1. Problem

According to the results of PISA 2012, the rank of Japanese students' skills was dropped in mathematics, reading, and science fields (OECD, 2014) even though the score of PISA had increased. It means that education system of other countries have improved more than the Japanese education system. It could be affected by less innovation of lessons in STEM subjects. In the youth stages of students, authentic learning is fundamental for triggering and adaptation to the next life and the evolution of technology (Moye, et. al., 2014). Students must possess their own life and develop thinking skills to solve problems and issues in the future.

The learning in this new era, scientific experiments are not sufficient to improve students' 21st century skills, but how to apply scientific concepts to design the technologies or products is required. The change of human life will be accompanied by the evolution of technology. Therefore, students have to be prepared for the future challenges. Scientific inquiry and engineering practices are required to encourage students to be a citizen who can adapt to new conditions (Bybee, 2013).

The goals of this study were to investigate effectiveness of learning materials and STEM lessons in triggering students to improve their 21st century skills. 21st century skills are needed to improve students' strategies and solutions, because most of success cannot be achieved by one action, but need more actions.

2. Methodology

The participants were ten middle school students in the third grade. They were divided into three groups. The instruments were worksheets to explore students’ initial knowledge about the separation of mixtures, especially crude oil, because crude oil is very important for human life. Another worksheet was consisted of designing, understanding of concepts, and impression of the STEM lessons. Besides worksheets, students provided 3 plastic bottles, scotch tape, net, bottle caps, electric blower, and mixtures (sphered styrofoam and plastic balls with different sizes).

The questions of worksheets were as follows: state of crude oil in the earth, the products from crude oil, how to separate new materials from crude oil, design of model for separating tools, also students were asked to evaluate effectiveness of tools and to redesign the model. Finally, students were asked to develop the theory of distillation, and impression of STEM lessons.

In these lessons, students not only had to write worksheets, but also had to design a tool to separate mixtures (sphered styrofoam and plastic balls). Students were given more than one chance to design the best product for separating mixtures. Mixtures (three different sizes of samples) were blown from below in order to describe the processes of distillation.

[Abstract] This research is to investigate the effectiveness of learning materials and lessons plan to provide understandings of separating mixtures by using STEM education approach. Furthermore, this is to define creativity, critical thinking, and metacognition of students. In these lessons, the participants were 10 middle school students divided into three groups. Students were asked to separate the mixtures (sphered styrofoam particles and plastic balls with different sizes) by using tools that made by students. Students had to design tools from plastic bottles. Students were given opportunities to try their products, and then redesign it. In order to collect data, students had to draw their designs in the worksheets. The results showed that students failed in the first attempt, because they did not consider the different sizes of mixtures. However, in the second attempt, they started to design tools that they considered the sizes of the mixtures. Due to the time limitation, they could not separate them completely. Their ideas and strategies will change after they develop and try their product. Therefore, these lessons provide students to improve their 21st century skills.

[Keyword] STEM education, authentic learning, creativity, critical thinking, metacognition
The lessons were conducted for 80 minutes in June 2015. The worksheets and their products were analyzed to know the effectiveness of learning materials and the lessons in providing students understanding of distillation and improving assessment skills.

3. Results and Discussion

According to the data, students only knew that the crude oil was in beneath the earth. However, they did not know the state of crude oil. After teacher showed the real state of crude oil, students knew that crude oil was a black solution. Few students assumed that crude oil came from tree fossil. However, crude oil usually comes from the large quantity of dead small organisms (zooplankton and algae). Furthermore, most of the students knew about the new materials from crude oil.

The third question about the method to separate crude oil. Students said that is explained in first grade science textbook, and then all of the students opened the science textbook; it meant that students remembered the contents of the textbook. This evidence showed that Japanese textbooks have a good effect on students' knowledge.

In designing separation tools, all of the students failed to separate the mixtures (sphered styrofoam particles and plastic balls). Students did not design a filtering system to separate the mixtures, because they did not consider different sizes of mixtures in the first attempt.

In the second attempt, there was one group who started designing of filtering system with holes of different sizes. This group had a good strategy to reach the goal of the task, even though they could not finish the task completely. Another group designed the product creatively, but the results were not effective. They did not understand what they needed to reach the goal of the task. To design products (engineering practices), students need not only creativity, but also critical thinking and metacognition. Based on the processes of each group to design a product, all three groups had showed good creativities, however, only one group had critical thinking and metacognition.

Due the time limitation, students could not finish making tools on time, so teacher could not assess their conceptual understanding. It means that STEM approach needs more time for reaching goals of learning.

![Picture a](image1.png), ![Picture b](image2.png), ![Picture c](image3.png)

Students' redesigns of filtering tool. (a) Making different size holes on bottle cap for first and second steps. (b) Reduce blower power. (c) Arrange bottles not straightly.

Each group had different ideas. These showed that they have creativity to make another way. However, effectiveness and efficiency of their products were different. These learning environment will improve students' 21st century skills.

Students' impressions prove some suggestions to develop next lesson plans and learning materials. There were some impressions in these lessons as follows: limitation of materials made students difficult to design products (good creativity skills, but few critical and metacognitive thinking); in order to make products, designing is important; time is not enough; considering all aspects is important; and using daily life materials to understand concept is interesting. It means that STEM education offers a new atmosphere in learning environment. Therefore, students have increased their interests in learning science through STEM education approach.

4. Conclusions and Next Problems

This research concluded that STEM education approach in science learning provides opportunities to improve 21st century skills among students effectively, however, these lessons need more time to complete the goals of learning. Furthermore, each student has different levels of thinking skills and, especially in critical thinking and metacognition. For next research, the participants should be more than 100 students to identify effectiveness of STEM education statistically.

References


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