Challenges in Developing Engineering Class Design at Middle Classroom to Improve Science, Technology, Engineering, and Mathematics (STEM) Education

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Abstract—In this paper, we discuss challenges in designing engineering class that was conducted in a middle school to improve STEM education in Indonesia. Engineering class design was implemented in several schools in US to embed STEM education into school curriculum that emphasized on engineering practice. However, the class design is newly introduced in Indonesia. In fact, the education system differences become a crucial challenge. The class design was created through STEM professional development program, where seven teachers from Muhammadiyah 8 Secondary School in Bandung are involved in it. The class designing method was initiated by giving STEM education knowledge review to improve teacher’s knowledge and perception. Furthermore, teachers were divided into two groups to analyze the contents in different level, and then they created big themes that cover several concepts in the contents. Finally, they plan students’ STEM based project in a worksheet format that adapted engineering process design. The challenges were analyzed using 3Ps instrument that adopted from Bybee (2013). The result implied they meet challenges in designing the class when they decided the STEM activity purpose, program, and practice, that reflect on time consuming, number of participant, activity location, products, occurred problems, and attained agreement among participant.

Keywords—Engineering class, STEM Education

I. INTRODUCTION

United State government realize the lack of scientist and engineer because of the interest decrease in science, mathematics, engineering and technology field that impact on the interest decrease in these careers [1]. To solve these problems, government emphasizes STEM improvement in education. It was suggested that government should take with respect for improving leadership and coordination [1]. Moreover, standards, assessment, teachers, technology education, and schools become crucial targets to be developed. It concluded that to meet the need for STEM-capable citizenry and future STEM expert; the Nation must focus on two complementary goals. First, they should prepare all students, including the girls and minority, and inspire all students to learn STEM. Second, they should promote better leadership with a coherent vision with careful oversight of goals and outcomes. Therefore, federal government started to improve STEM education by releasing new science standard, Next Generation Science Standard (NGSS) on 2013[2]. Recently, ACT evaluate STEM education development, they reported that the percentage of students’ interest in STEM has increase slightly over past five years [3]. The biggest increase were in Engineering and Technology area, especially mechanical-engineering area. These results showed that United State showed a success in promoting STEM education program. This fact triggers us to study about STEM education implementation strategy in U.S.

The successes of STEM education implementation in U.S haven’t been seen in Indonesia. The first implementation in 2013 faced challenges, especially in integrating Engineering (E) and Technology (T) in science learning [4,5]. The difficulty arise from limited experience to serve in STEM learning classroom. Reflect on implementation evaluation results, we develop engineering class design that adapted from Columbia Academy STEM program in Minnesota. We designed engineering class as an after school activity for middle school students. We grouped students into two different role-play; as supplier and producer, while the teacher act as client. In Indonesia the design is new and we have different education system with United State. Therefore we hypnotize that there will be many challenges occurs in adapting this design. This study focused on analysing the challenges in developing engineering class design process based on teachers’ perception toward time, participant, location, products, problems, and agreement [5].

II. METHOD

A. Research sample and professional development method

The development processes were conducted during teacher training activities. The activity was part of professional development (PD) program that organizes once a year. The first PD program was conducted in 2013; it aimed to introduce STEM education. The second PD was conducted on July 2015 that targeted to refresh teacher perception and repair the implementation method and strategy. Seven STEM teachers involved in it. Firstly, they were given STEM education review in other countries to refresh their perception of STEM
education. Second, they were asked to analyze curriculum content. They listed the content of science, mathematics, and computer technology courses refer to 2006 Indonesian national curriculum. Third, they were asked to pick big topic of project that can covers content of each courses. They should think systemic to get the idea. Fourth, they were asked to create students guidance in conducting the project. Finally they were asked to arrange recruitment and learning schedule for one semester.

B. Engineering class design

The class was designed refer to Columbia Academy, a middle school in Minnesota. We designed class of 20 students that grouped into 2 groups of supplier and 4 groups of engineer. It conducted as out-of-school activity school program, which should be chosen based on students’ interest. They were grouped based on their dominant intelligences profile using Multiple Intelligences Inventory (MII). The program served for seven and eight grade students, so we designed two engineering classes. The class started in the beginning of August 2015. It initiated with recruitment process in one week. There will be eighteen-class meeting, consisted of three projects for each class. Steps in conducting the learning are: 1) deliver the problem based on the topic of project, 2) divide students’ role-plays, 3) encourage and guide students to create a project proposal, 4) assess students’ proposal, 5) guide students in conducting the project, and 6) assess project result. Furthermore, we embedded engineering processes design into student’s activities; students were guide to identify the problems, to have brainstorming in-group, to design the solution, to construct the design, to test the product, to redesign the product, and finally share the solution.

C. Instrument and data analysis

In order to evaluate challenges in the developing processes, we create questionnaire to collect teachers’ perspective toward three areas: purpose, program, and practice in using STEM context that refer to how long time is needed, who are participated, location of implementation, what kind of product that produce in development processes, what problems occur along the processes, and how the agreement among participant was attained. This questionnaire was developed based on Bybee [5] perception in STEM education program evaluation. The questionnaire consists of two domains for each area. In the purpose area, we evaluate domain: a) establishing goals for STEM activities, b) establishing priority of STEM goals in STEM activities. In the program area, the domains are: a) developing material for STEM, b) implementing the class. And in practice area the domains are: a) changing teaching strategy for STEM, b) adapting material that suitable for students, teachers, and school need. Data were collected at the end of professional development program. It was analyzed qualitatively.

III. RESULTS AND DISCUSSIONS

A. Differentiation method of engineering class design

Implementation of STEM education in Indonesia was started on 2013. It has been conducting since November 2013 at a private junior high school in Bandung West Java Indonesia. Selected school has vision to improve student achievement in science, technology, engineering and mathematics. The principal wants students to be literate in STEM, to create better human resources in developing the country, to improve school quality, and to have better achievement in science and technology. Facing limitation of STEM knowledge, college collaboration, and school curriculum policy, it was decided to use other methods of implementation for the next school term semester. Project Based Learning (PBL) was taken as an approach of implementation in engineering class.

Engineering class design was built to improve STEM education that targeted to increase students’ creativity, intelligences, and problem solving skill. The design was adapted from Columbia Academy in Minnesota. However, we have different scheme of implementation. They design the class as a regular subject twice a week, while we design it as a class in out of school activity program. We design the activity based on the attained concept on science, mathematics, and computer technology contents. It aims to improve students’ concept mastery besides creativity, intelligences, and problem solving skills.

B. Project theme in engineering class design

TABLE 1. List of projects theme in engineering class design

<table>
<thead>
<tr>
<th>7th Grade</th>
<th>8th Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispenser Prototype</td>
<td>Healthy “Cilok”</td>
</tr>
<tr>
<td>The Earth Fever</td>
<td>Lung Breathing</td>
</tr>
<tr>
<td>Automatic Wind Blower</td>
<td>Hearth Work</td>
</tr>
</tbody>
</table>

TABLE 2. List of covered contents in science, mathematics, and computer technology subject in 2006 National Curriculum

<table>
<thead>
<tr>
<th>Science</th>
<th>Mathematics</th>
<th>Computer Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.7.1</td>
<td>M.7.1</td>
<td>CT.7.1</td>
</tr>
<tr>
<td>a. metal expansion</td>
<td>a. counting operation</td>
<td>a. use of computer</td>
</tr>
<tr>
<td>b. heat</td>
<td>b. arithmetic social</td>
<td></td>
</tr>
<tr>
<td>c. temperature changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. heat transfer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. compound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. chemical properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. physics changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. chemical changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j. chemical reaction</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S.8.1</th>
<th>M.8.1</th>
<th>CT.8.1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
During the professional development program, teachers
imply that there are some contents of mathematics, science,
and computer technology that could be integrated
conceptually. They built bridging theme to connect and
 correlate the concept in the content. They listed the covered
contents in 2006 national curriculum, and then decided the
project theme (Table 1). The covered contents that related to
the projects theme were shown in Table 2.

In general, the purpose of each topic is to improve
understanding concept of science, mathematics, and computer
technology contextually through an active learning. For
instance, the ‘dispenser prototype’ topic leads students to use
heat concept in creating the prototype. It also cover concept:
heat transfer (S.7.1a), temperature changes (S.7.1b), density
(S.7.1c), arithmetic social (M.7.2), counting operation (M.7.1),
and the use of computer (CT.7.1). Other sample describes on
‘healthy Cilok’ topic that covers contents of digestive systems,
chemical materials in food, counting operation, comparison,
power point, and excel.

### C. Challenges evaluation results

The process on developing class design evaluated using
3PS evaluation rubric that adapted from Bybee [6]. Teachers
who follow the development process are experience STEM
teacher in the school sample. They followed STEM program
implementation in the school for almost one year. However,
they face challenges in the first implementation, thus we
create new class design to deal with the challenges. The
development processes was initiated by professional
development program on STEM education. Teachers were
given brief review of STEM education implementation in
other country to refresh and improve their perspective. Based
on their perspective, we guide them to create a topic for
students’ projects, and put them into a workbook.

Challenges on the development process were identified on
time, participants, location, products, problems, and agreement
of teachers. Teachers’ perceptions toward these challenges
were illustrated on Table 3.

### Table 3. Teachers’ perceptions toward engineering class development processes challenges

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Time</th>
<th>Participants</th>
<th>Location</th>
<th>Products</th>
<th>Problems/issues</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Establishing goals for Engineering Class</td>
<td>80% chose: it need more than one hour</td>
<td>100% chose Engage fair (not much) colleagues, relevant community and students</td>
<td>70% chose It conducts in the location where easy to be accessed by participants</td>
<td>70% choose: It producing unique materials that needed by teacher, schools and students</td>
<td>80% chose: The problem related to: students, teachers, and learning materials</td>
<td>60% chose: There is good communication among participant so that the agreement did not take a lot of time and get fine quality</td>
</tr>
<tr>
<td>Establishing priorities for STEM goals in Engineering Class activities</td>
<td>80% chose: it need more than one hour</td>
<td>100% chose Engage fair (not much) colleagues, relevant community and students</td>
<td>70% chose It conducts in the location where easy to be accessed by participants</td>
<td>70% choose: It producing unique materials that needed by teacher, schools and students</td>
<td>80% chose: The problem related to: students, teachers, and learning materials</td>
<td>60% chose: There is good communication among participant so that the agreement did not take a lot of time and get fine quality</td>
</tr>
<tr>
<td>Developing material or adopting a program for Engineering Class</td>
<td>80% chose: it need more than one week</td>
<td>100% chose Engage fair (not much) colleagues, relevant community and students</td>
<td>70% chose It conducts in the location where easy to be accessed by participants</td>
<td>70% choose: The products are related to civic phenomena solutions that connected to STEM</td>
<td>80% chose: The problem related to: students, teachers, and learning materials</td>
<td>60% chose: There is good communication among participant so that the agreement did not take a lot of time and get fine quality</td>
</tr>
<tr>
<td>Implementing the Engineering Class program</td>
<td>80% chose: it need more than one month</td>
<td>100% chose Engage fair (not much) colleagues, relevant community</td>
<td>70% chose It conducts in the location where easy to be accessed by participants</td>
<td>70% choose: The products are related to civic phenomena solutions that connected to STEM</td>
<td>80% chose: The problem related to: students, teachers, and learning materials</td>
<td>60% chose: There is good communication among participant so that the agreement did not take a lot of time and get fine quality</td>
</tr>
</tbody>
</table>
STEM fields [10].
open-ended problems with the guidance of adult mentors from
establishing goals (environments where students can solve challenging complex
class. Most of them (80%) thought that they need more time in
time, participants, and problems in developing the engineering
Therefore, they perceived that they faced some challenges in
based on an analysis content in 2006 national curriculum.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Changing teaching strategies for STEM</td>
<td>80% chose: it need more than one week</td>
<td>80% chose Engage fair (not much) colleagues, relevant community and students</td>
<td>70% chose It conducts in the location where easy to be accessed by participants</td>
<td>70% choose: It producing better teaching strategies and stories in STEM</td>
<td>80% chose: The problem related to: students, teachers, and learning materials</td>
<td>60% chose: There is good communication among participant so that the agreement did not take a lot of time and get fine quality</td>
</tr>
<tr>
<td>Adapting materials to unique needs of teacher, schools, and students</td>
<td>80% chose: it need more than one month</td>
<td>80% chose Engage fair (not much) colleagues, relevant community and students</td>
<td>70% chose It conducts in the location where easy to be accessed by participants</td>
<td>70% choose: It producing better teaching strategies and stories in STEM</td>
<td>80% chose: The problem related to: students, teachers, and learning materials</td>
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</tr>
</tbody>
</table>

In general, teachers perceived that they faced challenges in time, participants, and problems in developing the engineering class. Most of them (80%) thought that they need more time in establishing goals (purpose), developing and implementing materials (program), and changing and adapting learning processes (practice).

The time consuming in deciding the purpose of the class designed was affected by the STEM education implementation target to increase student’s creativity, intelligences and problem solving skills. Therefore, teachers need more time to decide purpose, program, and practice of the projects theme. Student’s creativity could be triggered with the power of questions [7], and the problem solving skills could be trained through problem-based instruction [8]. On the other hand, students have different dominant intelligences that should be considered [9]. Finally, they decided to use technology competition strategy in the practice to provide constructive environments where students can solve challenging complex open-ended problems with the guidance of adult mentors from STEM fields [10].

IV. CONCLUSION

Overall, teachers develop adapted engineering class in different way to the adapted method in Colombia Academy, based on an analysis content in 2006 national curriculum. Therefore, they perceived that they faced some challenges in time, participants, and problems in developing the engineering class. Most of them (80%) thought that they need more time in establishing goals (purpose), developing and implementing materials (program), and changing and adapting learning processes (practice). Thus, it needs further implementation evaluation toward the engineering class design impacts for both students and teachers.

ACKNOWLEDGMENT

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