Development of mathematic’s teaching materials using project-based learning integrated STEM

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Abstract. Development of mathematic’s teaching materials using project-based learning model integrated STEM in junior high school not much done yet. Integration of STEM in education becomes a necessary thing to do based on the high demand for human resources who master the STEM field. Project-based learning provides space for students to choose activities to be undertaken during the lesson as well as providing opportunities for implementers of learning to observe activities that are considered more effective in developing student skills. The process of choosing the learning activities undertaken on each student begins with a thought process that results in a decision. This study aims to develop a project-based teaching materials which presents mathematical topics combined with other STEM fields. Based on the analysis of research data, the design of teaching materials often undergoes changes in arrangements of delivery and the amount of content that can be delivered is also accepted by students depending on the diversity of students' abilities.

1. Introduction
The rich natural resources have not made Indonesia a highly competitive country economically. Indonesia's low economic competitiveness is affected by workers with weak competitiveness. Efforts to improve the quality of workforce can accelerate the improvement of economic competitiveness. Increasing the competitiveness of labor is an integral part of human resource development.

The improvement quality of human resources is through education. The positive correlation shown by the country that excels in education also excels in economic sectors such as Singapore and South Korea. Research conducted by Maskymenko and Rabbani in the same year when children at the South Korean high school level succeeded in excelling in mathematics and science revealed that the country managed to build a workforce with high competitiveness [1].

Cooney and Bottoms stated that inadequate education in mathematics and science has led to a shortage of qualified workforce resulting in a global industry gap. The Asean Ministrrial Meeting on Science and Technology brings this issue as an important issue in education in ASEAN member countries. In other words, in order to remain competitive globally, ASEAN countries are encouraged to immediately enhance their learning in Science, Technology, Engineering, and Mathematics (STEM) at all levels of education [2].

STEM is an important issue in education today. Since the advent of the global movement calling for a new learning model for the 21st century, it has been argued that learning in formal education should be changed. Traditional approaches to the subjects of science and mathematics that emphasize rote or
simple procedural application will increase very little interest in students in continuing their studies and careers in the STEM field [3].

Mathematics is an important subject for immediate improvement and development. This is based on international benchmarking results where the score of Indonesian students for mathematics subject is lower than the subject of science. Mathematics learning to students to date is generally still as information delivery without much involving students to be able to build their own understanding. Though the ideal learning is student-oriented learning to make students learn actively. Project-based learning offers solutions for students to actively participate by choosing for themselves the activities and work to be done during the course of the project.

Mahanal stated project-based learning (Project-Based Learning) is an innovative learning that emphasizes contextual learning [4]. There is also the opinion of William about STEM used to address real-world situations through a design such as that used by scientists and engineers to solve existing problems. This becomes a very possible part to collaborate where project-based learning is integrated with STEM [5].

Based on the new need for a project-based learning integrated with STEM, the teaching materials must be developed according to those needs. Development of teaching materials can not be separated from the innovation in the material context contained therein but also about the evaluation of the teaching materials that have been made. The evaluation used in this study is the overall impression of students on new teaching materials that are under development.

2. Method
The teaching materials were developed following the development stages in the Research and Development model. The teaching materials development procedure includes the stages of data collection and information, planning, product manufacturing, small group testing, until the initial product revision. The researcher acts as an instrument during the research. Small scope trials were conducted on 36 students of class IX in a Junior High School in Bandung. Sample selection technique based on purposive sampling. Data retrieval during learning through observation of student response to teaching material and interview to know the impression of student after learning done.

3. Result and discussion

3.1 Development of teaching materials
Table 1 shows the results data in STEM teaching materials development process with PjBL model. The data analysis was done by the researcher starting at the beginning of the research. The results presented are the reduction of the overall data obtained by researchers during conducting research on field development.

| Process                               | Contents                               | Description                                                                 |
|--------------------------------------|----------------------------------------|-----------------------------------------------------------------------------|
| Data collection and information       | Observation of STEM learning           | Conditional, FPMIPA and KNU cooperation in iSTEM learning                   |
| Design                                | a. Collect the same topic draft        | Optional Sintak PjBL journal, PjBL K-13, syntax of learning STEM            |
|                                      | b. Analysis of learning syntax         |                                                                             |
|                                      | c. Design of learning situations       | Number of meetings, execution time, number of activities, individual / group |
|                                      | d. Determine the STEM fields that are  | The choice of STEM field to be the major field highlighted during the lesson|
|                                      | integrated into each activity          |                                                                             |
Table 1. Cont.

| Product Creation | a. Formulate learning objectives and material constraints for each activity  
|                  | b. Create a math concept map  
|                  | c. Starting from the real situation and contextual (Sains)  
|                  | d. Provide a basic question relevant to the observation result  
|                  | e. Train student skills using simple tools or technology products  
|                  | f. Give problem solved with student product design  
|                  | g. Ask question about the mathematical concepts derived from the product  
|                  | h. Collect information about students’ understanding of information selection  

| Stimulus students to observe natural phenomena  
| Skilled using simple equipment eg ruler, run (Engineering). Software (e.g geogebra) and hardware (Technology)  
| Students are allowed to choose products to be made (Engineering). Students use software (e.g geogebra) to prove math concepts  
| Ask students to communicate work steps and design results  

| Small scope trials | a. Analysis of students’ initial ability  
|                   | b. Analysis of supporting power student learning activities  
|                   | c. Design different situations at each meeting  

| Infrastructure and media  
| Choice of Material, depth of material, many activities, learning duration, individual / group learning engineering  

| Evaluation and Revision | a. Observe student interest and enthusiasm during learning  
|                         | b. Interview impression after learning  
|                         | c. Student portfolio analysis  
|                         | d. The researcher’s impression during the research  
|                         | e. Revised teaching materials  

| To find a better situation design to use  

Table 1 shows the process of developing teaching materials that have been done by researchers during the study conducted. There are several things that researchers do in each process. The process is fitted to the stages development of R & D so that the resulting research product is valid.

Initial observations on STEM learning were conducted by researchers during the Korean iSTEAM learning process at each of the two schools at junior and primary school levels. Preliminary observations were conducted before independent research was conducted. However, this does not reduce the essence of initial data collection relevant to the study. Using the same teaching materials, the topic of SMP mathematics can be taught and understood by elementary school children. It's just that the depth of the material is adjusted to look at the ability of students. From this it is obtained that the value of the flexibility of teaching materials that are made must be quite high.

Another contribution of preliminary information described earlier is to give consideration to the researcher when designing the learning situation. When compiling teaching materials for each activity, consider the number of meetings available to complete the selected math topic. Then the effective duration of learning is closely related to students’ ability to withstand situations designed for learning.
Therefore, the ability of teachers is highly relied upon to undertake an initial assessment of students' endurance in the implementation of learning.

The results of the study show that children who are highly capable will have a higher endurance over the duration of learning time and more likely to implement not just one activity in one meeting. Later, it was found that strict classroom control can increase students' concentration during learning. Creating an orderly classroom environment first makes students focus on learning. Designing table and seating positions in groups or ensuring students to sit in their respective seats is very trivial, but in this study, revealed that the small thing has an impact on the conduciveness of learning.

The design of teaching materials was prepared based on curriculum study. PjBL is a learning model contained therein. The hallmark of this learning model is the product. Not all topics in mathematics can be a real product. In drafting the design, researchers tried to bring out the characteristics of PjBL. Tiantong and Siksen reveal the characteristics of PjBL is centered on the learner [6]. The teacher acts as a facilitator and provides scaffolding if students are having trouble. The amount of time teachers spend delivering materials that use traditional pendants does not occur in this learning model. So the time of the learner or researcher himself more and focus on student observation during learning.

Another characteristic of PjBL is to support cooperative learning through communication, information exchange, knowledge and opinions among learners [6]. The design of learning situations that aligns with these characteristics is group learning. By exchanging information to solve a given problem, the teacher can observe the student's ability to reason, choose information, and decide on actions to resolve the problem. Briefly Facione mentions the student's ability as a critical thinking skill [7].

The ability to think logically or think critically is part of the ability trained during STEM learning according to Morrison [8]. Additionally, critical thinking is the core competence of 21st century competence in accordance with the published 4Cs by P21 [9]. This capability is an output that emerged during the study. And as a suggestion for further research is to examine the extent of this ability is more specific using the material that is being developed and quantitatively measured.

The realization of the PjBL model in this design, does not necessarily take the syntax already contained in the curriculum. Some considerations are made to obtain PjBL syntax in accordance with the STEM learning learning framework. By comparing the PjBL syntax advanced by experts in the Journal and PjBL syntax in the 2013 curriculum. The researcher decided to use the PjBL syntax elaborated from the experts' statements. This is because there are points that researchers have highlighted on the lesser K-13 syntax that can facilitate learning efficiently. Hence the elaborated PjBL syntax of expert statements is used in preparing RPP and teaching materials which are then integrated with the STEM field of choice.

Science and math are subjects that are part of the 2013 curriculum. While technological subjects and engineering techniques are only part of special skills subjects not even in the primary education curriculum. Therefore STEM education is only based on science and mathematics. Through these teaching materials, the selection of technology and engineering in learning is done on simple things first. In this study not to design technology but enough on the utilization of technology and do product-making projects as an effort in the introduction of engineering.

The integrated approach in STEM, ideally very suitable, but in the implementation of an embedded approach called by Roberts and Cantu is more suitable to do. In an embedded approach, one content serves as a major field [10]. The major field in the development of this teaching material is the field of mathematics. The integrity of the mathematical subject is maintained from beginning to end. Other fields of STEM are sought to relate to the main material. Eventually the material being evaluated or assessed is a mathematical material. So no wonder the evaluation section only contains math concepts.

3.2 Evaluation of the development teaching materials

Figure 1 and figure 2 show the results of the projects undertaken by the students through the initial design and then made the product.
Figure 1 shows that the product of the design of the students based on the results of the collection of information during the learning written by the students in the portfolio contained in figure 2. In the section shown figure above is the result of activities undertaken by several groups of students who get the tools and materials that can be made into the above product. There are also other groups who are given the setting to make other products with different materials but still using the same concept found the existence of different constraints. Based on this, the researchers concluded that activities would be more effective if using teaching materials with the same activities for all groups of students.

Student activities are also analyzed when students are asked to choose the field of STEM that accompanies the field of mathematics. The large distribution of different groups makes the teacher less able to condition the class to be overwhelmed when many questions from students about the lack of clarity of instruction in the teaching materials. One suggestion is to improve the existing teaching materials so that they are easy to understand and can be done independently. Another related suggestion is to decide which one field will be given equally for all students so that the class can be conditioned and that all learning objectives can be properly conveyed and monitored.

During the learning process, the researchers looked at the good impression shown by the students by following the learning to the end. However after random sampling for interviews can be extracted other information from students related to learning. Various impressions obtained by researchers. As a student, students love STEM-integrated lessons because they think learning to be relaxed is like playing, but others prefer a conventionally taught mathematics-oriented learning process.

Regarding the learning situation, it is found that giving the decision to the students to be able to choose the field of learning makes the students confused because the field of STEM is new for them and they do not know the specialization of their ability in that field. The ability of students to follow the learning does not necessarily make students feel comfortable with the many activities undertaken. Through the interview also obtained the results of activities undertaken during the learning should always adjust, it is very closely related to the ability of teachers or teachers in understanding the ability of their students.

4. Conclusion
The teaching materials should have a high value of flexibility and have a number of instructions to easy-to-understand. The depth of the material, the composition of the activity, the number of activities in one meeting until the product engineering results of the design can be changed according to the analysis of
students’ ability by the teacher and the student’s response to the learning. Development of teaching materials using PjBL syntax model elaborated from the experts who then are integrated with the syntax STEM. STEM approach used is embedded approach. Various impressions are shown by students. Most prefer STEM learning with the same material given for one activity and the number of activities fitted to the student’s endurance of study time.

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