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DEVELOPMENT OF STEM-BASED MODULES IN MATHEMATICS LESSONS FOR JUNIOR HIGH SCHOOL

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Abstract:
This study aims to determine the characteristics and quality of STEM-based modules in mathematics at junior high schools in terms of their level of validity, practicality, and effectiveness. The Borg and Gall model was modified by Sugiyono. The steps taken in the research consist of (1) Potential and problems, (2) Data collection, (3) Product design, (4) Design validation, (5) Product Design revision, (6) Product testing, and (7) Product revision. The research instruments were validation sheets, observing the teacher's ability to manage learning, student activities, teacher and student response questionnaires, and learning achievement tests. Validity obtained 3.81 (valid). Practicality with the teacher's ability to manage learning is 3.82 (very good) and the teacher's response is very positive with an average percentage of 91.6% of the two analysis results, so the module meets the practical criteria. While the criteria for effectiveness were obtained from the results of the analysis of observations of student activity, namely 89% in the very good category, the response of students to the module gave a very positive response with a percentage of 85%, and the learning achievement test showed a percentage of 88% so that the criteria for effectiveness were met.

Keywords: Module Development, STEM, Mathematics

PENGEMBANGAN MODUL BERBASIS STEM DALAM PELAJARAN MATEMATIKA UNTUK SEKOLAH MENENGAH PERTAMA

Abstrak:
Penelitian ini bertujuan untuk mengetahui karakteristik dan kualitas modul berbasis STEM dalam matematika di SMP ditinjau dari tingkat validitas, kepraktisan, dan efektivitasnya. Model Borg and Gall dimodifikasi oleh Sugiyono. Langkah-langkah yang dilakukan dalam penelitian terdiri dari (1) Potensi dan permasalahan, (2) Pengumpulan data, (3) Desain produk, (4) Validasi desain, (5) Revisi Desain Produk, (6) Pengujian produk, dan (7) Revisi produk. Instrumen penelitian adalah lembar validasi, mengamati kemampuan guru dalam mengelola pembelajaran, aktivitas

siswa, angket respon guru dan siswa serta tes prestasi belajar. Validitas diperoleh 3,81 (valid). Kepraktisan dengan kemampuan guru dalam mengelola pembelajaran adalah 3,82 (sangat baik) dan respon guru sangat positif dengan persentase rata-rata 91,6% dari kedua hasil analisis, sehingga modul memenuhi kriteria praktik. Sedangkan kriteria efektivitas diperoleh dari hasil analisis hasil observasi aktivitas siswa yaitu 89% dalam kategori sangat baik, respon siswa terhadap modul memberikan respon sangat positif dengan persentase 85%, dan tes prestasi belajar menunjukkan persentase 88% sehingga kriteria efektivitas terpenuhi.

Kata Kunci: Pengembangan Modul, STEM, Matematika

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INTRODUCTION

In essence, the development of science and technology has become an urgent necessity for the public, especially in the field of education. It is undeniable that education will always be a platform for the improvement of human resources (HR). This serves as a benchmark for countries to be more competitive in producing quality HR. Therefore, education, as the most important aspect in the development of a country, must be able to create efforts for innovation and utilization of technology in carrying out effective learning. Ultimately, everyone is required to keep up with the up-to-date IT trend. As we enter the 21st century, education is expected to produce HR who have strong communication and collaboration skills, expertise in using technology, creative and innovative thinking skills, as well as problem-solving abilities (Larson & Miller, 2011). To produce human resources who have these abilities, STEM can be applied in the learning process. STEM encourages and supports students in critical thinking (Siregar, Rachmadtullah, Pohan, Rasmitadila, & Zulela, 2018), solving problems, being creative (Seage & Turegun, 2020), being an innovator (Widya, Rifandi, & Rahmi, 2019), and also being a way to face the challenges of the 21st century (Husin, 2016).

The government, as a policymaker, must continue to develop strategies to improve the quality of education in Indonesia. Considering the heightened competition in the 21st century, basic skills such as reading, writing, and arithmetic are no longer sufficient for individuals to compete in a world full of challenges. Education must be able to prepare learners to compete in the

global community (Nahdi, 2019). Education in the 21st century is becoming increasingly important to ensure that learners have the skills to learn and innovate, use technology and media, work, and survive by utilizing life skills.

One of the efforts made by the government to advance education is by implementing an independent curriculum, which also demands competent resources in the fields of science (Kementerian Pendidikan, Kebudayaan, Riset dan Teknologi, 2022), technology (Haryanto, Dwiyogo, & Sulistyorini, 2015), engineering design, and mathematics so that education can incorporate these four disciplines. Through the 2013 Curriculum, multidisciplinary, active, and critical learning, interactive learning transformation, and collaborative or teamwork are expected to be created.

Mathematics plays a very important role in the development of science and technology as it serves as the fundamental basis for both the application of other disciplines and the development of mathematics itself (Siagian, 2016). However, in reality, students' perception of mathematics does not align with its role, as they consider it to be a daunting subject. Generally, when students are faced with difficult lessons, it tends to reduce their interest and motivation to learn, which ultimately has a significant impact on their math achievement (Suherman, 2015). This fact is reinforced by the release of the PISA 2018 results on December 3, 2019, which was announced by the Ministry of Education and Culture of the Republic of Indonesia, showing a decline in mathematics compared to 2015, even though only 70 countries were participating in the test. Indonesia ranked 73rd out of 79 countries with an average score of 397 (Tohir, 2019).

Considering the importance of mathematics in education, it is hoped that teachers will play a role in creating a fun learning environment. This can be done by choosing a teaching approach that is suitable for the independent curriculum and current developments. The role of teachers in this regard is crucial to implementing creative and innovative teaching approaches so that students enjoy learning mathematics (Witanta, Baiduri, & Inganah, 2019). The accuracy and suitability of choosing and presenting learning materials are essential to achieving the intended learning objectives. Therefore, STEM (Science, Technology, Engineering, and Mathematics) is an approach that can address these challenges.

Becker and Park (2011) study showed a positive effect on the learning process using the STEM approach. Furthermore, Septiani and Yuliarto (2016) stated that the STEM approach could train learners' cognitive, skills, and

affective aspects, and learners are not only taught theoretically but also in practice, allowing them to directly participate in the learning process (Utami, Jatmiko, & Suherman, 2018). That is why STEM is considered an appropriate approach for the independent Curriculum.

The success of a learning process depends not only on the teaching method and approach but also heavily relies on the instructional materials used. In the implementation of the independent curriculum, textbooks as the main instructional materials and learning resources are deemed the most important factor in determining the success of the learning process (Maulida, 2022). However, the results of a study conducted by Tjiptiany, As'ari, and Muksar (2016) concluded that implementing learning using textbooks to students has not shown optimal results. Therefore, in the education realm, a teacher is always demanded by the development to continuously enhance creativity in the learning process. One of them is by using appropriate methods such as STEM so that learning objectives can be achieved. By using STEM, teaching materials are packaged in different forms and features to optimize students' abilities. One of the objectives of this study was to determine the characteristics of the STEM-based mathematics module in circle material based on the basic competencies contained in the independent curriculum.

METHODS

The research method used is research and development (R&D). According to Sugiyono (2014), research and development is a method used to produce specific products and test their effectiveness. The study aims to develop and produce a STEM-based module for mathematics lessons in junior high school. The model applied in this research and development is based on the Borg and Gall method modified by Sugiyono. The researcher chose this model for several reasons, including 1) it has a systematic procedure or stages that can be carried out well and produce a viable product, 2) there is a stage for conducting a preliminary study so that the researcher can identify the actual problems that occur, 3) the developed product undergoes a testing process to determine whether it meets the criteria for validity, practicality, and effectiveness, and 4) the revision process will improve the developed product.

The research and development steps are carried out based on the Borg and Gall model, which is limited to the following steps: 1) Potential and problems, 2) Data collection, 3) Product design, 4) Design validation, 5) Design revision, 6)

Product testing, and 7) Product revision. The development of STEM-based modules for mathematics lessons in junior high school is carried out by limiting the steps to seven out of the ten stages mentioned above because of time limitations in the research process. The development of the product using the Borg and Gall model is only carried out until the stage of producing the final product, which is the STEM-based mathematics lesson module. In developing the product, it is not necessary to follow all the steps in the research model, and developers may choose the appropriate steps based on the situation and conditions encountered during the product development process (Haryanto, Dwiyogo, & Sulistyorini, 2015).

The instruments used in this research are validation sheets for experts, questionnaires for teachers' and students' responses, observation sheets for learning management, observation sheets for student activities, and a learning achievement test. The research was conducted at SMPN 39 Bulukumba with a sample of 25 eighth-grade students in the academic year 2021/2022. The trial was conducted to measure the validity, practicality, and effectiveness of the STEM-based module in mathematics for junior high school. The validity test was conducted by a team of validators consisting of two mathematics lecturers and one mathematics teacher.

Table 1. Module Validity Criteria

Score Intervals	**Criteria**
$3.5 \leq M \leq 4$	Very Valid
$2.5 \leq M < 3.5$	Valid
$1.5 \leq M < 2.5$	Valid Enough
$M < 1.5$	Invalid

Source: Arsyad (2016)

The practicality was measured using questionnaires for teachers and observation sheets for learning management using the STEM-based module developed. The effectiveness was measured based on the assessment of learning achievement tests, students' responses, and observation sheets of student activities.

RESEARCH RESULTS AND DISCUSSION

The development of a STEM-based module for mathematics lessons in junior high school in this study used the Borg and Gall model. One of the aims of this research was to produce a valid, practical, and effective module for grade VIII students of SMPN 39 Bulukumba. The researchers utilized seven steps in the modified Borg and Gall model developed by Sugiyono, namely: 1) Potential and problems, 2) Data collection, 3) Product design, 4) Design validation, 5) Design revision, 6) Product testing, and 7) Product revision.

1. Potential and Issues

This research is based on the potential of students as creative and capable generations. However, the reality in the field shows that students' mastery of the subject matter is still very low, as seen from the observation of learning achievement which is still below average. This is reflected in the results of the student's achievement where only 12 students reached the minimum passing grade (KKM), while 13 of them did not meet the criteria. Considering this situation, further research is needed to enhance the potential of each student so that they can compete globally and possess 21st-century skills.

The identification of potential problems was obtained from interviews conducted at SMP Negeri 39 Bulukumba, the location of the research. From the interviews, it was found that teachers have never developed teaching materials, especially STEM-based module development. The observation results show that in the learning process, students learn without utilizing technology that can help the learning process, and the modules used have not guided students to build knowledge. Therefore, there is no initiative from students to build their knowledge independently in terms of self-directed learning.

2. Data Collection

After going through the potential and issues stage, the next step is to collect information from relevant data sources to support the development of module preparation. Data collection is carried out by reviewing circle material from various sources and references, reviewing the applicable curriculum, and preparing it based on indicators of basic competencies. The analysis of the material in the module is carried out by collecting various sources and references as well as pictures related to circle and STEM material. The

curriculum used is the 2013 curriculum. The researcher prepares the module based on KD 3.7 with its indicator formulation.

3. Product Design

In this product design stage, the selection and determination of teaching materials are carried out to meet the criteria of being attractive and can facilitate students in achieving learning objectives in the form of STEM-based modules for mathematics lessons in junior high school. Before this, an assessment was carried out on the material contained in the mathematics curriculum applicable to the junior high school level, based on the basic competencies that will be formulated in the learning objectives to be achieved. Thus, the collection of data sources, pictures, and analysis of problems related to circles and STEM-based learning. The design of the STEM-based module for mathematics lessons is as follows:

Figure 1. Design of STEM-Based Module for Mathematics Lessons in Junior High School

4. Validation of Design

The validation process was conducted on the instructional materials and instruments that have been developed based on the considerations of experts/validators to determine the suitability of the STEM-based mathematics module. Based on the results of validation at this stage, the validation team has assessed the developed module and research instruments. The assessment results from each validator were averaged for each aspect, and then the overall average was calculated. In general, the validation results from the validators for the module and other research instruments are as follows:

Table 2. Recapitulation of Validation Results by the Validator Team

No.	Validated Items	Average Score	Criteria
1.	Module	3.5	Very Valid
2.	Teachers Response Questionnaire	4	Very Valid
3.	Students Response Questionnaire	3.7	Very Valid
4.	Lesson Management Observation Sheet	3.85	Very Valid
5.	Students Activities Observation Sheets	3.85	Very Valid
6.	Lesson Plans (RPP)	3.84	Very Valid
7.	Learning Outcome Test	395	Very Valid
	Average	3.812	Very Valid

Based on the table above, it can be seen that the average score from the validators is within the range of $3.5 \leq M \leq 4$, indicating that the assessment criteria falls under the category of "very valid".

5. Product Trial

The product trial stage is carried out to assess the practicality and effectiveness of the developed STEM-based module for mathematics lessons in junior high school. This stage is conducted after revising the STEM-based module for mathematics lessons in junior high school based on suggestions and input from experts. Some of the things observed during the product trial stage include the management of learning using the STEM-based module for mathematics lessons and the activities of students during the learning process using the STEM-based module for mathematics lessons.

After all the learning processes have been completed, students and teachers are given a questionnaire to determine their responses to the learning process using the STEM-based module for mathematics lessons.

The trial activity is carried out for four meetings, including the implementation of learning outcome tests and the completion of questionnaires by students and teachers regarding the STEM-based module. The trial was conducted from April 11 to April 23, 2022.

The data obtained from the module testing were analyzed and used as considerations for the module revision phase to become the final product of the development process. Here are the results of the STEM-based module testing:

a. Practicality Data Analysis

Practicality data were obtained from all activities related to teachers, including observations of learning management using the module and analysis of teacher responses to STEM-based modules through questionnaires.

b. Effectiveness Data Analysis

Effectiveness data were obtained from all student activities, including observations of student activities during the learning process using the module, student responses through questionnaires, and learning test results to measure one of the criteria for the feasibility of a developed product.

The observed student activities consisted of five activities. The average percentage of overall student activities obtained from the observation analysis was 89%, which is considered very good because it falls within the range of $80 \leq P \leq 100$. This analysis result indicates that student activities during the learning process using the module can be considered effective.

The STEM-based mathematics module response instrument was given to 28 students of class VIII.C after completing the learning process using the STEM-based mathematics module. The average percentage of student responses obtained was 85%, which is considered very positive because it falls within the range of $85\% \leq RS \leq 100\%$. This analysis result indicates that the STEM-based module for mathematics meets the effectiveness criteria.

The learning test instrument was given to 28 students who participated in the study after completing the entire learning process using the module. After the test, the results were checked based on the previously made assessment rubric. The percentage of mastery level from the learning test results is as follows:

Table 3. Percentage of Learning Achievement Test Mastery

Score	Category	F	Percentage
> 75	Mastery	22	88%
< 75	Not Mastery	3	12%

Based on table 3, it can be seen that out of 25 students who took the test, 22 of them passed with an average percentage of 88%, while 3 students were categorized as not passing with an average percentage of 12%. The analysis results indicate that the developed mathematics module is effective in the learning process.

6. Characteristics of STEM-Based Module in Mathematics Lessons at Junior High School

STEM-based teaching materials have great potential to be developed in mathematics learning. This is similar to the study conducted by Oktavia (2019) which is suitable for supporting the success of learning. One of the objectives of this study is to determine the characteristics of STEM-based mathematics modules on circle material based on the basic competencies contained in the 2013 curriculum. This module is designed based on STEM characteristics with the integration of natural science, technology, engineering, and mathematics. The integration of STEM in learning has been proven to improve the quality of learning, thus STEM-based education has been developing rapidly in recent years.

The developed module has characteristics that are typical of STEM-based modules in mathematics lessons, making it attractive to use in the learning process. Among them, the material contained in the module is circle material that has been arranged according to the latest curriculum applicable to the junior high school level. There are project tasks integrated with the four STEM contexts so that students are actively involved in the learning process, which shows their creativity, critical thinking, communication, and collaboration abilities. This was shown in previous studies, STEM-based learning can improve mathematical critical thinking skills (Sayekti & Suparman, 2020), creativity, communication (Lavi, Tal, & Dori, 2021), and collaboration skills (Triana, Anggraito, Ustinus, & Ridlo, 2020).

The Science component is applied in the form of project tasks by integrating the four STEM contexts into it. Science examines mathematical material related to natural phenomena or things that we encounter in the environment or nature. This is in line with the opinion of Puspitasari,

Sulandra, and Susiswo (2021) that teachers should strive to provide examples of mathematical problems related to daily life. Based on the phenomena in the surrounding environment, students solve problems by integrating techniques and mathematics. As Purwaningsih, Sari, Sari, and Suryadi (2020) have shown, problem-solving abilities increase after the use of STEM-based teaching materials.

The Technology component refers to the use of technology in the mathematics learning process. In the module, the technology component is presented in the form of QR codes or website links containing materials that students can access online using a laptop or smartphone. The integration of technology is aimed at ensuring that students are not technologically challenged and can adapt to the dominant development of technology. In addition, the evaluation questions in this module can be accessed using QR codes and website links, so that the scores obtained by students are directly sent to the teacher's email.

The Engineering component is presented in the form of a mini-mathematics lab designed to facilitate students in understanding the concepts of circle material so that students can learn how a concept is obtained. In addition to training students to construct knowledge from their experiences, they are also trained to collaborate with other students in the form of teamwork or small groups. This module is also equipped with "let's discuss" and "let's share" activities, which require students to actively participate in the learning process. These activities are conducted to discuss the findings of the concepts obtained in the mini-mathematics lab.

Furthermore, the advantages of STEM-based mathematics modules developed for mathematics lessons include guiding students to learn independently with or without a teacher, providing a mini-mathematics lab and project tasks that can help students understand the concepts in the circle material, and having many illustrations that facilitate students in understanding the material related to daily life.

7. Quality of STEM-Based Modules in Mathematics Lessons at Junior High School Reviewed from the Validity, Practicality, and Effectiveness Levels

a. Validity of STEM-Based Modules in Mathematics Lessons at Junior High School

STEM-based modules are designed to make students problem solvers, find solutions to problems, have innovation in creating something,

independently think logically, be proficient in technology, and be able to apply their knowledge in real life.

The results of research and development of STEM-based mathematics modules on circle material can be stated as valid in all aspects, but there are still suggestions for improvement, such as inconsistent use of the Indonesian language and less attractive display of some features. After revisions, the module met the criteria for implementation in trial activities. The development results indicate that the module is valid and by the characteristics of STEM-based modules. The same was found in the development of a based-teaching material conducted by Utami, Jatmiko, and Suherman (2018). The developed teaching material was a mathematics module on quadrilateral material. The validity test results of the teaching material showed a very valid score obtained from assessments by experts. These results are like the study conducted by Aminingsih and Izzati (2020), who tested the feasibility of STEM-based modules on set material for seventh-grade students and found that the validity criteria were also met.

b. Practicality of STEM-Based Modules in Mathematics Lessons at Junior High Schools

Teaching material is said to have met practicality criteria if: 1) it is practically stated that the product can be applied in the field theoretically, and 2) the level of product implementation is categorized as "good" (Rochmad, 2012). The practicality criteria of a module are measured based on the results of assessments of the response from teachers and the ability to manage learning using the module.

Based on the analysis of teacher responses to the STEM-based mathematics module developed, overall, a very positive response was obtained. Then, the results obtained from the observation analysis of the teacher's ability to manage learning using the module were in the very high category. From these results, it can be said that the STEM-based module in mathematics lessons in junior high school has met the practicality criteria. These results are consistent with the instructional material development carried out by Desy (Rahmawati, 2015). The developed instructional material is a module for basic chemistry learning, based on feasibility tests showing very practical values. Similar results were also shown by research conducted by Nessa, Hartono, and Hiltrimartin (2017), who developed a STEM-based textbook on three-dimensional space distance materials, which showed practical values and was proven to improve learning outcomes.

c. Effectiveness of STEM-Based Module in Mathematics Lessons in Junior High School

Effectiveness criteria were measured from the results of observations of student activities, analysis of student responses to STEM-based modules in the learning process, and test results. These three activities have been carried out and meet the effectiveness criteria, namely, for observing student activity during the learning process using the module, the percentage of the average of all meetings observed is categorized as very good. The results of the analysis of student responses to STEM-based modules are also in the very positive category. As for the analysis of learning test results, the percentage of completeness of students in the circle material using modules through learning tests is 88% of the total students, with an average test score of 81 categorized as high. Therefore, it can be seen that 22 students completed and mastered the material and 3 students did not.

These results are in line with the opinion of Akker, Van-Den, Bannan, Kelly, Nieveen, and Plomp (2010), that module development can be considered effective if the percentage of active student activity is greater than that of students who are quite active and less active, learning completeness reaches greater or equal to 70%, and student responses to the module are categorized as positive.

The integration of science, technology, engineering, and mathematics (STEM) in learning has been proven to improve student learning outcomes, leading to the rapid development of STEM-based education (Nurhidayat & Asikin, 2021). This was evident during the trial use of STEM-based modules in which students became more active in following the learning process and engaging in project activities presented in the module, resulting in a shift away from teacher-centered learning. The learning test results showed that the learning outcomes reached 88%, compared to less than 50% before the implementation of the module. Based on these results, the development of STEM-based modules was deemed effective for use in the learning process. In addition, Silvia and Simatupang (2020) and Sari, Sumantri, and Bachtiar (2018) have proven that STEM-based teaching materials are effective in improving students' science literacy skills.

Based on the results of the validity, practicality, and effectiveness tests conducted on the developed STEM-based mathematics module, it can be stated that the module is of high quality and meets the predetermined criteria for validity, practicality, and effectiveness analyzed through the development

and trial processes. Therefore, the STEM-based module for mathematics in junior high school, specifically for circle lessons, can be considered a high-quality teaching tool for use in the learning process.

CONCLUSION

Based on the research and discussion, it can be concluded that 1) the module integrated with the four STEM components has characteristics that are suitable for STEM learning. The module is equipped with a mini-math lab and project tasks that are integrated with STEM. The characteristics that make this module unique are attractive to use in the learning process to create an active learning atmosphere. 2) Based on the results of the STEM-based module development, it was found that the module met the criteria of validity, practicality, and effectiveness.

Based on the research and development of STEM-based modules in mathematics lessons in junior high school on the topic of circles applied in the trial activity, the author has several suggestions, namely: The module only contains circle material, so a STEM-based module on other topics needs to be developed to meet the needs of students and the conditions of each school. The project activities in the module should always be updated to follow the development of the times so that students can learn more about the benefits of mathematics in real life.

The limitation of this research and development is that STEM-based modules only cover circle material, so it needs further development for other mathematics materials.

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