



## How Students Apply Their Science and Technology Concepts in Developing Blind Stick through STEM Project?

Lukman Nulhakim<sup>1</sup>, Reza Setiawan<sup>2</sup>

*SEAMEO Regional Center for QITEP in Science, Indonesia*

<sup>1</sup>Head of Information, Data and Evaluation, SEAMEO Regional Center for QITEP in Science.

<sup>2</sup>Deputy Director for Programme, SEAMEO Regional Center for QITEP in Science.

### Abstract

STEM education plays an important role in developing the 21st-century skills of the students moreover it can also increase students' understanding of science and technology concepts and how to apply their knowledge to solve a real-life problem. The improvement of students' increased understanding of concepts is hypothetically linked to the engineering design process that happened in STEM learning. This study aims to identify how students apply their prior science-technology concept to develop a smart blind stick through the engineering design process (EDP). The descriptive case study method includes direct observations, interviews, and documentation analysis in three STEM lessons of 30 high school students were conducted. During three STEM lessons, students are improving their skills to apply their prior science concepts to solve the challenge, students also introduce to knowledge of coding in order to develop a smart blind stick project. This study shows an example of how the engineering design process facilitates the application of science-technology knowledge in solving given problems. To support the learning process the teacher uses scaffolding techniques and optimizes the engineering design process, especially at the research step.

**Keywords:** Engineering Design Process, Scientific Knowledge, STEM Project Based Learning

### Introduction

In today's world, attention to STEM education is increasing rapidly. STEM is a learning-based approach on the idea of educating students in integrative four specific disciplines — Science, Technology, Engineering, and Mathematics. STEM education aims to prepare students with essential skills to have the adaptability to the constant needs of this fast-growing society. It is strongly believed that competent and creative STEM practitioners will be needed in the future to disentangle the world's problems (National Research Council, 2014). To welcome the challenges in this uncertain future, SEAMEO QITEP in Science abbreviated as SEAQIS also has attention and concern in developing STEM education, especially in Indonesia.

Since 2018, SEAQIS has developed the STEM learning approach that can be integrated into the existing curriculum. Since STEM education has not been specifically defined and integrated into Indonesia's curriculum so far, SEAQIS examines the characteristics of STEM education that can be implemented in science learning in the classroom. From all the complex characteristics of STEM, SEAQIS believes that the Engineering Design Process (EDP) is the main characteristic that can help students improve their knowledge and skills, especially 21st-century skills. EDP facilitates students to apply the knowledge that can be used in solving contextual problems (King & English, 2016; Jolly, 2017).

King & English (2016) also stated that the engineering design process is an iterative process for formulating solutions to problems based on engineering principles by utilizing engineering thinking so that it is not only focused on designing technological solutions. Students not only need skills that are able to connect across disciplines, but they also need prior knowledge and skills to apply them to the design process. Preparing students to be competent in applying and integrating knowledge from multiple sources to solve engineering design problems is at the heart of a successful approach to STEM integration.

The evidence of successful STEM integration in the context of Indonesia's classroom has been collected. Every year SEAQIS organizes training to improve teacher competence in integrating STEM learning into the 2013 Curriculum. This training has successfully produced an output of STEM learning implementation in the classroom and has significant impact on improving the quality of learning. The other product of STEM implementation in the classroom is STEM-based products that have been developed by students through EDP, such as smart watering systems and blind sticks. However, in principle, these sole products developed by students couldn't provide a specific picture of how students apply their prior knowledge in making these products through EDP. Therefore, this study aims to identify how 12th-grade students apply their prior knowledge of the STEM concept to develop a smart blind stick through the EDP.

## **Method**

This research uses a descriptive case study method. One science teacher and student from grade 12 have stated their consent and actively participated in this study. The participants were 30 students (18 girls and 12 boys) of a Senior High School, Bandung, Indonesia. Data collection techniques include interviews, direct observations, and documentation analysis. The observation was used to collect data on students' learning processes. It is also a tool used regularly to collect data by teacher-researchers in their classrooms (Kawulich, 2012). The observation was used to collect data on the classroom learning scenario, implementation of the engineering

design process, and application of the science-technology concepts in STEM learning. Additional data from interviews of a teacher and ten students were obtained to gather an in-depth understanding of the STEM learning process.

## **Results and Discussion**

### **Observation of STEM Learning Process**

The observation of the learning process was started from lesson planning. The science teacher developed a STEM learning project which requires students to design and build a smart blind stick to help a visually impaired person to walk easier. Learning is designed by combining Science, Mathematics, and Technology through the engineering design process in a science subject. Students were granted access to learning resources such as personal computers, electrical components, and the Arduino microcontroller.

This learning activities with STEM project was carried out in three consecutive lessons. To optimize the learning process, the first and second lesson were focused on simple hands-on activities that provide students with experiences to understand new concepts and recall their prior science and technology concepts. In term of engineering design process, these first and second lesson consisted of three steps which are define the problem, research, and imagine. For the third lesson, students focused on planning and creating smart blind sticks collaboratively. Then, students created, tested & evaluated the blind stick. At the end of the lesson, students communicated their product.

The first lesson consisted of three simple activities, namely: a blink LED, a flip flop, and a traffic light. These three activities are initial phase for introducing students to coding knowledge and how to apply their prior science concepts in the smart blind stick project. Within this activities students could apply their prior science knowledge on dynamic electricity, closed electrical circuits, series and parallel circuits, and sound waves. These science concepts were given in previous lessons so that students that develop a smart blind stick would use their understanding of the concept to solve the problem. This meeting also led students to develop an understanding of new knowledge, a knowledge of coding.

The first activity was the LED blink activity, in this stage, students were equipped with a guided students' worksheet where students could follow all the direct instructions to make the LED light flash. Due to clear instruction on the worksheet, all the students effortlessly turn on the LED as ordered. The second activity was a flip flop, not significantly similar to the previous one, this activity levelling up the students to follow their instruction that translated as coding block code. Students are asked to re-create the source code that already provided by the teacher to turn on the red and yellow LED alternately. Most of the students were successful, yet two groups failed in this challenge. Based on the observation, there are two alternate reasons why the group couldn't accomplish the task. First, they likely misplaced the LED in the electrical circuit, and second, they presume incorrectly typed the source code. The teacher guides these two groups to evaluate their work and improve it, hence they able to successfully finish the task on the second attempt.

The last activity in the first lesson is a traffic light project where students are expected to make LED traffic lights (red, yellow, green LED to turn on alternately). No direct instruction or source code was provided in this activity. Students develop their own source code from scratch. In this challenge, all the group successfully making traffic lights as instructed. Some students had difficulties at first, fortunately, they were successful in the second or third attempt. Something that worth taking note of is the way students tried to fix the error themselves rather than asked their teacher for help.

A similar learning strategy with the first lesson was applied to the second lesson. There are three simple activities conducted in order to attune the students more with the idea of the engineering design process with Arduino. The activities were to turn on the bell, connect the proximity sensor, and project to find out the maximum distance of the sensor. In this meeting, students are expected to apply the science concept of sound waves. The teacher assumes the students already have a steady understanding of the concept as it has been learned by the students at the previous meeting. Unfortunately, students failed to apply this concept and complete the challenge. Due to

a class failure, the teacher decided to give a brief reminder of the science concept to guide the students developed their new solution. Interestingly, even the majority of the student couldn't internalize the concept of the sound waves to the activity, they have no issues implementing source code into the Arduino program. There are still several mistakes in the first attempt, yet students can overcome the problem and fix it themselves. It is strongly believed, the coding experience they got from the first lesson contribute to their better performance in the second meeting.

After students complete the activities in the second lesson, as the take-home task students were asked to design and make the smart blind sticks. They are asked to complete all design and construction processes at the third meeting. To get the best design, students are requested to make a sketch individually, present their sketch to their group, and the group will choose the best design to build. During the design process, students are guided to apply all the science concepts and knowledge of coding they got from the previous meeting. Each group was asked to design a blind stick sketch and an Arduino program. All groups work independently as they design, build, and test their project. Teacher interception is limited to the very minimal. In the third meeting, each group presented their project. It is observed that all the students succeeded in making the smart blind stick on their own.

The impressive thing is that each group creates a different solution for the same challenge. Some products use a combination of a bell and an LED, while others use a bell only as an indicator of distance. There are also some groups that make simple ringtones as indicators. This variation is not directly instructed in the student worksheet. Students use their prior science knowledge, knowledge of coding, and creativity to create a differentiator of their products. Regardless of the difference between the design and the actual product, students were satisfied with their product. Their final product resembles a design sketch in distance and coding indicators.



Figure 1 Documentation of students' product of smart blind stick.

- a. Students presented their blind stick,
- b. Students discussed source codes to run a program
- c. Students created a blind stick

## Discussion

This study shows an example of how students in grade 12 can be involved in STEM learning through the engineering design process and the role of science-technology knowledge in solving given problems. To provide meaningful STEM learning and enhance students' understanding and skills, teachers develop a smart blind stick project. With this project, teachers provide students with plenteous opportunities to explore and apply their prior science knowledge and new technology concepts through engineering design process, especially research step.

The statement was supported with the observation result that shows from two of the three lessons teacher are focused on the application of scientific concepts and understanding new technological concepts. While in the last lesson, the teacher encourages students to plan and create the blind stick solve a real-life problem by using their understanding of science-technology concepts that obtain before. The evidence also comes from student worksheets. Worksheets consist of simple activities and structured instructions related to the engineering design process. In terms of difficulty level, the level was increasing where the first activity is the easiest in every lesson. Through these activities, students are prepared for the skills and knowledge also provide more time to do research and obtain useful information that can be applied to design the smart blind sticks project.

Based on these two findings, the research obtains new insight on how the students can be succeeded in making smart blind sticks by applying the knowledge or science concepts through the engineering design process. The knowledge and skills of coding play a significant role in the smart blind stick project. In coding applications, students first get engaged in coding in a block-based program that works with the drag-and-drop system, and these codes are put into Arduino to make the smart blind stick able to function properly (Cakir & Guven, 2019). The application of the science concept and knowledge of coding cannot be separated from the role of the teacher who uses scaffolding techniques and optimizes the engineering design process, especially at the research step. These findings in line with previous research by King & English (2016) that reported the use of the engineering design process in elementary schools to build optical instruments by applying the STEM concept. The results show that students can apply core STEM concepts through design sketches, experiment through the construction phase, and apply structural changes to their designs through the redesign process. All the mentioned steps are part of EDP.

In this study, when the teacher directs students to do EDP through instruction on the worksheet, the students simultaneously reinforced the science and coding concepts they had previously

learned. Likewise, when students design and manufacture smart blind sticks with EDP stages, students indirectly have applied knowledge of scientific concepts. At this point, understanding and applying initial knowledge is an important key to helping students solve problems successfully.

### Conclusion

The application of the STEM concept is an important feature in STEM learning to solve a problem. In this case, the problem is making the smart blind stick. The use of the engineering design process, especially the research step gives students the opportunity to apply the science-technology concept and strengthening their engineering and mathematics skills. During the research step, the teacher provides a variety of simple activities that allow students to recall and apply STEM concepts simultaneously. Providing a variety of simple activities is the teacher's way of designing the application of STEM concepts. Through this combination, namely optimizing the engineering design process and scaffolding techniques, students are able to apply the STEM concept in designing and making smart blind sticks. However, students have different endeavors to complete projects successfully.

This study is a case study and only uses one class that implements STEM learning. So it cannot be generalized whether the learning outcomes will be in accordance with other conditions. It is recommended that further research be extended to other classes or schools that have not implemented STEM learning, in order to obtain more information about the application of STEM concepts through the engineering design process.

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