Promoting engineering for fourth-grade students through STEM learning

S Sulistia*, D A M Lidinillah, A Nugraha and K Karlimah
Program Studi Pendidikan Guru Sekolah Dasar, Universitas Pendidikan Indonesia
Kampus Tasikmalaya, Jl. Dadaha No.18, Tasikmalaya 46115, Indonesia

*sintasulistia12@gmail.com

Abstract. Learning that uses conventional methods does not facilitate students in the engineering process and is deficient in technology. Learning that is dominated by conventional methods is not effective in achieving the demands of 21st century skills. The purpose of this study is to develop STEM learning products (Science, Technology, Engineering, and Mathematics) in Elementary Schools so that learning is more meaningful. Research that has been conducted using Educational Design Research methods by using the stages of research according to McKenney & Reeves consisting of Analysis and Exploration, Design and Construction, and Evaluation and Reflection. Data collection techniques were carried out with interview techniques, documentation studies, observations and questionnaires. After two trials of learning design in elementary school consisting of 50 students, it was stated that this learning design was valid, practical and usable. Even do, students and teachers responded positively to the implementation of STEM learning designs. This STEM learning design can be used as an alternative by the teacher in carrying out the learning process involving the process of engineering and technology so that it can meet the demands of skills in the 21st century.

1. Introduction
In the 21st century, technology and science are developing so fast that students are required to master it so they can face challenges in the future. Students are required to be able to master 21st century skills facilitated by a relevant education. Based on the results of the PISA and TIMSS studies, the thinking ability of Indonesian students in the Science and Mathematics field is still below the average of other countries. Meanwhile, in the 21st century science and technology innovation has become an important concern in various countries in gaining the advantages and challenges of globalization and an increasingly rapid knowledge-based economy [1,2].

One of the learning that is relevant to the development of 21st century skill is STEM education. “STEM” began as “SMET” was introduced by the National Science Foundation (NSF) to emphasize the importance of the four disciplines both as competencies of workers and student competencies [3]. Science, technology, engineering and mathematics are defined separately as follows [4].

- “Science is a body of knowledge about the physical and natural worlds. Scientists seek to describe, explain, and predict the natural world and its physical properties” (p.21).
- “Technology is the body of knowledge, artifacts, process, and systems that result from engineering. Technology are produced by humans to solve problems or meet needs and are the product of the process of engineering” (p.21).
“Engineering is the application of knowledge to creatively design, build, and maintain technology. Engineers seek to optimize solution for problems, need, and desired while considering resources and various constrains” (p.22).

“Mathematics is the “science of number, quantities, and shapes and the relation between them. Mathematics uses number and symbols to describe relationships between concept. Many other disciplines, including science and engineering, often uses “the language of math” (p.22).

STEM is the integration of the four disciplines thus producing a "meta disciplines". STEM education is a new approach to learning science and mathematics in an integrated manner [5]. Thus technology and engineering have an important role in making STEM education a learning approach that is greater than the four fields separately. In the context of primary and secondary education, STEM education aims to develop students who have the STEM literacy [6]. Engineering components are emphasized in the process and design of solutions are compared to the solution. Engineering is a method that encourages students to conduct discovery, exploration and problem solving [7], besides being expected to develop engineering habits of the mind such as system thinking, creativity, optimism, collaboration, communication, and attention to ethical considerations [8].

Studies have indicated that students become better problem solvers, display more positive and motivated learning, and improve in their mathematics and science achievements [9,10]. Specifically, through the integration of engineering, students should become more aware of its role and presence in society and be able to apply engineering design processes to the solution of real world problems [8]. STEM education to develop 21st century skills is not only to be developed at the college and high school level, but can be introduced to elementary school students. The importance of STEM education at the elementary level is getting stronger, although the teacher education preparation programs do not focus on STEM education [11].

Students have an interest tendency and curiosity towards engineering, so that the teacher can explore it through engineering activities in elementary school. In order for students to be involved in the design process, the teacher can use the engineering project to integrate various fields of science, including science, technology, mathematics, language, art, and history; foster problem-solving skills; involve students in project-based learning; and develop a child’s ability to function in three dimensions [12].

There are several reasons why engineering can be introduced to elementary students [4] that are: engineering helps children and improve their world; engineering fosters problem-solving skills and disposition; engineering can increase motivation, engagement, responsibility, and agency for learning; engineering can improve math and science achievement engineering promotes educational equity engineering has the potential to transform instruction engineering is included in state and national standards.

There are three approaches to the STEM learning approach that are commonly used and can be adapted for STEM learning in elementary schools, they include silo, embedded, and integrated approaches [13]. Integration in STEM education can be done in the form of content integration and context integration [6]. These two integration models are related to the elementary curriculum that is thematic-integrative based and uses a scientific approach. The Engineering design process for elementary students can be done in a five-step process that leads students to:

- Ask (define the problem and identify constraints);
- Imagine (brainstorm ideas and choose the best one);
- Plan (draw a diagram and collect materials);
- Create (follow the plan and test it);
- Improve (discuss possible improvements and repeat steps 1-5) [4]

Generally, the learning process only uses lecture and demonstration methods. Moreover, in elementary schools, the process involves the engineering and technology in the learning process has never been applied in the process of learning of Science and Mathematics. STEM learning is increasingly needed in order to prepare students to master 21st century skills, as well as serve as an innovation in education.
Teachers should be able to design instructional design depicting STEM learning process. However, all teachers claimed not to know what STEM learning in the learning process and have never designed a STEM learning design.

It has been stated that there are two things that are of concern regarding the problems in STEM learning in elementary schools, namely elementary school teachers have weaknesses in proficiency and confidence in teaching science and mathematics as well as the lack of science and math content learned by teachers in college to support STEM learning [14].

With these views in mind, learning design is needed specifically designed for STEM learning school to promote engineering for students in elementary schools.

2. Methods

The research method used in this study is Educational Design Research (EDR). Design research:

... is defined as the systematic analysis, design and evaluation of educational interventions with the dual aim of generating research-based solutions for complex problems in educational practice, and advancing our knowledge about the characteristics of these interventions and the processes of designing and developing them [15].

The definition of design research is a development study variant that is different from the form of validation study. There are three steps to EDR, namely: analysis and exploration, design and construction and evaluation and reflection.

The research subject STEM instructional design development are elementary schools involving as many as 50 students. The sampling technique in this study used a purposive sampling technique. Data collection techniques in this study were interviews, documentary studies, observations, questionnaires.

This research is a collaborative research consisting of research and development of instructional design, instructional media development, the development of an assessment rubric 4C respectively on the development of learning using STEM learning. In this paper, the research aims to produce STEM learning designs in Elementary Schools for the fourth grade of Elementary Schools.

3. Results and discussion

3.1. Analysis and exploration

The results of the analysis and exploration of the learning process in the classroom can be said that teaching and learning activities in elementary schools are still conventional, while the learning process requires engineering processes and technology in order to meet the demands of the 21st century, namely students must have the skills or 4C skills.

3.2. Design and construction

The step of developing this learning design is focused on several activities, namely: making design principles, determining Core Competencies and Basic Competencies, determining learning indicators and objectives, determining teaching materials, determining hypothetical learning trajectories, and designing prototypes the beginning of STEM learning design. The following are the learning steps in the initial prototype of learning design.

3.3. Evaluation and reflection

3.3.1. The first phase of teaching experiment. Pilot activities the development of STEM learning design aims to obtain an overview of the learning of instructional design have been made as well as to determine the practicality of the product.
Table 1. The first phase of teaching experiment.

| Engineering step process | Students Activity |
|--------------------------|-------------------|
| **Ask**                  |                   |
| The activity of observing and asking questions from a video about the discovery of a light bulb was followed by all the students with great enthusiasm, this was proven by students answering a number of questions posed by the teacher. | ![Image of students engaged in an activity] |
| **Imagine**              |                   |
| At this stage, the teacher to demonstrate how to create media as well stringing Lakaraya to be made by each group. | ![Image of students with materials] |
| **Plan**                 |                   |
| Students from each group were asked to take the tools and materials needed to make a crocodile battery carbon lamp. | ![Image of students working on a project] |
| **Create**               |                   |
| Students begin to make products such as Carbon Batteries Lights Crocodile (Lakaraya) in accordance with the instructions contained in the work sheet which starts from making tubes of cardboard, clamping mechanical pencil lead, stringing 8 batteries, until the leads were turned on like a light bulb. | ![Image of students working on a project] |
| **Improve**              |                   |
| Students are asked to repeat the experiment 3 times. This is so that students can find out the location of the mistakes they made in the previous experiment and can correct those errors. | ![Image of students working on a project] |

3.3.2. **The first phase reflection.** Based on the trial 1st learning has run smoothly, but there are still some shortcomings that need to be improved so that learning can run smoothly and more optimally. The teacher's response to the design of learning made by the researcher, as a whole the learning steps that have been designed are relevant to the material. In addition to the response of teachers, researchers are also asking for a response from the students related to learning experienced by students during testing 1st. Positive response from the students and they were delighted.

3.3.3. **The second phase of teaching experiment.** The 2nd trials conducted after the repair to the products developed by the researchers is the design of STEM learning.
Table 2. The second phase of teaching experiment.

| Step Process Engineering | Students Activity |
|--------------------------|------------------|
| **Ask**                  | Students observe videos about the discovery of lightbulbs. From the video, the teacher with students doing debriefing. |
| **Imagine**              | The teacher demonstrates how to create Lakaraya. The teacher also asks several students to help the teacher. |
| **Plan**                 | Students are directed to take the tools and materials needed to make Lakaraya. |
| **Create**               | Students begin to work together to make LAKARAYA in accordance with the instructions on the Student Worksheet (LKS). |
| **Improve**              | Students try again or find out errors made when making Lakaraya, so students can correct these errors and not repeat mistakes in the future. |

3.3.4. The second phase reflection. The teacher's response to the implementation of the STEM learning design, as a whole the learning process includes all the material to be conveyed, besides that the material is well conveyed. The researcher also asked for a response from students to the learning that had been carried out. Students respond positively to learning in trial 2. So that students' responses to learning that have been designed by researchers are stated to be better than before.

Based on the trials that have been done twice on the design of STEM learning, it turns out that the STEM learning design is suitable for use in the current curriculum. STEM Learning Designs have valid criteria based validator expert, practical, so it can be used at Elementary School. The STEM Learning Design produced in the form of a Learning Implementation Plan STEM consisting of steps of learning. The steps of learning in the design of STEM learning have been developed using five steps of the engineering process for elementary students, consisting of ask, imagine, plan, create, and improve.

4. Conclusion

Based on the results of the research and development of the design of STEM learning with the media namely Lakaraya, the response was very positive. This learning is able to enable students to think according to the demands of the 21st century students must have 4C skills. The design of STEM learning is emphasized by the scientific approach according to the curriculum.
References

[1] L D English 2016 STEM education K-12: perspectives on integration Int. J. STEM Educ., 3 1 1-8
[2] M Honey, G Pearson and H. Schweingruber 2014 STEM Integration in K-12 Education (Washington DC : The National Academies Press)
[3] N Z Chesky and M R Wolfmeyer 2015 Philosophy of STEM Education A Critical Investigation
[4] C Cunningham 2018 Engineering in elementary STEM education: Curriculum design, instruction, learning, and assessment (Columbia: Teachers College Press)
[5] E L Mann, R L Mann, M L Strutz, D Duncan and S Y Yoon 2011 Integrating Engineering Into K-6 Curriculum J. Adv. Acad., 22 4 639–658
[6] R W Bybee 2013 The Case for Education Challenges and Opportunities (US: NSTA)
[7] R M Hall Engineering in K – 12 Education 1–85
[8] National Academy of Engineering and National Research Council 2009 Engineering in K-12 education: Understanding the status and improving the prospects
[9] J M Furner and D D Kumar 2007 The mathematics and science integration argument: A stand for teacher education Eurasia J. Math. Sci. Technol. Educ., 3 3 185–189
[10] K Stinson, S S Harkness, H Meyer and J Stallworth 2009 Mathematics and Science Integration: Models and Characterizations Sch. Sci. Math., 109 3 153–161
[11] E Smyrnova-trybulska, N Morze, P Kommers, W Zuziak and M Gladun 2016 Educational Robots In Primary School Teachers ’ And Students ’ Opinion About STEM 197–204
[12] C M Cunningham and K Hester 2007 Engineering is Elementary: An Engineering and Technology Curriculum for Children Eng. Educ., 1–17
[13] A Roberts and D Cantu 2012 Applying STEM Instructional Strategies to Design and Technology Curriculum PATT 26 Conf. Technol. Educ. 111–118
[14] S Blackley and J Howell 2015 A STEM narrative: 15 Years in the making Aust. J. Teach. Educ., 40 7 102–112
[15] T Plomp 2013 Educational Design Research: An Introduction in Educational Design Research : part a: An Intraduction 16