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Developing of STEM-Oriented Teaching Materials on Object Motion for Class VIII Junior High Schools

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Abstract

This study aims at developing STEM (*Science, Technology, Engineering and Mathematic*) oriented teaching materials on The Object Motion, testing the validity and analyzing the readability of the teaching materials that are developed. The method used in this research was *Research and Development* (R&D). The teaching materials developed in this study are STEM oriented by integrating the elements of science, technology, engineering design, and mathematics in a whole integration on The Object Motion materials. The teaching materials developed were validated by some experts to collect information related to the accuracy of the content and the validity of the teaching materials, and were also tested for their readability. The instrument in this study was a validation sheets to test the validity and a gap-filling test to analyze the readability of the teaching materials using descriptive analysis techniques. This research resulted in (1) STEM-oriented teaching materials having the characteristics of elements of science, technology, engineering and mathematics presented in a complete coherence, (2) the average validation score given by the experts was 85.68% in the very good validation category, and it was emphasized with the results of the Aiken's V test with the acquisition of Aiken's V validation coefficient of 1.14 in the valid category, (3) the acquisition of an average readability score of 85.18% in the category of easy-to-understand teaching materials. Based on these results, STEM-oriented teaching materials on Object Motion are suitable to use in the learning process of Science Courses in class VIII.

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INTRODUCTION

The standard of education process in elementary and secondary school level has indicated the need of learning process which is combined with the principles of scientific approach, interactive, inspiring, fun, and motivating students. A good learning process can yield competent human resources who are able to meet the increasingly complex global challenges (Johari *et al*., 2014). The objectives of science course learning can be achieved when the learning process can be understood and comprehended by the students, and the science course learning becomes meaningful. The importance of science course learning is not only limited to declarative knowledge, but is also able to apply the concept of science in real life (Syahroni *et al*., 2016). Learning activities must be directed at the learning process and implementation or application of the knowledge (Asyari & Hartati, 2015). One of the keys to achieve successful learning is the use of teaching materials in the learning process.

The low ability of students is influenced by several factors, including the curriculum, the choice of learning models and methods, learning facilities and teaching materials used by students (Kurnia et al., 2014). This can be seen from several studies that have been conducted on the teaching materials used in the Kurikulum 2013. The results of the study of Hapiziah (2015) concluded that (1) the student books used in the Kurikulum 2013 had not integrated the STEM approach, (2) 65.62% stated that the teaching materials used were difficult to understand, and (3) 79.69% stated that the teaching materials was used did not provide encouragement for students to learn independently, and it did not explore the abilities of students. There are many teaching materials owned by the teachers, but there are still some shortcomings, one of which is that the book is not designed to stimulate the students to think at high levels in solving authentic problems (Millah et al., 2012; Wahyu et al., 2016).

Based on the observations conducted at SMP NU Al-Ma'ruf Kudus, it was found that the use of teaching materials was still limited to teaching materials provided by the government. There was no development of the teaching materials carried out by the teachers to improve the students' competence, especially scientific literacy. The evaluation technique in science learning carried out by the techers still emphasized the cognitive level which demanded the ability of the C1, C2 and maximum of C3 levels, and had not adopted questions from PISA and TIMMS, because the exercises in the teaching materials were not yet applicative. The results of the assessment of seventh grade students of SMP NU Al-Ma'ruf Kudus on the material of the solar system using scientific literacy questions showed that the mastery of concepts and scientific literacy was still low; only as many as 48 students were able to answer the questions and got the results above the KKM out of 288 students whom were tested. The science course learning process that was carried out had not yet integrated science, technology, engineering, and mathematics.

The explanation above indicates that the low scientific literacy of the students was influenced by the low ability of students to understand, analyze and elaborate the problems using scientific concepts (Toharudin et al., 2011). Permanasari et al (2016) stated that the low competence of students at science courses so far is because they are seen not more than just memorizing activity and they are carried out merely at a practical level. Efforts that can be done to improve students' scientific literacy are by increasing the understanding of science concepts, scientific thinking, scientific skills and the students' ability to relate the science and technology in real life (Brickman et al., 2009; Toharudin et al., 2011). One approach that integrates science and technology is STEM.

STEM is a learning approach that uses integration among disciplines, where the application is carried out through active learning. *California Department of Education* as quoted by Rachmawati et al. (2017) reveals that STEM is a learning approach that involves critical thinking, analysis, and collaboration processes where students integrate processes and concepts in a real-life context. Gonzalez & Kuenzi (2012) states that STEM learning activities can be carried out at all levels from pre-school to doctoral degree both formally and informally. STEM is expected to be able to improve the thinking skills of students so that they are able to compete in a global environment, and enable students to become individuals who have scientific literacy (English & King, 2015). Mayasari et al. (2014) claims that through STEM learning, the students acquire

scientific and technological literacy that can be seen from reading, writing, observing, and doing science.

From the description of the background above, it is important to make improvements on the instruction in order to increase the students' competence, especially in the case of improving teaching materials. According to Sitepu (2012), teaching materials are one of the teaching resources that contribute significantly to the efforts of getting the opportunities for education and to improve the quality of learning. Several studies related to the development of modules or teaching materials have been conducted and have shown that they can improve the quality of education (Inzanah et al., 2014; Syahroni et al., 2016; Afriana et al., 2016; Pangesti et al., 2017; Nessa et al., 2017; Listiana et al., 2019; Utami et al., 2019; Siska et al., 2020)

The objectives of this study were (1) to describe the characteristics of STEM-oriented teaching materials (2) to analyze the validity of the teaching materials, and (3) to analyze their readability.

METHOD

This research was conducted at SMP NU Al-Ma'ruf Kudus on grade VIII. This study occupied the research and development (R&D) method from Sugiyono (2019) with descriptive analysis techniques. This study developed STEM-oriented teaching materials on Object Motion. The teaching materials developed were validated by experts consisting of material experts, media experts, and science teachers and a small scale readability test. The assessment instrument for STEM-oriented teaching materials refers to the BSNP (Badan Standar Nasional Pendidikan). The aspects assessed included the truthfulness of the content, presentation, language, and graphics as well as the level of readability of the teaching materials. The readability test instrument used the gap-filling test by eliminating 35 words in discourse, and the results were converted into Bormuth's criteria. Teaching materials were said to be easy to understand if the analysis of the readability test gets a minimum score of 57.

RESULTS AND DISCUSSIONS

The characteristics of STEM-oriented Teaching Materials

Results of this study are STEM-oriented teaching materials on Object Motion, as seen in Figure 1. The teaching materials developed are in accordance with the teaching material development standards of BSNP. The teaching materials are developed by implementing science, technology, engineering, and mathematics in one unit, so that the teaching materials not only present the concept of science, but also the application of science in technology and the application of civil engineering and mathematics in the concept of science.

Figure 1. STEM-oriented Teaching Materials

Science as the main aspect in the teaching materials developed was integrated in the form of discussion of material on The Object Motion and forces, including natural laws related to the concept of motion and the concept of force (Reeve, 2015). Science course materials in the teaching materials developed was presented coherently and systematically, and had been adjusted to the basic competencies (KD) in the revised 2013 curriculum. This showed that the existence of the teaching materials developed did not disregard the currently

present curriculum so that it can be used in the learning process. The integration of science in the teaching materials developed can be seen in Figure 2.

Figure 2. Science Integration in the Teaching Materials

The aspect of technology in STEM refers to various fields that involve the application of human knowledge, skills and abilities to produce something that can make life easier (Bruton, 2017). The technological aspects in teaching materials are integrated, among others, in the form of discussion of the application of the concept of force in bridge construction and the use of friction in life. In addition to this, the integration of technology in teaching materials was shown in the learning process carried out by the students; one example was the instructions given in teaching materials to students to find more information about the material discussed, by using the internet via cellphone or laptop. In the students' worksheet section, there was a YouTube link that could be accessed by the students if they had difficulty in doing the exercises or project assignments in the science course. Technology integration in teaching materials can be seen in Figure 3 and Figure 4.

Figure 3. Integration of Science Concepts in Teaching Materials

Figure 4. Involvement of Technology in the Use of Teaching Materials

The aspect of engineering or design in the STEM approach means the process of designing a product or work step (Bruton, 2017). Engineering aspects were integrated into teaching materials in the form of practicum activities and project assignments that can be carried out by the students during distance learning. The part *let's design experiments* on the teaching materials, invited the students to carry out a procedure or work steps to find scientific facts and concepts related to motion and force. The part *let's design a project* on teaching materials, invited the students to design a wind-powered car with various designs and invite the students to solve various problems in the design of the car they were making, so that the wind car products they produced were the best products. This could stimulate students to think critically in solving problems, be creative in doing product design, stimulate students to be able to apply science concepts in a product that is designed, and help students develop mastery of scientific concepts (Cantrell et al, 2006; Khoiriyah et al, 2018). The integration of engineering design in the teaching materials developed can be seen in Figure 5.

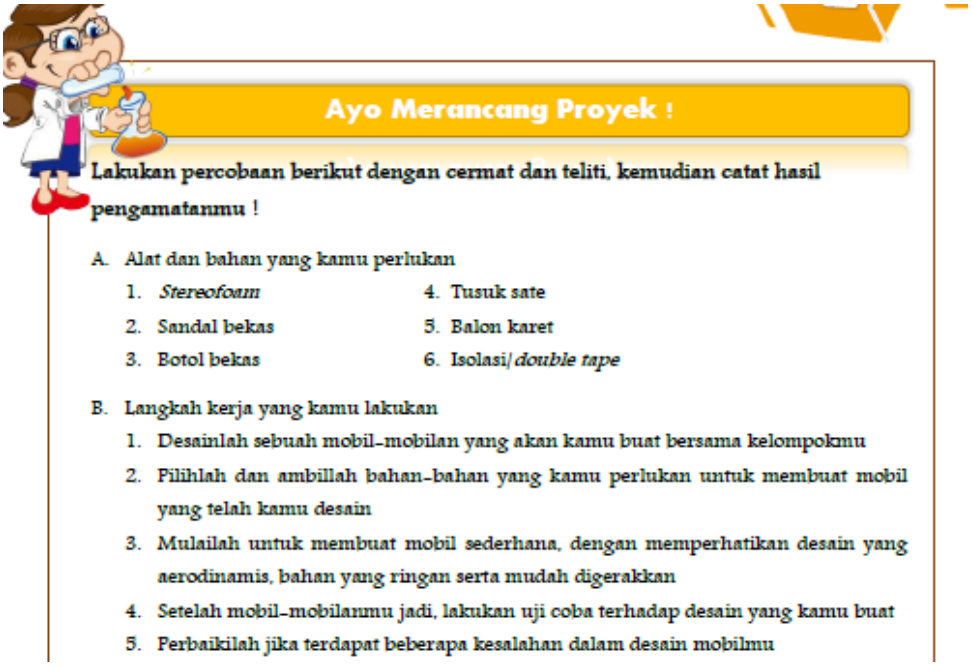

Figure 5. Integration of Engineering Design in Teaching Materials

Mathematical aspects in STEM help to interpret, analyze information, simplify and solve problems, assess risks, make decisions, make modeling, and explain abstract and concrete conceptual problems (Bruton, 2017). Mathematical aspects were integrated into teaching materials in the form of calculations through the equations of motion of objects and forces, for example, calculating the magnitude of the force through Newton's Second Law equation. In addition, in

teaching materials it also trains students to find the distance traveled by an object by using the concept of area under a graph of velocity against time, as well as training students to find the acceleration value of an object using a gradient or slope of a graph.

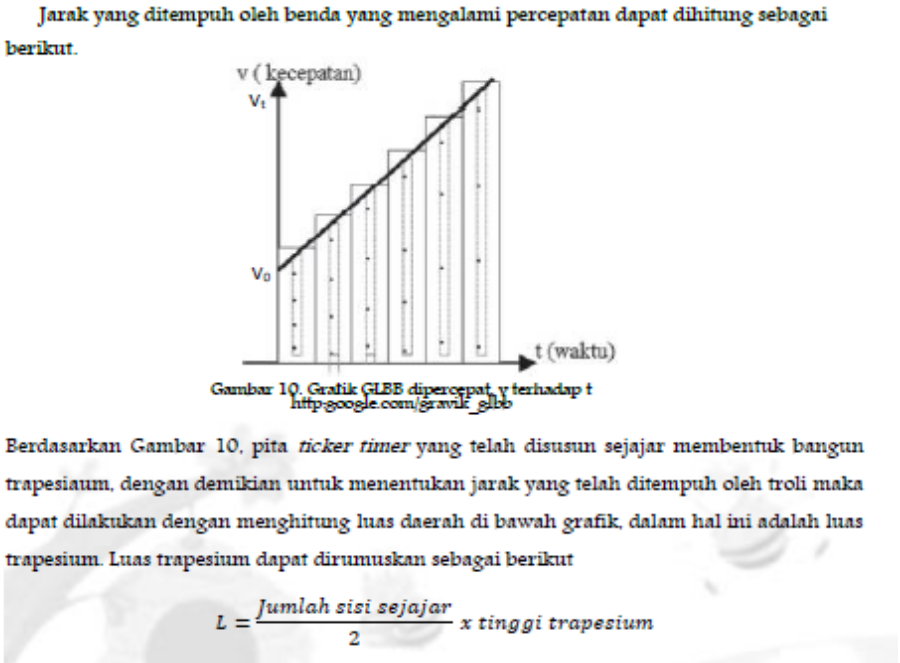

Figure 6. Integration of Mathematics in Teaching Materials

Besides prioritizing STEM elements in teaching materials, the presentation of material and examples presented in the teaching materials was arranged contextually, using the names of the areas around the research site and examples of events that were often encountered by the students. Teaching materials that are contextual in nature help students to understand the teaching material and the information conveyed, because the students feel involved and experience directly the conditions of the statements conveyed in the teaching materials. This is in accordance with the level of cognitive development according to Piaget, that children aged 11-15 years (junior high school level students) are in the formal operation period and can think logically about problems both concrete and abstract (Slavin, 2006).

As well as highlighting the four aspects of STEM, the teaching materials developed were equipped with examples of questions and their discussion, so that students could understand the problem solving process easily, the evaluation questions presented in the teaching material were questions adapted from PISA so that they could stimulate science literacy improvement of the students. In the final part of the teaching material, there were a summary of the material, a glossary, and a bibliography as a reference. The glossary in the teaching materials developed was arranged alphabetically and contains explanations of important terms related to the teaching material, so that students could easily find the explanations of words or terms that they had not previously known.

Based on the explanation above, it can be concluded that the teaching materials developed have components that comply with BSNP standards. The teaching materials developed have distinctive characteristics when compared to teaching materials in general, which lies in integrating elements of science, technology, engineering and mathematics in the teaching materials being developed, besides that the teaching materials developed are also contextual in nature. This is in accordance with Rusyati's (2019) research, which shows that the reconstruction of STEM-based teaching materials produces teaching materials with characteristics that contain a complete and rich concept of material that supports the improvement of students' scientific and technological literacy. Teaching materials that are contextual in nature attract students in achieving maximum competence (Suwardi, 2011). In addition, teaching materials are effective and attractive if they pay attention to the principles of

usefulness, adequacy, consistency and relevance (Asyhar, 2011; Toharudin et. Al., 2011).

Validation of STEM Oriented Teaching Materials

The teaching materials developed were validated by material experts, media experts and science course teachers with 2 people each. The results of the validation of STEM-oriented teaching materials can be seen in Table 1.

Table 1. Recapitulation of the Results of the Validation of Teaching Materials by the Experts

Validator	Average Score	Score Percentage (%)	Validation Criteria
Material Expert 1	3.24	80.88	Good
Material Expert 2	3.56	88.97	Very Good
Media Expert 1	3.82	95.59	Very Good
Media Expert 2	3.12	77.94	Good
Teacher 1	3.72	93.10	Very Good
Teacher 2	3.10	77.59	Good
Average	3.43	85.68	Very Good

Table 1 describes the acquisition of validation score for the teaching materials by each expert. The average percentage score given by the material expert is 84.93 with the very good category. The difference in scores given by material experts 1 and 2 is because in teaching materials there are still some materials that need to be revised, including connecting the equation of distance traveled to the area of gravity *v-t*, as well as the examples presented as much as possible are taken from the environment near the place the students live. The average percentage score given by media experts is 86.77 in the very good category. The difference in scores given by media experts 1 and 2 is because there are still some suggestions and revisions to teaching materials, including the use of cover images, preferably from personal documents, and the use of illustrative images that take too much from the internet. The average percentage score given by educators is 81.64 in the very good category.

Based on the assessment that has been given by all validators, it can be concluded that the average score of validation of STEM-oriented teaching materials on Object Motion material is 3.43 with a percentage of 85.68% in the very good validation category. These results are confirmed by the Aiken's V test, based on the V index on Aiken's V with a number of validators of 6, an item is said to be valid if it meets a V value of at least 0.78. The results of the Aiken's V test show that the coefficient of Aiken's V validation is 1.14, thus, the teaching material is said to be valid.

Assessment of STEM-oriented teaching materials on material motion of objects in terms of four aspects, namely aspects of truth of content, aspects of presentation, aspects of language, and aspects of graphics. The results of the validation of each aspect of STEM-oriented teaching materials on Object Motion can be seen in Table 2.

Table 2. Recapitulation of Teaching Material Validation Results in Each Aspect

Aspects	Score	Score Percentage (%)	Criteria
Aspects of Truth Content	3.43	85.63	Very Good
Presentation Aspects	3.50	87.50	Very Good
Linguistic Aspects	3.25	81.25	Very Good
Graphic Aspects	3.43	85.87	Very Good

Based on the assessment on the aspect of truthfulness of the content, the percentage was 85.63% with the very good category. This shows that the teaching materials being developed have material content that is in accordance with the 2013 curriculum. Based on the results of expert validation, it is found that the material presented in the teaching materials is complete, by including examples that are relevant to everyday life. The elements of science, technology, engineering, and mathematics in teaching materials are presented with an integrated STEM approach so that the students are able to benefit from STEM learning.

The percentage of the validation results of teaching materials on the presentation aspect was 87.50% with the very good category. This is because

STEM-oriented teaching materials are prepared based on the components of teaching materials according to BSNP, so that the teaching materials developed meet the requirements as suitable teaching materials. Presentation of material on teaching materials is presented coherently by linking scientific concepts into everyday life. The connection of scientific concepts can be seen by students through the concept maps available in teaching materials.

The assessment of the linguistic aspects of the teaching materials developed, got a score of 81.25% in the very good category. The teaching materials developed are compiled using simple language, and according to the level of emotional development of students so that it is easily understood by students. The results of validation from experts state that the teaching materials developed have communicative language, causing a two-way interaction between teaching materials and students, instructions given to students in practical and project activities are very clear.

The graphic in the developed teaching materials has a score percentage of 85.87% in the very good category. The teaching materials developed have met ISO standards, one of which is the paper size used in teaching materials. Teaching materials are prepared using A4 size paper, with the aim that the text and images on the teaching materials can be read by students. Textbooks prepared in learning must have a use value, so that the textbook must be attractive, colorful, and in a format that is familiar to students (Indrasari et al., 2020). Therefore, the book developed is compiled using a colorful layout design. The cover on the teaching material is designed to be as simple as possible by displaying illustrations or images that match the title of the teaching material, so that the title and image on the cover can represent the content of the teaching material. The layout used in teaching materials is consistent in each of its sub-chapters, the presentation of material in teaching materials is equipped with illustrations or pictures that are in accordance with the subject matter of the material, so that it helps students understand the material through the illustrations provided.

The results of the validation of STEM-oriented teaching materials as a whole showed an average score percentage of 85.68% with the very good validation category and Aiken's V coefficient of 1.14 in the valid category. This shows that STEM-oriented teaching materials on Object Motion material are suitable for use in the learning process. The results of this study are in line with research by Rahmatina et. al., (2020) which shows that the STEM-based teaching materials developed have a validation percentage of 78% and are in the valid category and suitable for use in learning.

The ideal teaching material is teaching material that is in accordance with the potential of students, and can stimulate students to be able to apply science concepts in everyday life and integrate science and technology in it (Zuriah et al., 2016; Rusyati et al. ., 2019). Several studies that have been conducted have shown that the application of the right learning approach and the use of appropriate teaching materials can increase the competence of students (Asyhari & Hartati, 2015; Safitri et al., 2015; Syahroni et al., 2016). One of the appropriate teaching materials to improve scientific literacy is STEM (Science, Technology, Engineering and Mathematic) oriented teaching materials, because by using STEM, students are trained to think at a high level in dealing with contextual problems, and are able to have the skills to face the 21th century in the era of the industrial revolution 4.0 (Ejiwale, 2012; Ostler, 2012; Bybee, 2013; Rusyati et al., 2019; Pujiati, 2019).

The Readability of STEM Oriented Teaching Materials

The readability test of teaching materials in this study was carried out by means of a gap-filling test. The readability test instrument consisted of 3 discourses on different themes which were taken from teaching materials by eliminating 35 words that were understood by the students. The readability test was carried out on the students of grade IX at SMP NU Al Ma'ruf Kudus who had received material motion objects. There were 32 students involved in the legibility test taken from the upper, middle and lower groups, with a total of 8 students in each group. Students were asked to complete the 3 discourses that had been given to determine the readability of STEM-oriented teaching materials on Object Motion material. The results of the teaching material legibility test can be seen in Table 3.

Table 3. Recapitulation of the Results of Teaching Material Readability Test

Discourses	Average Score	Score Percentage (%)	Criteria
Discourse 1	7.66	76.56	Easy to understand
Discourse 2	8.72	87.19	Easy to understand
Discourse 3	13.44	89.59	Easy to understand
Total / average	29.81	85.18	Easy to understand

The recapitulation of the results of the teaching material readability test shows the average number of the correct answers from discourse 1, discourse 2, and discourse 3 is 29.81 from a total of 35 points with an average score percentage of readability of 85.18 with the criteria of teaching materials easy to understand. Teaching materials with readability level criteria are easy to understand, can be used by students for independent learning (Widodo, 1993). Teaching materials with a good readability level can be used for learning and can improve students' thinking skills in solving problems and understanding the concepts presented in teaching materials (Abdulkarim, 2007 & Muslimin, 2011).

CONCLUSION

This research produces STEM-oriented teaching materials on motion objects with unique characteristics, namely that there are elements of science, technology, engineering and mathematics in a complete integration. Furthermore, the teaching materials developed are also contextual. Evaluation of STEM-oriented teaching materials on Object Motion material has an average score of 85.68% in very good validation category and Aiken's V coefficient of 1.14 in the valid category. Readability level of teaching materials at a score of 85.18% with the criteria for easy-to-understand teaching materials. Based on this, the teaching materials which are developed are worth applicable in the learning process.

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