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The implementation of STEM approach in teaching electricity and statistics to a group of ix grade junior high school students in Yogyakarta

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Abstract. Youth Manual (2016) predicted the increase of Science, Technology, Engineering and Mathematics (STEM) -related jobs in the next five years. One of the characteristics of these jobs is it's require capability to think and work interdisciplinary. STEM approach can be seen as a teaching approach that ask teachers to view Science, Technology, Engineering and Mathematics as an interrelated discipline and to teach the topics within the areas by using integrative and thematic approach and teach them based on a real phenomenon. This research was aiming at trying out the implementation of STEM approach to teach the topics of electricity in Science and Statistics in Mathematics to grade IX students by using real life phenomena and to measure students' learning results. The research implemented Design Research method. Data were collected by observation and test on students' understanding of the subjects. The data was analyzed quantitatively. The results demonstrate that the students' mastery on the subjects was good and excellent. This research suggested that STEM approach has a potential to be implemented in Indonesian Junior

1. Introduction

The development of science and technology and the globalization that is currently happening demands the world of education to prepare students to be ready to be involved and contribute to modern society. In 2015 the ASEAN Economic Community (MEA) or ASEAN Economic Market agreement entered into force. One of the agreement is that those who succeed at certain levels of education are entitled to obtain free employment in ASEAN countries. This agreement not only affects the economic sector, but also in other sectors, including education as a locomotive for human development. Because Indonesia was chosen as the center of the MEA free trade, the Indonesian government need to prepare, starting from preparing infrastructure to preparing in creating Human Resources (HR). All Indonesian people must be trained, qualified and professional through a quality education process.

Based on data from the Central Bureau of Statistics [1], the current work force in Indonesia is dominated by low educated people, namely those with junior and senior high school education. As of February 2015, there were 54.6 million workers with an elementary education background, 21.5 million junior high school students and 18.91 million high school graduates. Meanwhile, the working population is highly educated, totaling only 13.1 million people. The low number of workers graduating from higher education is because most people have not been able to reach higher education for economic reasons. Consequently, they feel enough with the education they obtain, which on average only graduates from junior high school.

The era of the Industrial Revolution 4.0 is an era faced by Indonesia today. Era where human life is always related to technology and information. Minister of Research, Technology and Higher Education



(Menristekdikti), Mohamad Nasir explained, based on the initial evaluation of the country's readiness to face the industrial revolution 4.0 Indonesia is estimated to be a country with high potential. From this, it can be said that Indonesia must be prepared to face the industrial revolution 4.0 [2]. This made the 4.0 industrial revolution good news as well as bad news for humans. This is because the industrial revolution will make it easier for humans to live their lives. However, indirectly human resources will be replaced by machinery and technology. According to Tritulsi & Sutopo [3] saying that "... the role of human beings has been shifted by technology, this is also a problem of the industrial revolution which will fundamentally change the way work, works and relates to one another." This has an impact on the next generation which needs to develop itself to be able to survive in the era of industrial revolution 4.0.

2. Literature review

Education has an important role in preparing resources to face the MEA and Era of Industrial Revolution 4.0 and the challenges of the 21st century. Broadly speaking, education has a role to provide skills both soft skills and skills. Quality human resources are produced by quality education. The high quality of education among community members is the main force to overcome the problems faced.

At present the improvement of the quality of education in Indonesia, especially in scientific disciplines of Science and Mathematics, is still being sought. This scientific discipline is a means of thinking to develop reasoning power, logical, systematic and critical thinking. During this time, science and mathematics learning prioritized the development of cognitive abilities in elementary level students, while C4 (analysis), C5 (evaluation), and C6 (making) cognitive levels were rarely touched. This causes students not to have Higher Order Thinking abilities or high-level thinking skills. In other words, if the teacher is still capable of Low Order Thinking Skills, students will not achieve Higher Order Thinking Skills.

Education affects the quality of human resources. The quality of human resources can be seen from the ability of graduates who have the skills, master the technology, and have extensive knowledge and professional expertise. In fact, Indonesia as a country entering the era of free competition still has low human resources. The low quality of human resources is influenced by the quality of education in Indonesia which is still relatively low. Students' ability to answer application questions and reasoning is lower than understanding. These results are supported by the 2015 PISA (Program for International Students Assessment) research published in 2016 which shows that Indonesia has an average value of 403 from the international averages of 500 and 501 [4]. Data from the 2015 TIMSS (Trends in International Mathematics and Science Study) research, Indonesia ranks 69th out of 76 countries involved [5].

Based on the results of observations made at the Stella Duce 1 Middle School in Yogyakarta to find out in class learning, it can be seen that teachers begin to use the scientific approach, but more often use the conventional approach. The results of observations made can be seen that students' ability to respond to questions by reason, asking questions when they do not understand the material is still lacking, even so when students are asked to analyze a problem, conclude the problem, and evaluate the problem is still lacking which has an impact on student learning outcomes less increase.

Responding to the declining progress of student learning outcomes and increasing competitiveness in the era of globalization and industrial revolution 4.0, the STEM approach emerged as an alternative. The STEM approach encourages teachers to integrate interdisciplinary techniques, mathematics, and technology in science learning so that the knowledge possessed by students is holistic and intact. The Education Council [6] states that schools should support the development of skills across interdisciplinary sciences, critical and creative thinking, critical thinking skills, problem solving skills and mastering digital technology, where it is a must have in the 21st century. Various skills and mastery of these competencies are the core goals of STEM learning.

There are several reasons for the encouragement of science learning using STEM, which is to give a broad picture to increase student interest in the future career in the STEM field. In addition to improving students' ability to understand complexity when faced with problems in real life. The National Research Council [7] describes research on the success of STEM programs in the US. With the success of STEM, trends arise in education in various countries to adopt STEM-based learning, one of them in Indonesia. All countries began to have a tendency to improve education by directing learning using the STEM strategy.

STEM activities are considered to be able to improve students' ability to associate and STEM results and encourage teachers to improve student outcomes.

Outcomes (learning outcomes) of students in science and Mathematics learning can be used as an overview of students' mental readiness in facing global challenges. The results of interviews with teachers and observations of student learning outcomes in the previous school year, students assume that science and mathematics subjects are considered difficult subjects. The learning process of most new concepts reaches the level of Applying (C3) and only a few concepts are considered by students to reach the level of Analyzing (C4).

The STEM learning process connects the teacher's commands carefully and continuously so that they are different from other classes [8]. What makes it different is the level thinking ability (HOTS) that is always seen in STEM learning. High level thinking ability (HOTS) is the highest level of the cognitive process hierarchy. This cognitive process will be greedy from student learning outcomes on cognitive aspects.

According to Tri Indra learning outcomes are changes in the behavior of students due to learning. Behavior change is because he achieves mastery over a number of materials given in the teaching and learning process. This achievement is based on predetermined teaching goals. The results can be in the form of cognitive, affective, or psychomotor aspects. PE behavior change in the cognitive domain, in general, can still be understood using Bloom's taxonomic categorization or that has been revised by Anderson and Karthwol [9].

Cognitive abilities acquired as a result of learning Bloom and his colleagues (Benjamin S Bloom: 1956) consist of six categories: remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and create (C6). Of the six categories used for evaluation or assessment of the cognitive domain according to high-level thinking skills are levels C4 to C6. Evaluation or assessment is one of the important factors in learning that can be used to determine the achievement of learning objectives. Achievement of competency and learning effectiveness can be found only if a comprehensive and accurate, valid and reliable assessment is carried out [10]. Assessment is very important because it provides information about the implementation of learning and feedback from students. Subsequent assessments are used as evaluation tools about student learning outcomes, weaknesses, and the need for further learning improvement programs.

3. Research Method

The research method used in this study is design research. According to Gravemeijer (Hasanah, 2012), design research is also called developmental research, which is a type of recovery method which is formed by classroom teaching experiments that centers on the development of instructional sequences and the local instructional theories that underpin them.

Design research is a study that revolves around the development of instructional stages of learning and learning theory in students. This design research aims to formulate, know, and develop teaching materials. Design research consists of three phases, namely preliminary design, experiment, and retrospective analysis.

In the preliminary design according to Simon and Baker in Mulyana the teacher formulates learning material, learning classes, learning activities, and learning hypotheses that will occur. In this study, learning material was taught about Electrical Energy and Statistics. In the experimental stage, the design that has been designed is tested on students. The purpose of this trial is to see whether the things that have been anticipated at the preliminary design stage are in accordance with the reality that happened or not. The research subjects were grade IX students at Stella Duce 1 Middle School in Yogyakarta with learning materials about Electric Energy and Statistics. The research was conducted in October 2017 and October 2018. In the retrospective analysis phase, all data obtained in the previous stage were analyzed and synthesized for improvement of learning design that will be used in the next cycle.

4. Results

The data obtained in this study are data collected from the Science and Mathematics learning outcomes tests in the form of summative tests in accordance with the basic competencies taught. The test instrument used for science subjects was in the form of five items of description, while for the Mathematics subject test in the form of a five-question problem. The questions given are adjusted to the indicators of achieving basic competencies taught. The indicators of achievement of competency tested are cognitive tests to obtain an overview of learning outcomes achieved by students with the STEM approach. Based on the data collected from the test results, it will explain the general description of the data obtained related to the acquisition of student learning outcomes and the discussion of the results of the study.

Tests are carried out after students have completed the learning activities using the learning design with the STEM approach. Learning with the STEM approach in class teaches students to cross-link the teacher carefully and continuously. This allows for differences with other classes without the STEM approach. What makes it different is the high-level thinking ability (HOT) that is always seen in STEM learning. High level thinking ability (HOTS) is the highest level of the cognitive process hierarchy. This ability occurs when someone gets new information, remembers it, and compiles it, connects with existing knowledge and produces this information as a goal or solution to a complicated situation [11]. Trained students like this will have an influence on the development of their education. The application of student knowledge about STEM and its skills make it look different from non-STEM students.

The level of test questions used to measure student learning outcomes after learning with learning design using the STEM approach are levels C4 through C6.

These test questions are used for two cycles both in science subjects and in mathematics. Student learning outcomes based on the test given refer to the school's Minimum Obedience Criteria (KKM). Students are recorded as complete if the student test scores are more or equal to KKM. If less than KKM students must follow remedial to KKM limits. The KKM value for science and mathematics subjects at Stella Duce 1 Middle School class IX is 76.

The research data obtained is the result of two cycles of research. The first cycle was conducted in October 2017. The student learning outcomes of the first and second cycles for science subjects are presented in Table 1

Table 1. Students' Learning Achievement on Cycle 1 dan cycle 2

	Cycle	
	1	2
Highest score	100	100
Lowest score	65	70
Average	82.64	85.14
Standard of Deviation	7.88	6.81

Students' learning outcome	Level of Mastery	Classification
Cycle 1	83.33 %	Good
Cycle 2	91,67%	Very Good

Tabel 2. Students' learning achievement in Mathematics on cycle 1 and cycle 2

	Cycle	
	1	2
Highest score	98.33	97.5
Lowest score	77.5	80.00
Average	85.69	89.53

Standard of Deviation	6.01	3.67
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Stidents' Learning achievement	Level of Mastery	Classification
Cycle 1	100 %	Very Good
Cycle 2	100 %	Very Good

Learning outcomes with the STEM approach are carried out through two cycles. The average assessment results based on mastery in the first cycle for science subjects get a percentage of 83% with good criteria, while for Mathematics subjects the percentage of mastery is 100%. This criterion has actually fulfilled the requirements to categorize that the developed lesson plan is feasible ($\geq 75\%$). However, there are several aspects that need to be revised in the RPP that are developed and will then be reassessed by the validator through the second stage of assessment. The revised RPP includes sections: 1) learning objectives must be in accordance with ABCD guidelines (audience, behavior, condition, and degree), 2) learning methods used must be explicitly stated, 3) activities that emphasize the STEM approach are focused only on by students. Teachers must design learning activities that can motivate students' curiosity about the material to be studied, 4) learning materials made more complete, 5) writing formulas need to be corrected according to the applicable rules, and 6) there are still some errors in typing.

The revised lesson plan was then tested again on the second cycle of science and mathematics learning. The learning outcomes based on mastery in the second cycle of science subjects gained a percentage of 91.67% which was in the excellent category. Learning outcomes based on mastery of the second cycle of Mathematics subjects obtain a percentage of 100% which is in the excellent category. The results of the RPP trial at this stage have shown that the RPP with the developed STEM approach is suitable for use in science and Mathematics learning. RPP products can be said to be feasible because they are in accordance with the purpose of developing this device, namely to improve student learning outcomes.

Overall for the learning outcomes with the STEM approach are presented in Figures 1 and 2 about the analysis of the items tested on science and mathematics subjects.

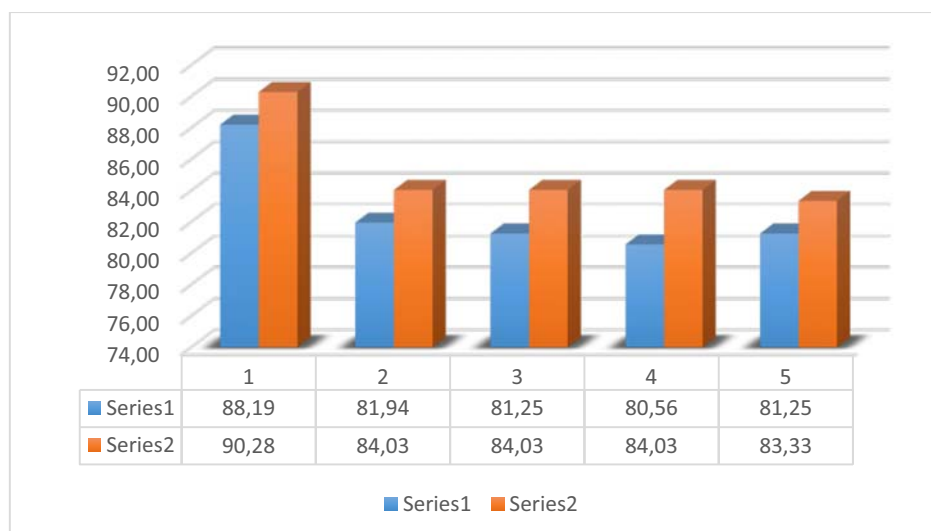


Figure 1. Analysis of items about the description of science subjects

Based on the graph in figure 1 about the item analysis the description questions for science subjects the acquisition of students' science scores has increased from the first cycle to the second cycle. The highest level of mastery in question number one is because the level of difficulty of the problem is easy for students to do. Problem number two, number three, number four, and number five the acquisition of students in the category is good and there is an increase in the second cycle. The increase in the second cycle was due to the revision of learning in the previous RPP so that it had an impact on student learning outcomes. The questions given use the categories of cognitive abilities levels C4, C5, and C6.

In the first cycle, student learning outcomes were the lowest in question number four. Problem number four is a calculation application problem based on the observation data table. Students experience difficulties when calculating because the numbers obtained in the experimental results are not round numbers and calculations do not use tools such as calculators. Whereas in the second cycle the learning outcomes were the lowest in question number five. Problem number five is related to the application of a formula to calculate electricity costs that must be paid for a month based on the use of a kWhmeter in each student's home. Data on kWhmeter use have been collected by students for two weeks before learning. Difficulties in students' experience when performing calculations based on physical power data at home from a kWhmeter with complicated numbers.

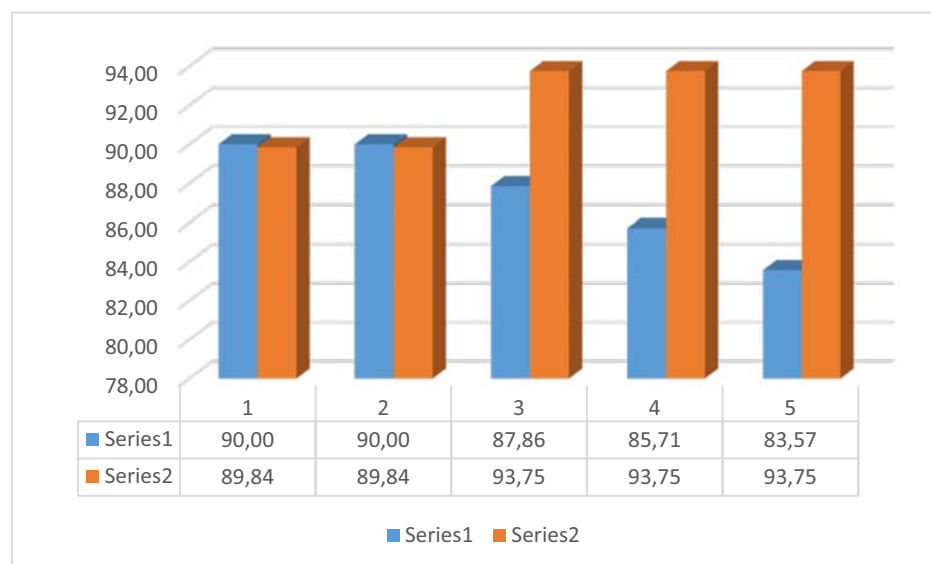


Figure 2. Analysis of items about the description of Mathematics subjects

Based on the graph in Figure 2 about the item analysis, the description questions for Mathematics subjects, the acquisition of students' Mathematics scores has increased from the first cycle to the second cycle. The highest level of mastery is in question number three, number four, and number five because the difficulty level of the problem is easy for students to do. Problem number one and number two student acquisition in category is very good and there is an increase in the second cycle. The increase in the second cycle was due to the revision of learning in the previous RPP so that it had an impact on student learning outcomes. The questions given use the C4, C5, and C6 level cognitive abilities categories. Mathematics learning outcomes from questions number one to number five feel in the very good category because the statistical material taught for junior high school level is still in the basic category (mean, mode, median, and graph).

5. Conclusion

Based on the results of the research and discussion it can be concluded that the learning of Science and Mathematics with the STEM approach can improve student learning outcomes for Electrical Energy and Statistics subjects of class IX junior high students. Improving student learning outcomes with the STEM

approach is also influenced by the learning design used to develop learning that integrates science material and Mathematical material effectively.

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