STEM-based Science Learning Design in the 2013 Curriculum

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Abstract. This paper is aimed to discuss about design of STEM-based science learning in junior high school in the 2013 curriculum, and use the model of Project Based Learning (PjBL). STEM is an teaching and learning approach that integrates science, technology, engineering, and mathematics to reach the 21st century skills which is proclaimed in 2013 curriculum. In this paper only discuss one of teaching and learning model that supports and appropriate with the STEM approach namely the Project Based Learning models. Learning strategies for integrating STEM education are identified as project-based, problem-based and inquiry-based learning. Through this learning model the students carry out a project in collaborative ways in yielding a product.

Keywords: STEM-Based; Science learning design; Curriculum.

1. Introduction

The curriculum has an important role in process of education. Curriculum has an important roles and influence learning activities as well. The National Curriculum (2013 Curriculum) equips Indonesian students to master 21st-century skills. They need to be prepared to have 21st-century skills such as critical thinking skill, creative, they are able to solve a problem, and make a decision and cooperative way through collaboration and communication [1]. The learning undertaken by teachers must be oriented toward the 21st-century learning that has the characteristics as follows: (1) learning approach centered on students; (2) students are taught to be able to collaborate; (3) learning material is associated with problems faced in daily life; and (4) in an effort to prepare students to be responsible citizens [2].

In achieving the above objectives it is necessary to have an approach that can accommodate 21st-century learning characteristics. One of the approaches that can accommodate 21st-century learning characteristics, and one approach that can accommodate the characteristics of 21st-century learning and strengthen the 2013 curriculum implementation, the STEM approach was adopted (Science, Technology, Engineering, and mathematics). What is STEM? STEM as an acronym for Science, Technology, Engineering, and Mathematics [3]. Science: the study of the natural world; Technology: any modification of the natural world made to fulfill human needs or desires; and mathematics: the language of numbers, shapes, and quantities that seems so irrelevant to many students [4]. Other definition of technology and engineering, technology is any modification of the natural world made to fulfill human needs or desires, and engineering is a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants [5].

Additionally, STEM education, as the world peoples’worldviews are changing, challenges the meaningful framework of it in its practical nature. Shilling in his reports through the Department of
Education of the US (2016)/[6] argues, “The complexities of today’s world require all people to be equipped with a new set of core knowledge and skills to solve difficult problems, gather and evaluate evidence, and make sense of information they receive from varied print, and, increasingly, digital media. The learning and doing STEM helps develop these skills and prepare students for a workforce where success results not just from one knows, but what one is able to do with that knowledge.” The movement and spirit of STEM Education then leads to an effort of building critical human capital competencies for a 21st-century economy. [7]

There are several STEM definitions put forward by experts that STEM is defined as combining scientific disciplines, technology, engineering, and mathematics [8]. STEM is an interdisciplinary field consisting of four disciplines namely science, technology, engineering, and mathematics [9]. Integration of STEM in class is a type of curriculum integration [10]. An expert stated that STEM is more than just a group of subject areas. This is a movement to develop deep mathematical and scientific foundations, students must be competitive in 21st-century work [11]. But this movement far surpasses students who are eager for certain jobs. STEM develops a set of thinking, teamwork, investigative and creative skills that students can use in all areas of their lives. STEM is not an independent class - this is a way to intentionally include different subjects throughout the existing curriculum [11].

The STEM approach helps teachers in teaching and learning. As one expert said, STEM education is a growing trend, many believe it can help teachers meet this challenge [3]. STEM integration has several characteristics in learning science. There are six characteristics of a great STEM lesson: (1) STEM lessons focus on real-world issues and problems; (2) STEM lessons are guided by the engineering design process; (3) STEM lessons immerse students in hands-on inquiry and open-ended; (4) STEM lessons involve students in productive teamwork; (5) STEM lessons apply rigorous math and science content your students are learning; (6) STEM lessons allow for multiple right answers and reframe failure as an necessary part of learning [4]. The STEM approach helps students and teachers in solving problems in learning. Some of the benefits of the STEM approach make students able to solve for better, innovators, investors, independent, logical thinkers, and literacy [12].

To apply the STEM approach to science learning many learning models can be used. Learning strategies for integrated STEM education have also been identified and classified as project-based learning, problem-based and inquiry-based learning [9]. Selection of learning model submitted to a teacher to adjust the characteristics of teaching materials.

In this paper only one class room is discussed to apply the STEM approach with the PjBL (Project Based Learning) model. The implementation of the PjBL model is considered in accordance with STEM and in line with the 2013 curriculum [10]. The PjBL model emphasizes contextual learning through complex activities, such as students' freedom to plan exploration of learning activities, carry out collaborative projects and ultimately produce products [11]. The PjBL model is a learning model that uses the object in learning. A project is carried out by students independently or in groups within a certain period, and produces products, and the results presented. The PjBL model collaborates with students and investigates teams of 4-5 people.

The skills will need and developed students in team is planned, organize, negotiations, and make the consensus concerning the tasks undertaken by each of team members. The skills will need and developed students were an essential skill as they foundation for the success of the project.

The Directorate of Junior High Schools conducted gradually in developing STEM-based science teaching materials. Until now the STEM learning unit in the junior high school science subjects was only two, namely the classification of material and its changes - making prototypes and energy and electric power - energy saving miniature homes. While the teacher's ability varies greatly in designing STEM-based science learning. Therefore, the authors consider that it is necessary to do Junior High School Science Learning Design to help them and participate in socializing them through seminars.

The rest of this paper is organized as follow: Section 2 discuss STEM-based science learning design in the 2013 curriculum. Section 3 concludes this work.
2. STEM-based Science Learning Design in the 2013 Curriculum

Before designing STEM-based science learning with the PjBL model, we must first equip ourselves with knowledge about STEM and PjBL. In the Preface section, several STEM definitions have been disclosed. As a strengthening of the STEM definitions, STEM is not only a practical strengthening of education in the STEM field separately, but rather develops an educational approach that integrates science, technology, engineering and mathematics by focusing the educational process on solving real problems in daily life and professional life [13].

Learning design with the STEM approach with the preparation of Learning Implementation Plans, consisting of basic competencies, indicators of competency achievement, learning objectives, prerequisite abilities, 21st-century skills development, development of strengthening character education, material analysis, learning scenarios (approaches, models, methods and descriptions activities) learning resources, tools and materials and assessment.

In this discussion not all Learning Implementation Plans were discussed, but only a few components. The teaching materials for the STEM approach must of course be adjusted to the characteristics of STEM learning. Not all topics in the curriculum can be taught using the STEM approach in accordance with their scientific characteristics [1] is shown in Table 1.

| Table 1. Identifies science, technology, engineering, and math |
|---------------------------------------------------------------|
| Science | Technology |
|----------|------------|
| 1. Factual : ..................................... | ........................................ |
| 2. Conceptual: .................................. | ........................................ |
| 3. Procedural: .................................. | ........................................ |
| 4. Metacognitive: ................................ | ........................................ |
| Engineering | Mathematics |
| .................................................... | ......................................... |
| .................................................... | ......................................... |

The following is a Learning Design with a STEM Approach [1], [2]:

2.1. Basic Competencies and Indicator of Achieving Competence

a. Basic Competencies
In this section basic competencies are written for the realm of knowledge and skills that are consistent with selected STEM topics.
b. Indicators of Achievement of Competence
In this section the formulation of competency achievement indicators is written in accordance with the Basic Competencies selected and written according to the indicator writing criteria.

2.2. Learning Objectives
This section describes the learning objectives according to the indicators formulated.

2.3. Analysis of STEM Learning Materials
This section identifies learning processes that are appropriate to the four domains of science, technology, engineering, and mathematics.

Description in the analysis section of STEM learning material as in the Table 1 above, it is quoted from Kelly and Knowless in [14] that integration between Science, Technology, Engineering, and Mathematics fields are described as follow:

a. Science
1) Understanding a problem and what might need to be investigate;
2) Generating questions that can be investigated;
3) Investigation with a purpose – experimentation, modeling, learning from cases, managing variable, accurate observation and measuring, seeing patterns;
4) Informed decision making, reporting on justifying conclusions;
5) Iteration toward understanding;
6) Explaining scientifically
7) Investigating planning;
8) Analysing and interpreting data from scientific investigation using a range of tools for analysis (tabulation, graphical interpretation, visualization, and statistical analysis) locating patterns.

b. Technology
1) Identifying criteria, problem specifications;
2) “Messing about” with and understanding materials;
3) Investigation for the purpose of application-designing and running models, reading and learning from case studies;
4) Informed decision making, reporting on and justifying design decisions;
5) Iteration toward a good enough solution;
6) Explaining failures and refining solutions;
7) Prioritizing criteria, trading them off against each other, and optimizing.

c. Engineering
1) Begins with problem, need or desire that leads to an engineered solution;
2) Using models and simulation to analyze existing solutions;
3) Engineering investigation to obtain data necessary for identifying criteria and constraints and to test design ideas;
4) Analyzing and interpreting data collected from test of designs and investigations to locate optimal design solutions.

d. Mathematics
1) Mathematical and computational thinking are fundamental tools for representing variables and their relationships. These ways of thinking allow for making predictions, testing theory, and locating patterns or correlations;
2) Mathematical and computational thinking are integral to design by allowing engineers to run tests and mathematical models to assess the performance of a design solution before prototyping.

2.4. Learning Design

Learning Design describes generally about the essential concepts, learning models, Scientific and Engineering Practice and the Crosscuting Concept which is used in the presentation of a topic with the STEM approach, presented in the Table 2.

Table 2 Learning Design

| Material/Topic | Essential Concept        | Description of STEM PjBL | Scientific and Engineering Practice | Crosscuting Concept |
|----------------|--------------------------|---------------------------|-------------------------------------|---------------------|

2.5. Prerequisite ability

This section explains the abilities that must be had before, both by the teacher and students before carrying out STEM learning on selected topics.

2.6. 21st- Century Skills Development
This section explains the 21st century skills that are trained in learning, namely thinking critically, thinking creatively, communicating, and collaborating. The description of each task is as follows \cite{2}:

1. Critical thinking developed when people who taking part in art activities, making, testing and improving products;
2. Creative thinking, developed when people who taking part in art activities, making, testing and improving products;
3. Communicate, which is developed when students doing a special discussion, making, testing and improving products and presenting them;
4. Collaborate, developed when people who taking part in art activities, making, testing and improving products;

G. Development of Character Education Strengthening

This section explains the values of Strengthening Character Education that are trained in learning activity, such as religious, nationalist, independent, integrity, and mutual cooperation. Description of each of the characteristics developed in learning as follows \cite{3}:

a. Religion, including gratitude, tolerance, confidence, not imposing a will, loving and maintain the integrity of God's creation;

b. Nationalism, including obeying the rules developed when students taking a lessons;

c. Independent, including hard work, creative and innovative, discipline, not giving up easily, and lifelong learners are developed when students carry out activities design, create, test, and improve products;

d. Integrity, including honesty and responsibility developed when students carry out activities to design, create, test, and improve products;

e. Mutual cooperation, including cooperation developed when students carry out discussion activities, gathering information, designing, creating, testing, and improving products.

2.7. Learning Scenarios

Learning steps are described for each class meeting into learning activities, syntax in STEM - PjBL learning model, activity description, and time allocation needed according to the number of meetings that have been determined. The following are the stages of the STEM - PjBL learning process (see Table 3) \cite{9}.

Phase 1. Reflection

The purpose of this first phase is to bring students into the context of the problem and inspire students to immediately begin investigating. This phase is also intended to connect what is known and what needs to be learned.

Phase 2. Research

The second phase is a form of student research. The teacher provides science learning, chooses reading, or other methods to gather relevant sources of information. The learning process occurs more during this stage, student learning progress concretizes abstract understanding of the problem. During the research phase, teachers often guide discussions to determine whether students have developed conceptual and relevant understanding based on the project.

Phase 3. Discovery

The discovery phase generally involves the process of bridging the information and information that is known in the preparation of the project. When students are independent and determine what is still unknown. Some STEM-PjBL models divide students into small groups to present possible solutions to problems, collaborate, and build collaboration between friends in groups.

Phase 4. Application

In the application phase the purpose is to test the product / solution in solving the problem. In some cases, students test products made from the conditions set before, the results obtained are used to correct
the previous step. In other models, at this stage students learn a broader context outside STEM or link between STEM disciplines.

**Tahap 5. Communication**

The final phase in each project in making products/solutions by communicating between friends and class. Presentation is an important step in the learning process to develop communication and collaboration skills as well as the ability to accept and apply constructive feedback. Often assessments are carried out based on the completion of the final step of this phase.

**Table 3: Learning Scenarios [5]**

| Learning Steps | Learning Model Syntax | Activity Description | Time Allocation |
|----------------|-----------------------|---------------------|-----------------|
| Preliminary    | Reflection            | Describe teacher and student activities ranging from introduction to cover according to the characteristics of learning activities with the STEM approach |                |
| Core activities| Research              |                      |                 |
|                | Discovery             |                      |                 |
|                | Application           |                      |                 |
| Closing        | Communication         |                      |                 |

2.8. **Learning Resources**

This section presents learning resources that are used as references in STEM learning in selected topics.

2.9. **Tools and Materials**

This section presents the needs of tools and materials used as references in STEM learning on selected topics.

2.10. **Learning Assessment**

This section identifies the techniques and forms of assessment used to see the achievement of Basic Competencies based on the GPA that has been formulated and the assessment instruments used.

2.11. **Bibliography**

This section presents various references used in compiling units according to the rules of writing bibliography.

2.12. **Appendix**

1. Student Worksheet
2. Teacher's instructions

3. Conclusion

Based on the results of the discussion above, it was concluded that the design of STEM-based science learning in the 2013 Curriculum integrates science, technology, engineering and mathematics designed to develop the skills of critical thinking, creative, communicating and collaborating, developing the strengthening of religious character education, nationalist, independent integrity and mutual cooperation as well.

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