Strategies of Teaching: Promoting Science Technology Engineering and Mathematics (STEM) Education Through Cross-cutting Concepts

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Abstract. Recently, the rapid development in science and technology has a tremendous impact on education system, resulting in a global change in education system. Unfortunately, such changes are not always accompanied with changes in the quality of education system. These conditions create problems toward the provision of decent education in science and technology among students. For example, the lack of understanding toward science and technology among elementary science teachers result in the lack of scientific experiments. These conditions need to be improved by raising the awareness of elementary teachers toward strategies to teach and learn science. The present study aims to investigate the promotion of STEM (Science, Technology, Engineering, Mathematics) among pre-service teachers using cross-cutting concepts. The present study applied pre-experiment design method with one-shot case study to obtain the results. The results show that cross-cutting concepts seem beneficial to raise the awareness of pre-service elementary teachers toward science learning as well as the benefits of scientific experiment projects.

1. Introduction
Rapid development in science and technology has a tremendous impact on education system, resulting in a global change in education system. Unfortunately, such changes are not always accompanied with changes in the quality of education system. These conditions create problems toward the provision of decent education in science and technology among students. For example, the lack of understanding toward science and technology among elementary science teachers result in the lack of scientific experiments. In the fact that, pre-service teachers on primary education in Spain is also a lack knowledge on scientific work and got failures to promote learning sequence base on inquiry (Montero-Pau, et.al: 2017). Hence, all this time the improvement of science education only result in the developments of cognitive oriented. This is where pre-service teachers play their parts in improving the quality of science education. However, different educational backgrounds of pre-service teachers might lead to the differences in their understanding toward scientific concepts. This situation occurred among a group of pre-service elementary teachers at faculty of teachers training and education of Universitas Islam "45" Bekasi. There seems to be lack of understanding of scientific concepts among pre-service teachers due to lack of scientific experiments during their high school time. This lack of understanding can be seen from their low achievements in a science class in their first semester. This situation needs to be improved by providing pre-service teachers with teaching and
learning strategies that may develop their understanding in science. Educational strategies need to be renewed to improve knowledge and educational practices (Chiu et al., 2015). The awareness toward the importance of STEM could be one of solutions to enhance educational quality as it will challenge the educators to create a more dynamic school. Accordance Epstein et al. (2011) STEM education indicate a strong comprehension of Mathematics, science, engineering and technology which comprise as STEM competences. STEM might help to facilitate pre-service elementary students to learn correlation concept in science. Defined cross-cutting concepts as bridge disciplinary core boundaries of science and engineering field with purpose to help students understanding for connecting their knowledge from the different disciplines into a coherent and scientifically (Bednar, 2014). Lazano argues that a cross-cutting concept might be an initial step to introduce STEM (NSTA, 2017). Therefore, promoting STEM education through seven stages of cross-cutting concepts seems beneficial to improve understanding toward science. According to National Research Council (NRC) the seven stage of cross-cutting concepts are (1) pattern, (2) cause and effect: mechanism and explanation, (3) scale, proportion, and quantity, (4) system and system models, (5) energy and matter: flows, cycles and conservation, (6) structure and function, (7) stability and change (NCR, 2012). The objective of the present research is to investigate pre-service elementary teachers in learning STEM based education on using cross-cutting concepts. In order words, the research is important as strategies to facilitate pre-service elementary teacher learning in different disciplines of science and the real world contexts.

2. Methodology
The present research applied a pre-experiment design with one shot case study. In this regard, the participants were given a treatment and the results will be observed (Sugiono, 2011). Creswell defines a case study research as “…a qualitative research approach in which the investigator explore a bounded system (a case) or multiple bounded systems (cases) over time through detailed, in depth data collection involving multiple source information (e.g. observations, interviews, audio-visual material, and document and report), and report a case description and case-based theme” (2011, p. 97). The participants of present research were 83 pre-service elementary teachers at faculty of teachers training and education of Universitas Islam ”45” Bekasi. They were divided into small group discussions in learning science which focused to promoting STEM. The discussion themes were water rocket, catapult, force and motion and paper-bridge. They were used because they were considered familiar among learners. All participants chose the topic based on their interests. The participants were encouraged to perform their own experiments within small groups, providing them with opportunities to perform scientific experiments using cross-cutting concepts. The data collection was performed over two months. Supplementary data were collected from student group interviews and written responses. The analysis of experiment process was recorded on video. Data triangulation was conducted by comparing to students’ experiment (Creswell, 2012). This involved a comparison of analysis of the video records with other sources, such as science books to discover the possible source, and supplementary data, particularly the written responses of students that had been collected.

3. Results and Discussion
The result of research had shown that STEM could promote every theme which students had chosen through cross-cutting concepts. STEM facilitates the students’ knowledge in connecting in some disciplines to learn. According to Epstein et al. (2011), STEM education help to promote an integrated content in areas of science, technology, mathematic and engineering. Actually, the urgency of STEM disciplines indicates a good chance (Li, 2014) and certain of science career (Xie, 2015). However, the instruction of seven stages of cross-cutting concepts which were given to students provides them with valuable experience related to scientific work as well as attitudes. The impact of whole cross-cutting concepts shows that students have a deep understanding about the related concepts from various disciplines (NRC, 2012). Taking from learning outcomes shown by students’ results suggest an
improvement in science achievements \( g = 0.54 \). Results clearly show interpretation of \( 0.30 < g < 0.70 \) that students’ still in average level (Hake, 1999).

However, the process of promoting STEM based science teaching and learning on phenomena in daily life could facilitate students to discover deeper scientific and Mathematics concepts. However, it might be still difficult for students who do not like science or Mathematics. It is shown in the three of stage of cross-cutting concepts which consist of counted scale, proportion, and quantity; energy and matter: flows, cycles and conservation; and stability and change. Therefore, the concepts of scientific and Mathematics seem to be not deeply investigated. Challenging pre-service teachers to improve their understanding of Mathematics literacy seem important to build such relationship. In addition, STEM needs extra time to be integrated in related disciplines.

In addition, educators must be able to show authentic and realistic learning to promote STEM engagement (Chapman et al, 2016) by pedagogical approaches (Kennedy et al, 2014; Kelley et al, 2016; Yeland, 2016) and effectively with scientific thinking and practices (Marginson et al, 2013). On the other hand, successful students’ of STEM disciplines in South Korea depend on educators’ belief and competences in promoting student learning STEM education in elementary school (Park et al, 2016). In fact, research has indicated a lack of preparation to implement STEM disciplines, these encompass in South Korea where educators’ hesitation cause dissatisfied teaching experience in STEM (Jho et al, 2016). In Japan, educators have problem in preparing and integrating STEM lesson (Saito et al, 2015). In USA, educators seem to be worried in teaching STEM due to limited knowledge in science and Mathematics (Daugherty et al, 2014). In Australia, educators’ abilities in Mathematics are still below standards (Marginson et al, 2013). Students’ competences (creativity, critical thinking skill, collaboration, and communication) have been monitored during data collection. They are shown from their learning processes shown on their videos, photos, reports and product. According to Rivet et al (2016), cross-cutting concepts can be considered as a visible bridge to students’ activities and product. It could be given as an effect of experiment exposure on varying students groups. Data from written responses show that students learn science based on STEM themes (water rocket, force and motion, catapult and paper-bridge) through stages of cross-cutting concepts. Students could also describe their strengths and weaknesses in their experiment project.

However, learning through cross-cutting concepts can also result in failure. Nevertheless, the participants support each other in clarifying their ideas and explanation for sharing, testing and refining design ideas for suggested revision. The cross-cutting concepts facilitated students’ cognitive abilities to connect notion from earth and space science, biology, physics, and chemistry (NRC, 2012). Cross-cutting concepts provide metaphorical perspectives as tools to help students to engage in science and engineering practice in more diverse and successful ways (Rivet et al, 2016). All disciplines can apply similar activities by exploring each concept (NSTA, 2014). The seven stages of cross-cutting concepts are (1) pattern, (2) cause and effect: mechanism and explanation, (3) scale, proportion, and quantity, (4) system and system models, (5) energy and matter: flows, cycles and conservation, (6) structure and function, (7) stability and change, purpose to guide the student thinking process and grow scientific attitudes. Innovation in science teaching and learning in this century can provide keen experiences and grow creativity as well as critical thinking skill, collaboration, and communication to develop students’ potentials in a fun and deep learning in science. Tips for other researchers in implementation STEM as well as learning approach is minimalize barrier, consist from concept related, ideas, and time needed.

4. Conclusion

Overall, teaching strategies to promoting STEM through cross-cutting concepts could improve pre-service elementary teachers in learning science. The present study is important because it can promote STEM programme to improve pre-service elementary teachers in learning science as well as providing with practices in science teaching and learning. The results show that cross-cutting concepts could improve students’ competences which consist of critical thinking, collaboration, creative and
communication which also encourage student’s learning experiences. Teachers need to help by making needed lesson plans to fix existing problems because students’ scores point out a school failure to create a good-quality generation. This is where the role of the school ecosystem is required for bettering the future.

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