Implementation of KS-STEM Project: Bridging the STEM curriculum into Science education

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Abstract. Currently, interest in STEM education is growing in the world. In Indonesia, STEM practice is gradually developing. Through the partially “KS-STEM Project”, this study was addressed. The project is a longitudinal cross-country project between Taiwan and Indonesia. In regards to the three philosophical foundations (epistemology-ontology-axiology), this study addresses three research questions, as follows: 1) To what extent does the Fuel Cell Car Science Kit facilitate junior high school students’ understanding of the essence of STEM education; 2) To what extent do the students’ outcomes deal with fuel Cell Car Science Kit; 3) What topics can students learn from the Fuel Cell Car Science Kit. The research used a descriptive qualitative approach by using instruments: “Fuel Cell Car Science Kit” as a STEM kit. Participants of the study included 32 junior high school students in East Java, Indonesia. The results of the study included: (1) the description of how STEM Kit facilitates the students’ understanding of the essence of STEM education; (2) the students’ outcomes dealing with the STEM Kit; and (3) several topics that students learn from the STEM Kit. The implication of the current study is to introduce and to involve Indonesian students, especially junior high school students to STEM education.

1. Introduction

According to the NARST strands, there are fifteen (15) issues majoring in science education. One of them is science learning in informal contexts. This strand is specified for teaching and learning in community programs, after-school programs, outdoor settings, museums, and communications media. The strand is also giving more opportunities among science educators and science researchers to integrate science, technology, and society. However, technology and society are not enough, we need mathematics and engineering. In other words, we need the integration of science-technology-engineering-mathematics (STEM).

The term “STEM” began as “SMET,” standing for science, mathematics, engineering, and technology. In the 1990s, “the National Science Foundation (NSF) revised the term in order to emphasize the importance of these four separate disciplines” [1]. “The acronym was changed into STEM to help promote it, yet there is still a considerable number of Americans that associate STEM with stem cell research” [2]. Throughout the last decade, there has been developing of interest in STEM education [3]. Currently, the acronym “STEM” literally stands for science, technology, engineering, and mathematics. It can be defined in two ways: “(1) the more traditional way, it is the individual ‘sil’ fields of science, technology, engineering and mathematics education; and (2) the concept of integrated STEM education; it includes the teaching and learning practices when the subjects are purposefully
integrated” [4]. This new strand has a strong philosophical foundation. Chesky and Wolfmeyer [2] addressed the epistemology, axiology, and ontology of STEM as a singular unit as shown in Figure 1.

![Figure 1. Epistemology, axiology, and ontology of STEM (reorganized from Chesky and Wolfmeyer [2])](image)

The teaching and learning process in STEM realizes through blended unilaterally or one filed may be the dominant base field. Therefore, the elucidations of its exact meaning very broadly. These range from very specific (e.g., mathematics, physics, chemistry, biology, information sciences, and engineering) [5] to very extensive (e.g., “an across the discipline of practices and processes that transcend disciplinary lines and from which knowledge and learning of a particular kind emerges”) [6]. Therefore, understanding across disciplines is a very important aspect of STEM education.

Recently, the concept of STEM became popular in Indonesia. The STEM practice is gradually developing in Indonesia [7], such as “a partnership program between local schools in Riau province and Honeywell about science and technology” [8]; “an ongoing project between Columbia University and the Institut Pertanian Bogor to improve the teaching of STEM in Indonesian high schools” [9]; and “an innovation strategy to build students’ disaster literacy through STEM-D (Science, Technology, Engineering, Mathematics and Disaster) Education” [10]. However, “some of these programs were more emphasized on the secondary and higher education rather than lower levels of education, such as elementary and junior high school” [7]. For the young generation, Bottia et al. [1] endorsed that “the feasible approaches for inspiring, reinforcing and preparing more of the nation’s youth to choose a STEM pathway for their futures”. Therefore, this study dedicated to junior high school student in principal integrating STEM education.

Through the partially of “KS-STEM Project” (KS = Ku-Suprapto), this study was addressed. The project is a longitudinal cross-country project between Taiwan and Indonesia. The objectives of the project are to: “(1) provide all students with skills needed for success in the 21st century; (2) improve academic performance; (3) narrow achievement gaps; and (4) foster potential interest in STEM professions” [7]. For practicality, the Fuel Cell Car Science Kit was utilised to integrate between formal science curricula in junior high school and STEM education in this research. “The Kit guided students to invent their own clean energy applications using fuel cells and renewable hydrogen created using
solar energy and water. The set was equipped with a complete curriculum on renewable energy with easy experiment, manual kits and background history on the technology. The sub-topics of the experiment include the effect of heat on solar panels, finding the solar panel’s maximum power, electrolysis mode (generating Hydrogen and Oxygen from water) and fuel cell mode (generating electricity from Hydrogen and Oxygen)” [7].

Based on the rationale above, the aim of the current study is to introduce Indonesian students, especially junior high school students to STEM education. Finally, in regards to the three philosophical foundations above, this study addresses three research questions, as follows:

1) To what extent does the Fuel Cell Car Science Kit facilitate junior high school students’ understanding of the essence of STEM education?
2) To what extent do the students’ outcomes deal with Fuel Cell Car Science Kit?
3) What topics can students learn from the Fuel Cell Car Science Kit?

2. Method
Participants of the study included 32 students grade eight from East Java, Indonesia. The research used a descriptive qualitative approach by using instruments: STEM-Fuel Cell Car Science Kit. The apparatus was developed by Horizon Educational Company.

2.1. Fuel Cell Car Science Kit
The STEM- Fuel Cell Car Kit empowers students to ascertain the principles behind the real-scale fuel cell vehicles currently being rolled out across the globe. “A reversible Proton Exchange Membrane (PEM) fuel cell first electrolyzes water to separate oxygen and hydrogen molecules, this hydrogen is then converted into electrical energy to power the car” [11-12].

2.2. KIT contents
The Fuel Cell Car Science Kit consists of: “chassis with LED light & motor, reversible PEM fuel cell, Hydrogen tank, Oxygen tank, inner gas containers, 0.75 Watt solar cell, 2 x 2mm connecting leads, battery pack with connecting leads (2 X AA batteries), plastic plug pins for fuel cell, and transparent silicon tubing” [11]. Figure 2 shows the STEM: fuel cell car apparatus.

Figure 2. STEM - Fuel cell car apparatus

3. Result and Discussion

3.1. To what extent does the Fuel Cell Car Science Kit facilitate junior high school students’ understanding of the essence of STEM education
The Fuel Cell Car Science Kit provides an activity that makes it possible for the students to experience and sense the STEM education. Through the following student’s activities, they got the meaning of being a STEM member. Totally, we train 9 activities (see Table 1) to students in order to explore the physical variables based on the prototype of fuel cells car. By implementing the learning model of guided inquiry, the students got the meaning about the essence of STEM, the interconnection among science in a fuel cell, math in a fuel cell, technology and engineering in a fuel cell. The guided inquiry was chosen as a learning model because of the educational level of students in junior high with the main character is the transition from concrete to abstract thinking.
### Table 1. Some activities from STEM kit.

| Student activities                                                                 |
|------------------------------------------------------------------------------------|
| “Assembly and operation of the kit”                                                |
| “The Effect of Heat on Solar Panels”                                              |
| “The Effect of Shade on Solar Panels”                                             |
| “The Effect of Tilt Angle on Solar Panels”                                        |
| “Finding the Solar Panel’s Maximum PowerPoint”                                    |
| “Electrolysis Mode Generating Hydrogen and Oxygen from Water”                     |
| “Fuel Cell Mode Generating Electricity from Hydrogen and Oxygen”                   |
| “Determining the Minimum Voltage for Water Decomposition”                         |
| “Polarization States for Hydrogen Fuel Cells”                                     |

#### 3.2. To what extent do the students’ outcomes deal with fuel Cell Car Science Kit?

To answer the second research question, through student activities in class which clearly exhibits the science of electrolysis and the breakdown of water into oxygen and hydrogen. The following is the example of student outcomes that include a solar panel for powering electrolysis.

**Objectives:** “Build and test a hydrogen fuel cell car to explore the concepts of electrolysis and renewable energy” [11-12].

**Materials:** Fuel cell car science kit, distilled water, stopwatch

**Procedure:**

These discussion questions will help you assemble your car. Read each of them carefully and discuss your responses with your group, then use your answers to put your car together. As you assemble your car, write down any interesting observations you have in the Observations section below.

1. The body of your car (attached to the motor) has many places where other pieces can attach to it. Discuss with your group where you think individual pieces should go.
2. Where would you attach the wheels? Does it matter which wheels go where?
3. How would you attach the H₂ and O₂ cylinders to the body of the car? Does it matter where they go?
4. Look at the fuel cell. It has two short tubes attached to it. Are there any other places on the fuel cell where you could attach the longer pieces of tubing?
5. When turned on with electric current, the fuel cell will produce hydrogen and oxygen gas from the water inside it. How will you trap the gas so that it doesn’t float away?
6. What source of electricity will be better at separating the hydrogen and oxygen in the water: the solar cell or the battery pack? How should the electricity source be connected?
7. How do you know when the fuel cell is generating hydrogen? How can the hydrogen be used to power the car?

**Observations:**
Write down anything interesting you observe while building or running the car.

Once your car is assembled, see how long it will run on its hydrogen fuel. Try making more hydrogen and running the car again. How long can you get the car to run? Try at least four times and write your results in the Data Table 1.

Try and make some changes to the car to make it run faster. Could you increase its fuel capacity? Can you decrease friction in some way? Does it matter what kind of surface it runs on? Discuss some possible changes you could make to your car and run your experiment to see if your changes result in a longer run time. Put your results in the second Data Table 2.

**Figure 3.** Sample of procedure in a fuel cell car experiment in the student worksheet.
3.3 What topics can students learn from the Fuel Cell Car Science Kit?
There are two main topics students can learn from the Fuel Cell Car Science Kit, namely electrolysis and fuel cell itself. The following are the example of student handbook in STEM class project (see Vignette 1 and Vignette 2).

Vignette 1. Electrolysis

The simple process of electrolysis is shown in Figure 5. Electrolysis is a process in which an electric current can decipher an electrolyte substance. That is, the electrolysis process changes in electrical energy into chemical energy (redox reaction). There are three main characteristics of an electrolysis process, which are as follows.

a. The presence of free ions in an electrolyte solution. These free ions will receive or give electrons which are flowed through the solution.

b. There is an external DC current source, for example, a battery.

c. It has two electrodes, namely the cathode and the anode, in the electrolysis cell.

In electrolysis cells, the cathode functions as a place for the reduction reaction and as a negative pole, while the anode is the place for the oxidation reaction and as a positive pole.

Figure 4. Sample of the data table for students in the student worksheet.

Figure 5. Standard electrolysis [11-12].
Vignette 2. Fuel Cell.

Figure 6. A single “Proton Exchange Membrane (PEM)” fuel cell configuration [11-12].

4. Conclusion
There were some conclusions of the study. Through the partially of “KS-STEM Project”, this study was addressed. The project is a longitudinal cross-country project between Taiwan and Indonesia. The objectives of the project are to: “(1) provide all students with skills needed for success in the 21st century; (2) improve academic performance; (3) narrow achievement gaps; and (4) foster potential interest in STEM professions”. For practicality, the Fuel Cell Car Science Kit was used to integrate between formal sciences curricula in junior high school and STEM education in this research. The main
findings of the study included some description: (1) the STEM Kit facilitates the junior high school students’ understanding of STEM education; (2) the students’ outcomes dealing with the STEM Kit; and (3) several topics that students learn from the STEM Kit. The implication of the current study is the KS project engages Indonesian students, especially junior high school students to STEM education.

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