-posttest scores with moderate criteria.

The fourth effectiveness test is the t test. The t test is used to find out whether the results of the SRL questionnaire are in the minimum moderate category, namely 56.75, this criterion is based on the SRL criteria from Maryati & Suryaningsih (2021). The results of the t test on the SRL posttest data in this study were obtained $t_{count} = 10.465 > 1.688 = t_{table}$, so H_0 rejected. This means that the average SRL after using teaching materials is more than 56.75 or is in the moderate SRL category.

The fifth effectiveness test is the z test. The z test was used to find out whether the results of the SRL questionnaire reached the minimum moderate SRL criteria after using complete classical teaching materials with a proportion of at least 75% or not. The results of the z test on the SRL posttest data in this study were obtained $z_{count} = 2.753 > 1.645 = z_{table}$, so H_0 rejected. This means that the proportion of SRL that achieve the moderate minimum criteria after using teaching materials is more than 75%.

The sixth effectiveness test is the paired sample t-test. The paired sample t-test is used to determine whether there is a difference in SRL between before and after using teaching materials. The results of the paired sample t-test data pretest and posttest SRL in this study were obtained values $Sig(2 - tailed) < \alpha$

= 0.05 on the SRL pretest and posttest. This is meaningful H_0 rejected, which means there are differences in SRL between before and after using teaching materials. Furthermore, to determine the magnitude of the increase in SRL before and after using teaching materials is calculated using the N-Gain formula, an N-Gain value of 0.31 is obtained. This means that there is an increase in pretest-posttest scores with moderate criteria.

Based on the description above, it appears that all indicators of effectiveness are met. Therefore, it can be said that the developed STEAM-based teaching materials effectively improve students' problem-solving abilities, according to research conducted by Kharisma & Asman (2018) which states that teaching materials can improve problem-solving abilities. In addition, research conducted by Najamuddin et al. (2022) also stated that STEAM teaching materials were effective in increasing students' problem-solving abilities. This is due to the integration of STEAM elements in the problems presented in teaching materials that are in accordance with what students encounter in their daily lives, will give students the opportunity to solve these problems by utilizing the knowledge they have before, so that students' problem-solving abilities will increase. In addition, the developed STEAM-based teaching materials are also effective in increasing SRL, according to what was stated by Agnezi et al. (2019) that the application of STEM in textbooks can improve critical, creative, and independent thinking skills, as well as research conducted by Nurmala & Izzatin (2018) which states that textbooks can foster SRL. This is due to the integration of STEAM in each of the problems presented will make students more motivated in learning because learning is not just memorizing concepts, STEAM integration can encourage student curiosity because it relates to their real world, this is what can grow SRL (Amalia et al., 2022).

3.7 The final product

The final product in this study is STEAM-based teaching materials on direct and inverse proportion that is feasible, easy to understand, and effective in improving problem-solving skills and SRL.

4. Conclusion

Based on the research and development that has been carried out, it can be concluded that the STEAM-based teaching materials on direct and inverse proportion have met the following requirements. 1) The feasibility level of STEAM-based teaching materials (Science, Technology, Engineering, Art, and Mathematics) in class VII students of SMP/MTs with direct and inverse proportion worth and turning around a value of 92.82% with very decent criteria. Furthermore, the feasibility is divided into four parts, namely, content feasibility score of 92.22%, presentation feasibility of 93.64%, linguistic feasibility of 89.33%, and graphic feasibility of 96.08%; 2) Readability level of STEAM-based teaching materials (Science, Technology, Engineering, Art, and Mathematics) for class VII students of SMP /MTs with direct and inverse proportion worth and turning value of 63.30% with easy-to-understand criteria; 3) Teaching materials based on STEAM (Science, Technology, Engineering, Art, and Mathematics) with material direct and inverse proportion effectively improve mathematical problem-solving abilities and SRL as shown by: a) the average mathematical problem-solving ability of students after using teaching materials is more than or equal to the Minimum Completeness Criteria, b) the mathematical problem-solving ability of students who achieve Minimum Completeness Criteria after using complete teaching materials in a classical manner with a proportion of at least 75%, c) improvement of students' mathematical problem-solving abilities after using teaching materials is in the moderate minimal category, d) average SRL after using teaching materials are in the minimal moderate SRL category. e) SRL that is in the minimal moderate SRL category while after using teaching materials complete in a classical manner with a proportion of at least 75%, f) Improvement of SRL after using teaching materials is in the moderate minimal category.

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