

The Development of STEM-Based Teaching Materials to Improve Science Literacy for Grade III Elementary School Students

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ABSTRACT

21st-century learning requires teachers to deliver students to 4C skills in facing the Industrial Revolution 4.0. This study aims to develop valid, practical, and effective STEM teaching materials for Grade III Elementary schools. It is development research with the ADDIE model and a total of 58 third-grade elementary school students as the research subject from three elementary schools in West Pasaman Regency. The research data is from developing STEM teaching materials for grade III Elementary school. The results of the data analysis of the validation of teaching materials by experts and education practitioners obtained an average of 92.7 very valid categories. The results of the practicality test using teacher and student questionnaires obtained an average of 92.85 and 92.93 with very practical categories. The effectiveness of these teaching materials is also shown by the increase in the average scientific literacy of students after using STEM teaching materials is 87, with a very effective category. Based on the results above, it can be concluded that the STEM material for grade III elementary school is declared to be very valid, very practical, and effectively used to improve students' scientific literacy in grade III of elementary school.

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1. INTRODUCTION

The 21st century is marked by rapid advances in information technology and the automation of many routine and repetitive jobs. The development of the 21st century is accompanied by the development of science and technology in daily life (Eliyasni et al., 2019). The development of technology and communication aims to achieve 21st-century skills. 21st-century skills are a series of skills that require students to master various skills, such as skills to develop life and careers, skills in learning to innovate and skills in technology and different information (Mahanal 2017). One of the 21st-century skills that students must master is scientific literacy skills (Pratiwi, 2019). Scientific literacy is an ability that can make students understand science, carry out the communication process and can implement science in solving problems based on scientific thoughts. Scientific literacy can

also be defined as a skill used to tackle everyday life's problems (Feinstein, 2011). Therefore, science skills need to be taught in elementary school age.

Science literacy skills are abilities developed through the 2013 Curriculum learning process (Inzanah et al., 2017). One of the objectives of developing the 2013 Curriculum is to improve students' literacy skills so that scientific literacy skills are included in the objectives of developing the 2013 Curriculum. Scientific literacy is the ability to utilise scientific knowledge, examine various questions, and draw conclusions through empirical evidence to understand and make decisions about nature and the changes that occur through human activities (Chiang and Tzou, 2018). Scientific literacy focuses more on the use of scientific knowledge in the processes of everyday life (Cervetti et al., 2012). There are three aspects of scientific literacy competence: explaining and understanding various forms of data and facts scientifically; explaining and understanding natural phenomena scientifically; and designing and analysing scientific discoveries (OECD, 2013). These three competencies are essential to be mastered by students, especially students at the elementary school level. It aims to make science and technology mastered by students more meaningful.

Increasing the interest and activity of students under the characteristics of elementary school students can be done using the STEM approach (Khalil and Osman, 2017). STEM is an approach whose learning pattern aligns with the 2013 Curriculum, which uses an integrative thematic approach. STEM is an educational approach that integrates science, technology, engineering and mathematics into an integrative thematic learning model (Dewi, Sumarmi, and Putra 2021). This approach is considered to the needs of the times because it allows students to develop optimally without separating their knowledge (Calabrese Barton and Tan 2018). The application of the STEM approach indirectly requires students and teachers to think creatively to develop learning that can activate students and develop engaging learning (Capraro and Slough, 2013). Teaching material is needed to support STEM-based learning and adjust the learning according to students' characteristics, which helps teachers and students learn more directed and organised.

Teaching materials are a set of materials that are deliberately arranged systematically to facilitate students' understanding of learning materials (Cahyadi 2019). Teaching materials are a set of learning tools arranged to facilitate teachers' learning process and make it easier for students to understand learning materials to achieve the planned learning objectives (Nurdyansyah, 2015). The use of teaching materials is a must in the learning process in elementary schools (Magdalena et al. 2020). Teaching materials for students in elementary schools aim to make it easier for students to understand abstract material. Previous research also stated that teaching materials could improve the quality of learning, such as learning outcomes, thinking skills and learning activities (Hutama 2016). Therefore, it is crucial to prepare teaching materials for the learning process in elementary schools.

Some of the results of previous studies are related to STEM. First is research by Aldila et al., (2017) titled "Development of STEM-Based Teaching Materials to Grow Students' Creative Thinking Skills". The research results produce STEM-based teaching materials that are very useful for students and the general public. These materials can be used for various groups, especially 5th-grade elementary school students. Second, Lestari et al. (2018) Lestari et al. (2018)'s research entitled "Implementation of Student Worksheets With STEM (Science, Technology, Engineering, And Mathematics) Approaches to Improve Students' Critical Thinking Ability" uses the ADDIE development method. The research results in producing STEM-based worksheets that are effectively used in everyday learning in elementary schools. Third, Nisa & Nugroho (2017), entitled "Development of Character-Based STEM teaching materials for Elementary School Students" resulted that STEM teaching materials were developed in terms of character integration aspects, pedagogical aspects, construction aspects according to character experts, the material and curriculum show feasibility with good grades and the teaching materials are ready to be applied in research in the initial trial process. The feasibility of teaching materials used can be seen from the content, language that is easy to understand, and attractive presentation. The developed STEM teaching materials are effective in instilling honest and caring characters. Based on the observation of honest and caring

character in the experimental class and control class, it can be seen that the increase (expected gain value) in the experimental class is more significant than that in the control class.

STEM is still relatively new in education, so its application in learning, especially in elementary schools, still requires careful preparation. The learning process must be designed systematically in the form of STEM integration to achieve the desired goals in the STEM teaching and learning process. STEM-based materials are expected to answer these learning problems because, with STEM-based materials, students undergo the learning process independently, so they tend to be active while learning. STEM-based materials help students because public schools are not equipped with laboratories for experimentation or practice; STEM-based materials are an effective way to motivate students to learn.

2. METHODS

This research was designed using the Research and Development (R&D) method. According to Sugiyono (2015) development research is a method used to produce specific products and test the effectiveness of these products. The design of the learning module development in this study was adapted from the ADDIE development model. Molenda (2015) explains that ADDIE is a model that can be used to design more general learning. ADDIE must be used to develop learning products systematically to create an effective, efficient and enjoyable learning process. According to Pribadi (2011), the ADDIE model consists of five stages: analysis, design, development, implementation, and evaluation.

This development research procedure contains the steps that must be carried out at each stage of its development. The development procedure is under the steps of the ADDIE development used. More details can be seen in the following image:

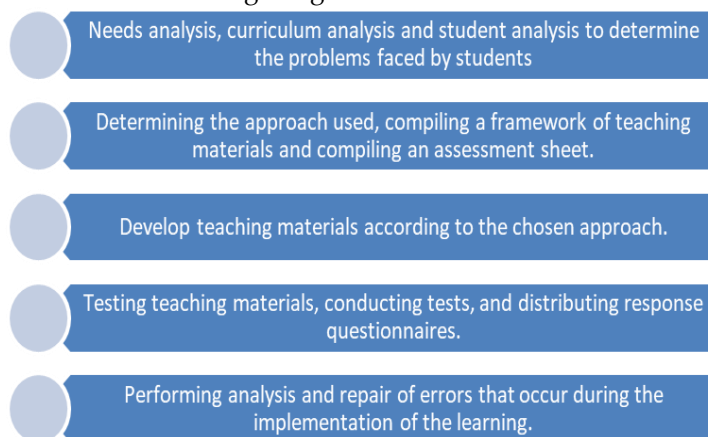


Figure 1. STEM-Based Teaching Material Development Scheme

2.1 Trial Subject

In this study, the trial subjects were several elementary schools in Sungai Aur District, including SDN 16 Sungai Aur, 20 students; SDN 07 Sungai Aur composed of 24 students; and SDN 13 Sungai Aur, consisting of 14 students.

2.2 Data Collection Instruments

Interviews and observations are a preliminary study to find out what appears in the field. Furthermore, interviews will also be conducted in trials with primary school teachers who are the research sites for researchers. In addition, a validation sheet is applied to the data linked to the expert validation results of the product under development. Validation sheets will be given to experts who validate STEM-based educational materials to obtain data, and contributions/suggestions from experts on the results of the validator's assessment will be tested for validity.

Questionnaires or were be designed to obtain data related to the responses of teachers and students regarding the products developed. The questionnaire's results were taken into consideration to improve the product that the researcher developed and to be able to assist in determining what aspects of the product components need to be revised. This questionnaire consists of a needs analysis questionnaire for teachers and students, a practicality questionnaire for teachers and students and a product evaluation questionnaire. The results of the data analysis from the questionnaire will determine the needs analysis during the preliminary study and the practicality and effectiveness of the product being developed.

Learning outcomes determine the percentage of student success after using STEM material in integrated thematic learning.

3. FINDINGS AND DISCUSSION

The development of STEM-based teaching materials is carried out by following the development research steps proposed by Personal.

The product's initial design is to be developed, namely STEM-based teaching materials for third-grade elementary school students. In this stage, three changes occur until the final product is considered to be used for testing the use of teaching materials. The differences between each can be seen in Table 1 below:

Table 1. Product Design

Product 1 (Initial)	Product Revision 1	Product Revision 2
1. Contains 2 subjects, namely Indonesian and mathematics.	1. Contains 3 subjects, including SBdP and Indonesian.	1. Contains 3 subjects and activity content based on the STEM approach.
2. Consists of 3 lessons.	2. Adds up to 9 lessons.	2. Consists of 9 lessons, and each one are enriched with exciting pictures and tasks.
3. More activities in the field of science.	3. Activities begin to be varied and enriched.	3. Text is more varied.
	4. The title of the PB is made according to the experiment to be carried out.	4. The images used are more attractive.
		5. The learning steps are richer in engineering activities.
		6. The title of each PB is adjusted to the theme.

3.1 Validity of STEM-Based Teaching Materials

After obtaining a product model of STEM-based teaching materials designed for third-grade elementary school students, testing the validity of the teaching materials was carried out. In the research step, product validity testing is carried out at the development stage. Product development was carried out from January to March 2022. At this stage, the validity of the developed STEM-based teaching materials is tested.

The validity test aims to determine the level or validity of the teaching materials developed. Three aspects are assessed for the validation test: media, material, and language. The following is a description of the validator's validation results.

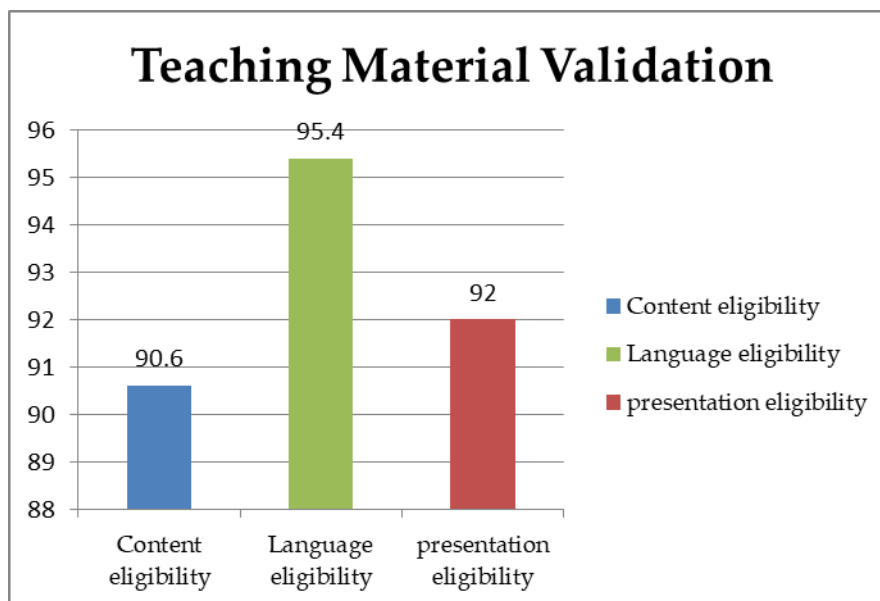


Figure 2. Validation Results of STEM Teaching Materials by Expert Lecturers

3.2 The Practicality of STEM-Based Teaching Materials

The practicality test was given to the third-grade teacher at SDN 16 Sungai Aur, who assessed the practicality of using teaching materials, which were divided into 4 variable criteria detailed into 7 indicators on the questionnaire sheet provided by the previous researcher. The following are the results of the practicality test for teachers.

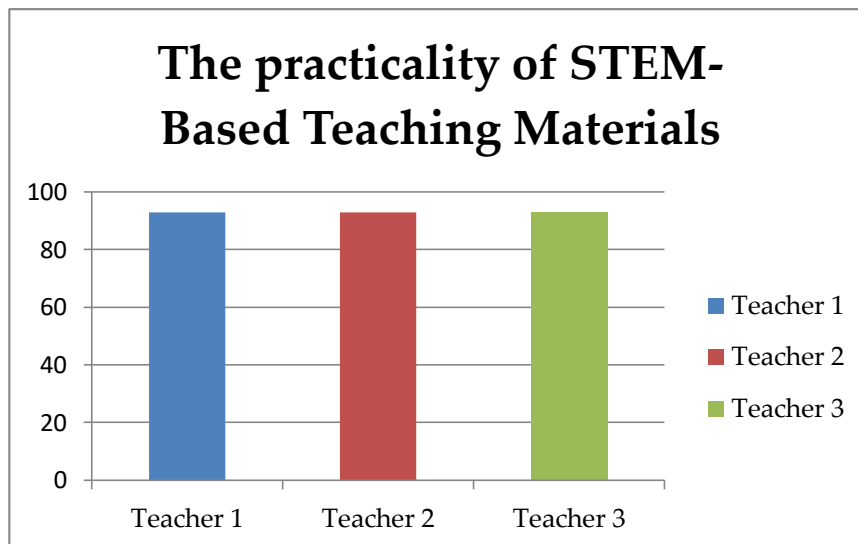


Figure 3. Results of Teacher Responses to the Practicality of STEM Teaching Materials

From the experimental data on teaching materials from the teacher's aspect, it was found that teachers liked using STEM teaching materials because of the practicality of use. In contrast, the contents of STEM teaching materials were not like teaching materials sold on the market. Students do the task according to the steps given in the teaching materials. The teacher also does not work too hard, only supervises as a facilitator, directs and answers students' questions, and provides assistance if students need it. The function of the teacher is no longer as a learning centre but rather to direct and encourage students to learn.

3.3 Student Practical Test

The following is a recap of the results of filling out the student response questionnaires on the practicality of STEM teaching materials for grade III Elementary School.

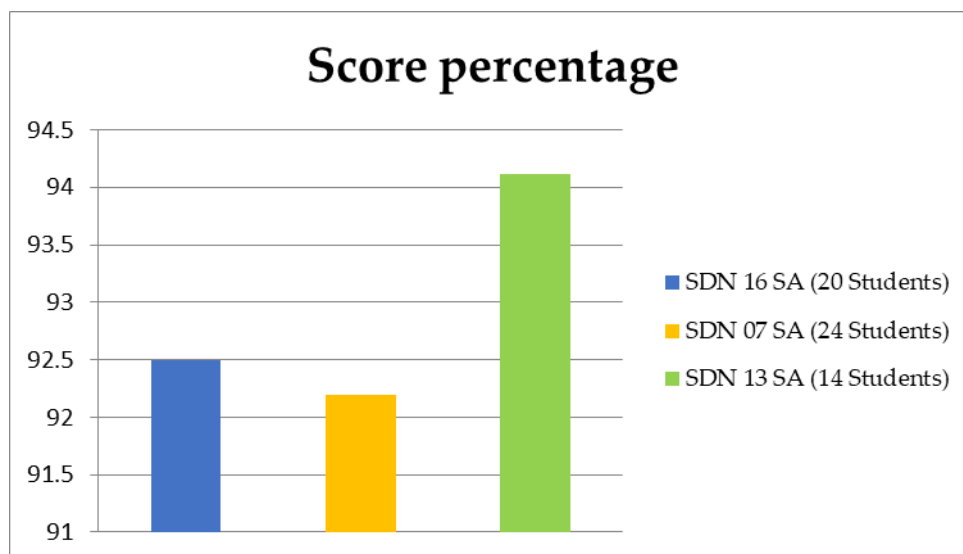


Figure 4. Results of Student Responses to Practicality STEM teaching materials

In general, students felt motivated and helped to understand the material contained in STEM teaching materials. The results of the practicality test of the students' aspects showed a high level of practicality of teaching materials, namely 92.93 and categorized as very practical. Furthermore, students also gain new experiences with teaching materials that are different from those they have used.

3.4 Effectiveness of STEM-Based Teaching Materials

The effectiveness test is conducted to measure the effectiveness of using STEM teaching materials in this study. As for measuring the effectiveness, the effectiveness questionnaire instrument under the learning indicators is carried out according to the teaching materials made. The minimum criteria limit for students to pass in working on this evaluation question is if students get a score of more than 75. Below are the test results of the effectiveness of using STEM teaching materials in the realm of knowledge (cognitive) in three elementary schools.

Table 2. Results of Students' Cognitive Area Assessment

No	School	Subject			Total	Average
		Indonesian	Math	SBDP		
1	SDN 16	86,50	83,00	80,50	250,00	83,33
2	SDN 07	92,50	89,17	86,88	268,54	89,51
3	SDN 13	90,71	86,43	85,00	262,14	87,38
Total		269,71	258,60	252,38	780,68	260,23
Average		89,90	86,20	84,13	260,23	86,74
Percentage (%)		90	86	84		87
Category		Very High – Very Effective				

From the three schools where product trials were held with a total of 58 students, it was found that the student's ability in Indonesian subjects got the highest results, namely 89.90 with a percentage of completeness of 90% and categorized as very high with very effective conversion. Mathematics learning outcomes get an average of 86.20 with a mastery percentage of 86% and are categorized as very high with very effective conversion. The results of learning Arts, Culture and Skills get an average of 84.13 with a mastery percentage of 84%. Overall, the average cognitive aspect learning outcome gets an average of 86.74 with a percentage of completeness of 87% and is categorized as very high with very effective conversion.

The following graph describes the learning outcomes of students' cognitive aspects in general.

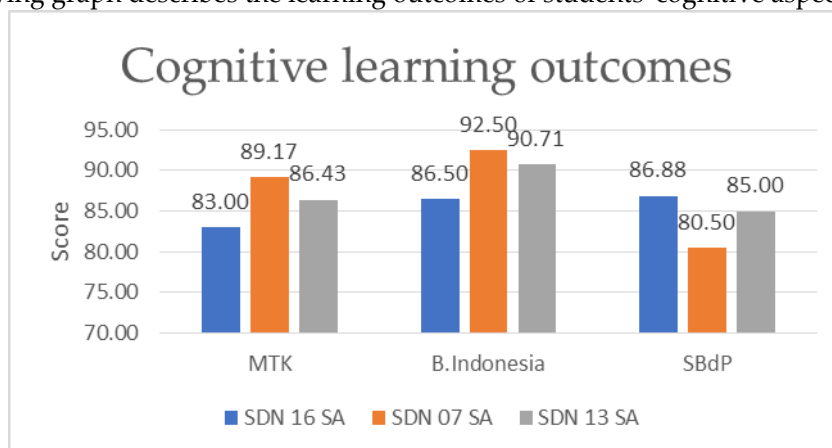


Figure 5. Cognitive Learning Outcomes (Effectiveness Test 1)

The most prominent learning outcomes of students are mathematics, and students from SDN 07 Sungai Aur get the highest average learning outcomes compared to the other two schools. Overall, the cognitive domain evaluation test results in thematic learning using STEM teaching materials are in the category Very Good (A), which indicates that STEM teaching materials are effective enough to be used in learning.

Affective assessment is carried out during learning activities using an observation sheet filled in by the class teacher according to the 2013 Curriculum assessment guide on attitude assessment. The following is a summary of the assessment results of students' affective domain assessment.

Table 3. Results of the Assessment of the Affective Realm of Students

No.	School	Attitude Aspect				Average
		Honest	Discipline	Responsible	Confident	
1	SDN 16	3,30	3,15	3,25	3,45	3,29
2	SDN 07	3,58	3,50	3,63	3,58	3,57
3	SDN 13	3,50	3,21	3,36	3,43	3,38
Total		10,38	9,86	10,23	10,46	10,24
Average		3,46	3,29	3,41	3,49	3,41
Percentage		86,53	82,20	85,27	87,18	85,30
Category		Very High – Very Effective				

The attitude assessment in the 2013 curriculum is different from the previous curriculum. By the latest 2013 Curriculum assessment guidelines, affective assessment no longer records all behaviours requested by the curriculum but instead on behaviours that stand out very well or need guidance. The following is a graph of the results of the assessment of the affective domain of third-grade elementary school students after the effectiveness test of using STEM teaching materials.

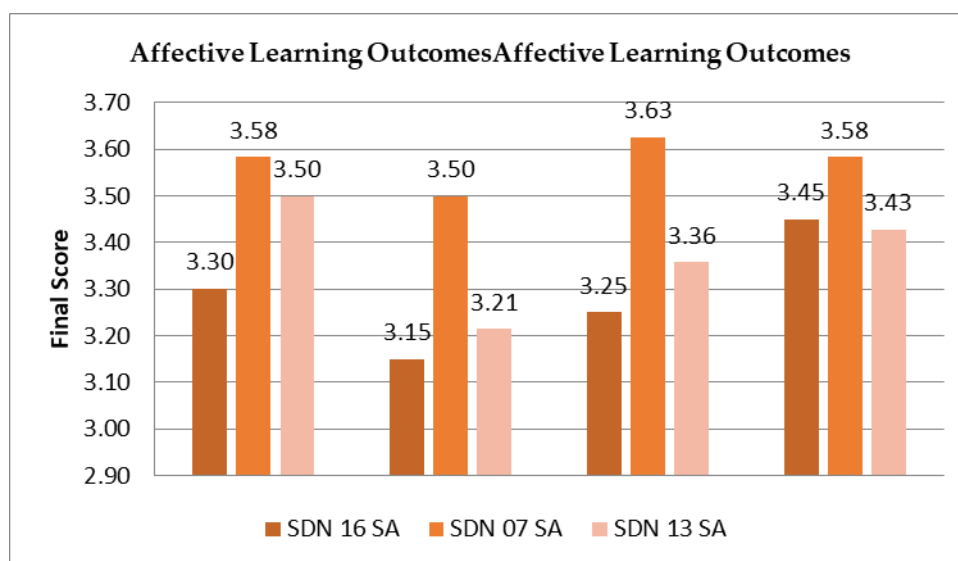


Figure 6. Affective Learning Outcomes (Effectiveness Test 2)

Another advantage that is the accompaniment effect of the trial of STEM teaching materials in schools is the change in students' attitudes towards researchers. Previously, when researchers came to school, few students came to greet researchers, even though the researchers were their teachers at the school. However, after learning using STEM teaching materials has been completed, students, especially class III, always run to meet researchers and shake hands with researchers whenever researchers come to school. It proves that using teaching materials with learning designs and assignments with fun activities can change the respect and character of students at school.

In the psychomotor aspect, the ability of students to explain a scientific phenomenon is still below the other two scientific literacy abilities that are of concern in this study. The ability of students to interpret data and scientific evidence gets the highest results. The following are the results of scientific literacy research that enter this research's psychomotor realm.

Table 4. Results of the Psychomotor Domain Assessment of Learners (Effectiveness Test 3)

No.	School	Aspects of Scientific Literacy			Average
		Explaining a scientific phenomenon	Evaluating and designing scientific investigations	Interpreting scientific data and evidence	
1	SDN 16	3,40	3,45	3,55	3,47
2	SDN 07	3,33	3,33	3,63	3,43
3	SDN 13	3,50	3,79	3,64	3,64
Total		10,23	10,57	10,82	10,54
Average		3,41	3,52	3,61	3,51
Percentage		85,28	88,08	90,15	87,83
Category		Very High – Very Effective			

Based on the table above, it can be seen that the ability to explain a scientific phenomenon gets a percentage of 85.28%, the ability to evaluate and design scientific investigations gets a percentage of 88.08%, and the ability to interpret data and scientific evidence gets a percentage of 90.15 %. It shows that the third aspect of scientific literacy is the highest achievement and also proves that the scientific literacy ability of students is the most significant aspect of the change in this study.

During the discussion, all students actively participate in discussion activities and are willing to contribute to conveying their ideas and opinions. Moderately capable students raise opinions confidently and are not shy. However, several times there are still errors in polite grammar, such as curtly answering their friends' questions and not using greeting words. Students with high abilities are less actively involved in learning because they feel they know what to do, so they work more alone and pay less attention to the teacher in explaining learning. In summary, it can be seen in the following graph.

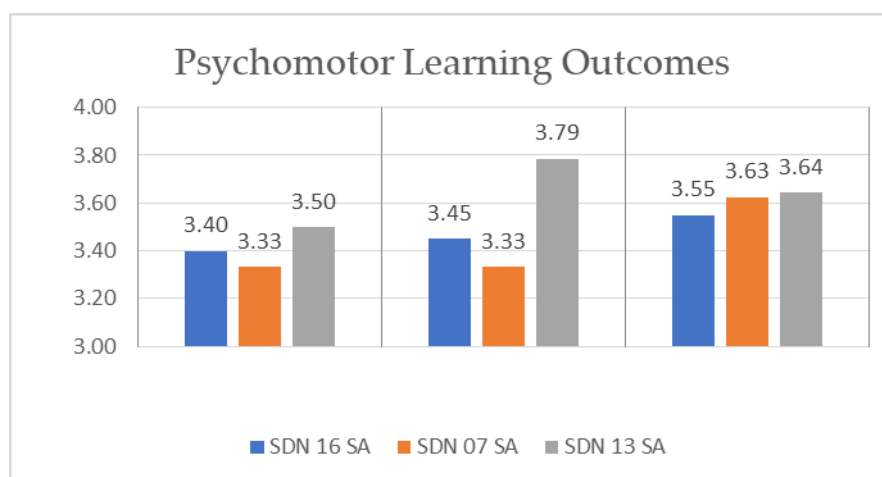


Figure 7. Psychomotor Learning Outcomes (Effectiveness Test 3)

The results of the psychomotor aspect of scientific literacy analysis show that students with low abilities consider the STEM teaching materials to provide clear instructions for doing it. However, some students still show a lazy attitude toward work because they still need an additional explanation from the teacher to work on some parts they did not understand in STEM teaching materials. In addition, STEM teaching materials are also considered complete by students with moderate and low abilities because they need questions in the form of exercises. Students expressed difficulties interpreting scientific data with medium and low abilities because they considered the error to come from themselves due to the lack of language skills in telling their activities at school and the low ability of students to make sentences to tell stories.

The following is a recap of the results of the three assessment areas that have been implemented.

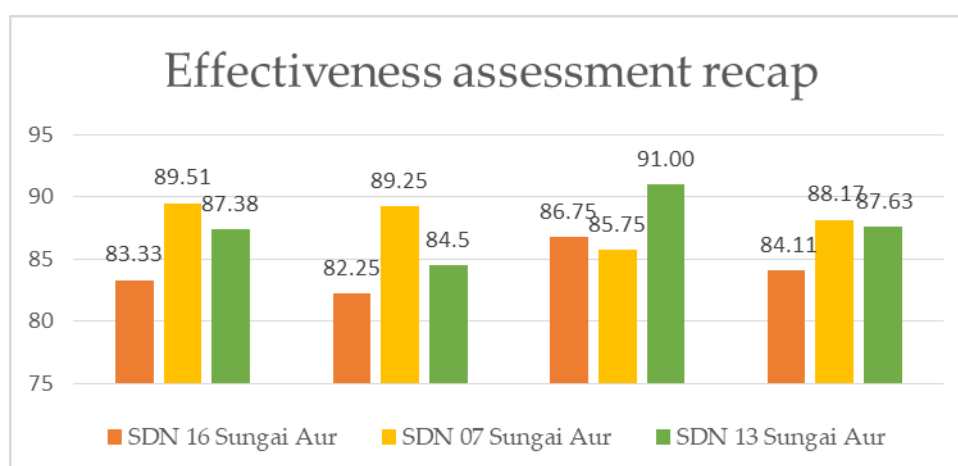


Figure 8. Recap of Student Learning Outcomes (Effectiveness Test)

At this evaluation stage, two evaluations must be carried out. First, formative evaluation is carried out during the final revision of the developed product, based on input, suggestions, and criticism from the instrument in the form of a questionnaire received from validator experts, teachers and students and researcher notes during the product implementation stage. This stage is carried out so that the developed products can be used effectively for school learning. This activity was carried out before the product was tested. The second stage is a summative evaluation at the end of the study in the form of the effectiveness and practicality of the product resulting from the product testing activities carried out (Erviana 2019). Summative evaluation of STEM-based teaching materials is focused on the practicality and effectiveness of teachers and students. The evaluation of teaching materials aims to increase students' scientific literacy skills after using the developed STEM-based teaching materials.

As previously explained, after testing the practicality and effectiveness of STEM teaching materials, the results of the practicality test of teaching materials from the teacher aspect are 92.85 with a percentage of 93% and are categorized as very practical. As for the practicality aspect of the students, it was obtained at 92.93 or 93% and categorized as very practical. For the effectiveness test, the final result was 87 and categorized as very effective. Thus it can be concluded that the STEM teaching materials that have been made already meet the requirements to be used as teaching materials in class III Elementary School.

Discussion

Development of STEM-Based Teaching Materials

The STEM-based teaching materials developed in this study using the ADDIE development research stages result from collaborative thinking between researchers and practising teachers at schools. The product developed is in the form of 9 STEM-based learning activities that can be carried out in class III Elementary School based on core competencies and essential competencies in the 2013 Curriculum. Activities complement the development of teaching materials to increase scientific literacy in schools for students.

STEM-based teaching materials developed with the ADDIE development research model include activities based on Science, Technology, Engineering (Engineering), and Mathematics with the application of an integrated thematic approach that is in accordance with the demands of education in the Industrial Revolution 4.0 era and developing students' 4C skills (Communication, Collaboration, Critical Thinking, and Creativity).

The STEM-based teaching materials developed are different regarding the development of work steps. The content of the material developed, as well as experimental activities that require students to explore their surroundings, develop students' basic scientific literacy skills, and improve other skills demanded by character-based education, in the 2013 Curriculum.

The STEM-based teaching materials developed consisted of observing, reading, conducting experiments, designing a working model, drawing, reflecting, and self-reflection. The merging of content in mathematics, Indonesian, and cultural arts is not visible in their activities. Therefore, students do not realize that they are getting four lessons of content at once because the teaching materials are designed so that there are no restrictions on the content of learning materials from one another. Activities in STEM-based teaching materials require students to express their opinions honestly to improve their personal communication skills.

The results of the development of the STEM-based teaching material model for third-grade elementary school students show that the development research model following the ADDIE stage of developing STEM-based teaching materials is proven to improve the scientific literacy of third-grade elementary school students in West Pasaman.

Validity of STEM-Based Teaching Materials

Testing a study requires validity. According to Trianto (2010), validity means that the assessment provides accurate information about the developed media. The STEM teaching materials

were declared valid (Connors-Kellgren et al. 2016). Suppose it meets the specified requirements in terms of content and structure. It is called content validity. In addition, these components must always be related, also called structural validity (Slavit, Nelson, and Lesseig 2016). In this study, validation is further detailed into product validation, namely content, language and presentation.

Based on the validation data analysis of STEM teaching materials by experts and educators, an average result of 92.7 was obtained. From the category that has been developed, it is a very effective category. Thus, it can be concluded that the developed STEM material is under the curriculum requirements. An efficient evaluation of the developed STEM material shows that STEM material can be used as a learning resource to improve students' scientific literacy.

The Practicality of STEM-Based Teaching Materials

STEM learning materials that have been declared valid by the validator are then tested for practicality. It is said that STEM teaching materials are practical, and teachers and students can use the materials to learn without problems (Aldila et al. 2017); (Anggraini, Anwar, and Madang 1999). The practicality test is carried out through practicality questionnaires by students and teachers. Based on the analysis of the results of the practicality test using a teacher's questionnaire, an average of 92.85 was obtained in the efficient category. Based on the results of the questionnaire filled out by students, it was also obtained an average of 92.93. The developed STEM teaching materials are equipped with learning process activities, displaying STEM learning materials that are attractive to students. In addition, students also said that it did not require too many guidelines to complete each sheet on the STEM course material.

Effectiveness of STEM-Based Teaching Materials

Effectiveness can be achieved if STEM teaching materials are valid and practical. The effectiveness of the developed STEM teaching materials can be seen in students' learning outcomes. This effectiveness test was carried out in 3 meetings starting from 3 elementary schools and field tests. Assessment is used to determine the effectiveness of the learning process after using STEM teaching materials. The resulting assessment was based on questionnaires and interviews of students' learning motivation after using STEM teaching materials. The analysis results show students' scientific literacy after learning by using STEM teaching materials, proving that the STEM teaching materials used are adequate for learning.

4. CONCLUSION

Based on the search results that have been carried out, several conclusions were obtained. STEM material has been developed under curriculum guidelines, and indicators on STEM material have been formulated to determine the material presented by student development. In addition, the use of language in teaching materials uses simple, short and straightforward sentences to facilitate students' understanding of learning. STEM learning materials are also designed with attractiveness to motivate students to engage in learning well. Then, the STEM teaching materials' activities are adjusted to students' characteristics, which can increase students' activities and activities in the learning process. The STEM teaching materials developed were stated to be very good, with an average acquisition of 92.7 in the learning process, especially the sixth-grade thematic learning in the third grade of elementary school. The developed STEM teaching materials are stated to be very suitable for use in third-grade elementary schools. School students understand the interrelated material through the educational materials developed. It is proven by the practicality test result of teachers and students who obtained an average questionnaire of 92.85 and 92.93 with an efficient category. The STEM materials developed were reported effective based on increasing student motivation. The measurements were compared between measurements before using STEM materials and after using STEM teaching materials in learning with scores and were considered very practical for use. For other researchers, in order to be able to develop STEM teaching materials further with a broader school scope and different situations and conditions.

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