Engineering design model: Environmental problem-solving ability, motivation and student perceptions

C Sutia¹,²*, D F Suparyana³ and S Sagita⁴

¹Departemen Pendidikan Biologi, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
²SMAN 1 Parongpong, Jl. Cihanjuang Rahayu No. 39, Kab. Bandung Barat, Indonesia
³SMAN 1 Ngamprah, Jl. Kenanga Raya PCI 2, Kab. Bandung Barat, Indonesia
⁴Temasek Independent School, Jl. Sindang Sirna No. 8, Bandung, Indonesia

*jajakabelekok@gmail.com

Abstract. This study aims to describe students' learning motivation, student perceptions and students' ability in designing problem solving of environmental pollution through learning of EDM. This is a descriptive study which involved 60 high school students in the West Bandung regency. Students were divided into two groups: EDM 1 and EDM 2. Students in EDM 1 are given the freedom to choose the tools and materials that will be used in making prototype while the students in EDM 2 are required to choose the tools and materials provided by the teacher. The results showed that students' ability in designing environmental problem solving through learning of Engineering Design Model (EDM) in EDM 1 and EDM 2 was not different (87.2% and 86.6%). Students in the EDM 1 class were superior to the ability to model prototype tools. While students in EDM 2 classes tended to be superior in the ability to identify problems. The result of student perception analysis showed that students in EDM 1 class had more motivation to innovate and had higher creativity than EDM 2 students.

1. Introduction
A globalization era has had a tremendous impact on human life. Globalization seems to have overthrown barriers between nations and countries that present an open competition. No country can escape the effects of globalization including Indonesia. The defiance for Indonesia is to prepare human resources who have 21st century skills and can compete globally.

There are several skills that must be possessed by students in the 21st century. These skills are creativity and innovation, communication and collaboration, research and information literacy skills, critical thinking, problem solving and decision-making, digital citizenship and technology concepts and skills [1]. One of the skills required in the 21st century is the ability to solve problems which is crucial for every student since problems are omnipresent.

Most learning process in Indonesian schools put little emphasis on problem solving skills, which make them less developed compared to other skills. As a result, students infrequent make the best solution to solve the problems. It happens because the teachers lack of knowledge on learning that can stimulate students’ problem-solving ability. One of the lessons at school which is expected to stimulate problem-solving skills is Engineering Design Model (EDM) learning [2].

Engineering Design Model (EDM) is the learning method based on the power of designing solutions to problems [3]. The educational community has identified a number of the core characteristics of the EDM, including (1) the design process begins with a problem definition; (2) design problems have many
possible solutions and engineers must find systematic approaches to choosing between these approaches; (3) design requires modeling and analysis; and (4) the iterative design process[2]. EDM has a basic structure of analysis-synthesis-evaluation [4]. This structure guides students as designers through the process of analyzing problems, synthesizing sources and information into solutions, and evaluating solutions. EDM is one of the new findings to guide the development of learning in school [5].

A general model of engineering design is illustrated by Li, Y., Huang, Z., Jiang, M., & Ting-Wen, C [6]. The process begins with problem identification; continues through the development of a conceptual design, prototyping, and testing; and ultimately culminates in a sustainable implementation plan to result in the creation of a marketable product designed to solve the initial problem. The model is especially helpful in visualizing the “iterative and intertwined nature of defining, generating, testing, and evaluating ideas.”

Figure 1. Steps of engineering design model.

The existing research concerning engineering design-based science learning has mainly focused on contributions to science content learning. These studies generally describe significant results that promote the personalized comprehension of science concepts involving physics, i.e., Newton’s laws of motion, distances and angles, and kinematics [2, 7]. For example, Bethke Wendell and Rogers (2013) investigated the effect of an engineering design-based curriculum on elementary student science attitudes and science content using Lego. Their results showed significantly better performance in science content [8].

In America, EDM learning has been applied at elementary school level through high school, while in Indonesia EDM has not been applied to students in schools. Due to the differences of aspects and habits that Indonesia and the United States have, the writers are intrigued to apply the EDM in Indonesia to see how effective the learning will be. The researchers want to investigate students’ ability in designing problem solving environmental pollution through EDM. The Environmental material is chosen and the students are expected to have awareness and sensitivity toward environmental issues, such as pollution in Indonesia. In the 2013 curriculum, the basic competency of environmental materials is students are required to be able to solve environmental problems by making waste product recycling design and environmental conservation efforts. The issue in this research is about water pollution. Water quality issues are a major challenge that humanity is facing in the twenty-first century [9].

2. Method
This research uses a descriptive method. Descriptive research method is a research method that is intended to describe the phenomenon that took place at this time or the past [10]. This study describes the student profile when designing a solution of the environmental pollution problem through
Engineering Design Model (EDM). The research involved 60 high school students in West Bandung regency who were divided into two classes. The EDM 1 class (n=30) determined the tools and materials in accordance with their own proposed solution while the EDM 2 class (n=30) selected the tools and materials provided in the student’s workbook.

The ability to design problem-solving in this research includes five main stages: problem identification ability, solution ability, design model prototype ability, ability to make the prototype, and redesign ability. These ability are measured using the instrument of the scoring section. The motivation of learning and perception of students is measured by using questionnaires and interviews. The data obtained were then processed by converting them into percentages and interpreted by categorization [11].

3. Results and discussion
The data of the study consisted of individual data and group data. Individual data at the EDM stage involve the ability to identify problems, to find solutions and to design prototype models. While the group data on the EDM stage involve the ability to create a prototype model and redesign the prototype model. In addition, data on students’ motivation and perceptions about the application of EDM in classroom learning was also taken into account.

The ability to identify problems in both classes is 73%. The results showed that students were still confused in finding water quality problems because some students still did not understand about the water quality problem. Based on the interview, students did not recognize the term of "quality" and found difficulties in setting up the problem.

According to the National Research Council, to identify the problem designers need to ask questions to determine the problem, and then they need to determine the criteria for a successful solution, and finally, they need to identify obstacles [5]. A general agreement suggests to make a successful completion design requires vigilant observation to collect information needed to understand the problem. Creating problem formulas is one of the stages to determine the problem, to define the criteria for solutions and to identify the obstacles. The criteria in formulating the problems are making questions to investigate the problems, consisting of two variables and in accordance with the core problems.

The ability to determine the solution according to the problems in the EDM 2 class is better than EDM 1 class, 87% and 90%, respectively. It is in line with the ability to identify the problem. Based on the findings, the ability to make solutions according to the problem depended on the ability to identify each problem. As the previous opinion suggests that in determining the solution of EDM, there are two characteristics involved: first, the designer must produce many solutions; and secondly, they must develop a system to choose the solution according to the problem [2].

The ability to design the prototype model of the tool in both classes has no significant difference, which is 87%. Although the student’s workbook has inadequate tools and materials, the EDM 1 class had the freedom to choose them while for EDM 2 class, the teachers elected the tools and materials. The achievement in both classes is even because both used the same learning mode. The EDM is student-centered learning model based on hands-on-mind-on. The EDM provides a possibility for students to integrate Math and Science concepts and apply their understanding in projects that have implications on their lives and community [12].

The design proposed by students in the EDM 1 class is more varied than EDM class 2. There were 8 types of design proposed in the EDM 1 class and 7 types of design proposed in the EDM 2 class. The students submitted their own design before discussing it with the group to decide the group’s design to be used for the next stage (create and test the prototype). Each class was divided into 6 groups.

The students in EDM 1 class (89%) have higher ability to make the prototype model than students in EDM 2 class (83%). The students in EDM class 1 independently made the problem-solving design. This is completely different from the students in EDM 2 classes who could only choose the tools and materials provided by the teacher. Thus, the creativity of the EDM 1 class is higher than the EDM 2 class.

The ability to redesign the prototype of the EDM 1 and EDM 2 classes is equal, 100%, because all students in both classes were given reflection tasks to develop their prototype/product which were redesign the prototype to fix the error on the previous prototype. This finding is in line with the previous
research that it is a key aspect of the engineering design and is therefore the final characteristic that we examine in this study. Iteration refers to everything from thought experiments about how ideas might play out to repetition of particular processes [2].

The result of questionnaire about learning of EDM can be seen in table 1. The questionnaires result given to students indicated that students in the EDM 1 class were more motivated to innovate and recreate because the students in the EDM 1 class were given the independence to choose the tools and materials as they wished. EDM learning helps students in designing environmental problem solving. Based on table 1, both EDM 1 and EDM 2 classes showed that EDM in learning about environmental pollution provides benefits for everyday life, especially in the environmental field. 80% of students stated that there are some difficult stages in EDM learning about environmental pollution.

Table 1. Student perceptions concerning EDM learning about environmental pollution.

| Statement                                                                 | EDM 1 Percentage | Interpretation       | EDM 2 Percentage | Interpretation       |
|--------------------------------------------------------------------------|------------------|----------------------|------------------|----------------------|
| EDM Learning about environmental pollution motivates students to always innovate and be creative. | 90%              | Almost entirely      | 67%              | More than half      |
| EDM Learning about environmental pollution can lead to learning to solve environmental pollution problems. | 93%              | Almost entirely      | 77%              | Almost entirely      |
| EDM Learning about environmental pollution provides benefits for everyday life especially in the environmental field. | 90%              | Almost entirely      | 90%              | Almost entirely      |
| EDM Learning about environmental pollution makes it easier for students to design a solution to environmental pollution problems. | 77%              | Almost entirely      | 67%              | More than half      |
| There are some difficult steps / steps in EDM learning about environmental pollution such as identifying problems and determining the right solutions. | 80%              | Almost entirely      | 80%              | Almost entirely      |

These findings are in line with the previous research that has found the positive impact of design activities in learning environments. Previous research has demonstrated that engaging in design can support students in representing (and hence learning) disciplinary content as well as improving student motivation, ownership, and engagement [2]. Our findings add to this literature, suggesting that educators must work hard to develop contexts and problems that challenge students to engage with the quantitative aspects of engineering. By ensuring that students are fully engaged with the quantitative aspects, engineering educators can promote the most learning in their students both in Math and in Science as well as in Engineering.

4. Conclusion

It can be concluded that students' ability in designing environmental problem-solving through learning of Engineering Design Process (EDM) in EDM 1 and EDM 2 class is relatively not different (87.2% and 86.6%). Students in the EDM 1 class were superior to the ability to model prototype tools. While students in EDM 2 classes tended to be superior in the ability to identify problems. The result of student perception analysis showed that students in EDM 1 class had more motivation to innovate and had higher creativity than EDM 2 students.

Acknowledgments

Researchers would like to thank SEAQIS for supporting this research by providing research grants through SEAQIS Research Grants 2017.
References

[1] Permendikbud No. 21 Tahun 2016 tentang Standar Isi Pendidikan Dasar dan Menengah
[2] Berland L, Steingut R and Ko P 2014 “High School Student Perceptions of the Utility of the Engineering Design Process: Creating Opportunities to Engage in Engineering Practices and Apply Math and Science Content,” Journal Science Education and Technology (23) p 705–720
[3] Trilling B and Fadel C 2009 21st Century Skills: Learning for Life in Our Times (San Fransisco: John Wiley & Sons)
[4] Schubert T, Jacobitz F and Kim E 2012 “Student perceptions and learning of the engineering design process: an assessment at the freshmen level,” Research Engineering Design (23) p 177-190
[5] National Research Council 2012 A framework for K-12 science education: practices, crosscutting concepts, and core ideas (The National Academies Press, Washington)
[6] Li Y, Huang Z, Jiang M and Ting-Wen C 2016 “The effect on pupils' science performance and problem-solving ability through Lego: an engineering design-based modeling approach,” Journal of Educational Technology & Society 19 (3) p 143
[7] Mitnik R, Nussbaum M and Soto A 2008 “An Autonomous educational mobile robot mediator,” Autonomous Robots 25 (4) p 367–382
[8] Bethke Wendell K and Rogers C 2013 “Engineering design-based science, science content performance and science attitudes in elementary school,” Journal of Engineering Education 120 (4) p 513–540
[9] Schwarzenbach R P, Egli T, Hofstetter T B, Von Gunten U and Wehrli B 2010 “Global water pollution and human health,” Annual Review of Environment and Resources 35 p 109-136
[10] Cohen L, Manion L and Morrison K 2002 Research methods in education (Routledge)
[11] Koentjaraningrat 1990 Pengantar Ilmu Antropologi (Jakarta. Djambata)
[12] Mangold J and Robinson S 2013 “The Engineering design process as a problem solving and learning tool in K-12 classrooms,” In 2013 ASEE Annual Conference & Exposition (p 23-1196)