

Contents lists available at [ScienceDirect](#)

Kasetsart Journal of Social Sciences

journal homepage: <http://www.elsevier.com/locate/kjss>

Preservice teachers' understanding of STEM education

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ARTICLE INFO

Article history:

Received 14 February 2018

Received in revised form 5 May 2018

Accepted 21 July 2018

Available online xxxx

Keywords:

preservice teacher,

STEM,

STEM education,

STEM education understanding,

teacher training

ABSTRACT

STEM Education is promoted by the government throughout Thailand, but STEM teacher training in the universities is not well developed. This study investigates the understanding of STEM education by 87 preservice teachers from the Faculty of Education in a university in Bangkok, Thailand. The preservice teachers were asked to respond to an online questionnaire about their understanding of STEM Education. Six preservice teachers who had interesting responses were interviewed for more clarification. The results showed that most of the preservice teachers perceived STEM as the integration of science, technology, engineering, and mathematics, but did not explain more about the nature of the integration. They did not explain how the four disciplines were integrated but focused on the outcomes of the integration. While the preservice teachers' ideas about the importance of STEM varied based on their majors, most participants perceived STEM as a teaching strategy. The findings of this present study indicate the importance of promoting preservice teachers' understanding of the integrated nature of STEM and the connections among the disciplines.

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Introduction

STEM is an acronym of the integration of science (S), technology (T), engineering (E) and mathematics (M). STEM education is promoted in many countries to prepare their citizen to understand STEM and have multidimensional capabilities to use in modern life. Moreover, STEM is often expected to solve the problems of the low scores on international assessments such as TIMMS and PISA, and the decreasing number of students who want to have a job related to science and technology. For example, the USA has a national plan to increase the number of graduates with STEM degrees to maintain America's competitive position in the global economy.

STEM Education in Thailand has been promoted by the government because Thailand faces a decrease in student numbers in science programs both in school and university, has a low score in international science and mathematics testing, and has an inadequate STEM workforce (Chulavatnatol, 2013). Moreover, in 2016, the Thai Prime Minister presented a new economic model titled Thailand 4.0 which promotes creativity, innovation, and the application of technology in various economic activities. To develop the nation to align with Thailand 4.0, STEM Education is expected to prepare every Thai for an inclusive society where everyone needs to have personal and social skills to work collaboratively with others from many disciplines (The National News Bureau of Thailand, 2017). To prepare the future STEM-literate citizen, teachers are a key and their preparation for STEM teaching is important (Rinke, Gladstone-Brown, Kinlaw, & Cappiello, 2016). A STEM professional development program is necessary to help teachers understand the nature of integration, and make explicit the

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Peer review under responsibility of Kasetsart University.

¹ Co-first authors.<https://doi.org/10.1016/j.kjss.2018.07.017>2452-3151/© 2018 Kasetsart University. Publishing services by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).Please cite this article in press as: Pimthong, P., & Williams, J., Preservice teachers' understanding of STEM education, Kasetsart Journal of Social Sciences (2018), <https://doi.org/10.1016/j.kjss.2018.07.017>

connections between science, technology, engineering, and mathematics (Pearson, 2017).

Literature Review

STEM is the integration of science (S), technology (T), engineering (E) and mathematics (M) which relates to both workforce and daily life experiences. STEM is relevant because in the nature of the world, each discipline (S-T-E-M) does not exist alone and complex and multidimensional problems are encountered by all (Moomaw, 2013; Talley, 2016; Vasquez, Comer, & Sneider, 2013). STEM Education is provided to achieve educational aims that prepare people for future life and the workforce. The integration and application of S-T-E-M concepts and processes are required by all, and young people should have opportunities to participate in real multidisciplinary situations (Bybee, 2010, 2013; English, 2017; Stohlmann, Moore, McClelland, & Roehrig, 2011; Vasquez, Sneider, & Comer, 2013). For this reason, the theoretical framework adopted for this study is related to an integrated approach to STEM. There are a range of approaches that have been adopted in different education contexts, involving single or multi discipline contributions to STEM activities. However, the rationale for an integrated approach in this study is that such a framework will optimize opportunities for participation in real-world contexts, which are essentially multi-disciplinary.

However, the research showed that preservice teachers have misunderstandings or misconceptions about STEM (English, 2017; Radloff & Guzey, 2016). This present study aimed to explore the preservice teachers' understanding of STEM education. The research question considered was: What is the preservice teachers understanding of STEM Education?

Methods

The concept which framed this research was related to a constructivist view of learning which holds that students construct their learning by relating new information to prior knowledge. Therefore, developing an awareness of students' current perceptions was fundamental to developing a STEM education course which would suit their needs and facilitate new knowledge. A survey was used in this present study to gather data at a particular point in time with the intention of describing the nature of existing conditions (Cohen, Manion, & Morrison, 2017).

Participants

The participants in this study were 87 preservice teachers majoring in Teaching science (SC), Teaching mathematics (M), Home economics education (HO), Business and computer education (C), Physical education (PE) and Health education (HE) from the Faculty of Education in a university in Bangkok, Thailand. All of them had passed a compulsory methods course in their major.

Data Collection

An invitation to complete the online questionnaires (Google Form) was sent to 204 preservice teachers in year 3

and year 4 during the first semester of the 2018 academic year. Eighty-seven (43%) participants voluntarily responded to the questions. An online survey design (Cohen et al., 2017) was used in this study because it was easy to create and convenient for the participants to answer. The participants' responses were automatically collated to aggregate or compare the data. The interviews with six participants lasted about 5–10 min per person and were conducted via a video call using Line Application.

Data Analysis

The data were analyzed using thematic analysis (Braun & Clarke, 2006; Joffe, 2012) based on the similarities of responses. Each theme (category) was shown together with a description to enhance understanding of each theme. The analysis of responses from the open-format online questions were elaborated through interviews with selected participants in order to probe and clarify their responses. One of the questions (the ninth question) in the survey asked respondents to draw a diagram to represent their ideas related to STEM. These diagrams were also analyzed thematically but separately from the open-ended questions.

Results

In response to the first question, most participants (77) said that they had heard about STEM. A similar result was found in the second question to which 77 participants identified S-T-E-M as Science, Technology, Engineering and Mathematics. In the third question, the participants were asked to identify how they had heard about STEM. It was found that 72 participants said that they heard about STEM from teachers, instructors, and educators. These first three questions indicated that most of the preservice teachers in this group were familiar with the term "STEM" and their information came from teachers, instructors, and educators.

According to the concept of STEM, the participants were asked for the fourth question what they thought STEM is. Most participants (20) identified STEM as the integration of S-T-E-M. For example, SC21 explained her idea about the integration of S-T-E-M as "... apply all four subjects into one activity". However, many participants did indicate some advantages of STEM such as "The integration of S-T-E-M to apply to everyday life". Most participants responded to the fifth question: What is the purpose of STEM education? With the ability "to relate STEM to everyday life" (12 participants). In the sixth question, the participants were asked is STEM important for you? And most (78) agreed that STEM was important for them but none provided any reasons. To elicit an understanding of how STEM relates to their major area of study, the seventh question was: How does STEM relate to your major? It was found that most participants who explained how STEM related to their major were from science. For example, SC13 mentioned that "Because science is one part of STEM, I think science is an important topic of STEM". The eighth question: What is integration? Revealed that most participants had ideas of connecting and/or combining two or more subjects. For example, C 9 explained "to combine content knowledge from many subjects to teach together". For the ninth

question, the participants were asked to draw a diagram to illustrate how they visualized integration. An inductive thematic analysis approach (Joffe, 2012) was used for the examination of the diagrammatic representations of the meaning of STEM integration, in which the themes were developed from the diagrams. Each diagram was analyzed, and its key features noted. The key features were then grouped into themes which represented the ideas that were conveyed in the diagrams (Braun & Clarke, 2006).

There were seven themes which developed from the analysis. In the first theme, the nature of STEM integration was defined through its outcomes which had three sub-themes: 1) problem solving, 2) projects, and 3) student-centered innovations.

Theme: Outcomes

In the problem solving sub-theme, all the diagrams mentioned problem solving as an outcome of STEM. The diagrams show the integration of S-T-E-M and had solving the problem as the outcome of this integration. Figure 1 is an example of a diagram presented in this way.

The individual interview was conducted to probe SC21's ideas about solving the problem being the outcome of the integration, namely:

Interviewer: ... Why do you think this [problem solving] is important?

SC21: From my study, I have learned that STEM promote children to apply what they have learned to their daily life.

Interviewer: Is application to daily life emphasis on solving problem?

SC21: Yes ... um ... I think it is also related to career. I think not only teachers can use STEM, but other careers can use STEM. For example, agriculture or industry because STEM apply to many careers.

From SC21's responses, she confirmed that STEM can promote children to apply what they learn for solving problems which is also related to a career.

For the project sub-themes, projects were represented as the outcomes of STEM and were presented in two groups, namely some diagrams that showed the projects which can be used in real life and others as diagrams which

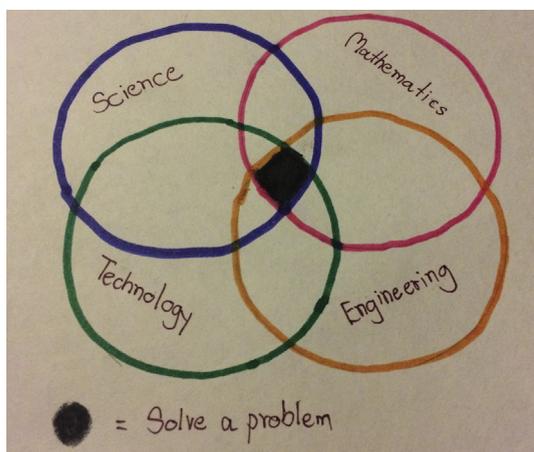


Figure 1 Outcomes (problem solving) –SC21's diagram as an example

did not show any integration but indicated that projects develop from each discipline separately.

Finally, the diagrams in the student-centered innovations sub-theme prioritized the importance of students as the creators who apply STEM in everyday life to develop innovations. Within this sub theme, there were two groups holding different ideas regarding integration. Some diagrams showed the students' abilities to apply integrated STEM into their life to create innovation, and others showed the students' ability to apply STEM to their life and create innovations, but in a silo approach.

Theme: Relationships Between S-T-E-M

The second theme related to the question of "how S-T-E-M integrates?" but few preservice teachers were included in this theme. Figure 2 is an example of this theme.

To clarify, SC 22 who was interviewed about his diagram, responded:

Interviewer: Look at your diagram. Could you please explain more about the diagram?

SC22: As I said, everything needs to be integrated, science, mathematics, engineering, technology. I think everything is related. It should not be separated. So, when we teach one topic, we can relate four disciplines and it is STEM.

SC22's response shows the idea that science, technology, engineering, and mathematics need to come together because they are related to each other.

Theme: Separate S-T-E-M

This third theme did not show any relationship or integration among S-T-E-M, although some diagrams use the word "integration". This theme represents the idea of each subject being separate with their specific characteristics, such as mathematics related to ratio. Figure 3 is an example of this theme. For a deeper understanding, C17 was asked to describe more about her diagram. She said "... I put math in as the heart because I think calculation is important. If we have the logic of calculation, we can apply to other things. After that, for science, I focus on science skills, experiment and observation. In this point at engineering, we can combine math and science knowledge to design innovation for facilitating our life or solving problems. And then we use technology to help us to easily do anything, labor-saving or using technology for broadcasting our innovation". C17's explanation does not show any relationship or integration among S-T-E-M, but she emphasized the importance of each subject by giving explanations related to the nature of each discipline.

Theme: "S-T-E-M = STEM" Without Any Explanations

This theme represented those diagrams which did not reveal any ideas about how S-T-E-M integrates together. Figure 4 shows one example of this theme.

Theme: STEM as Teaching

The fifth theme was categorized into three sub-themes namely ideas about teaching with some integration, ideas about teaching without integration, and ideas about

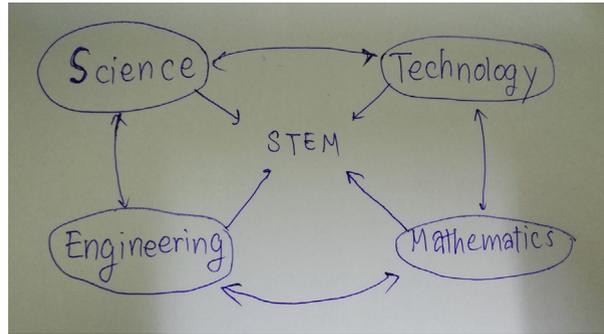


Figure 2 Relationship among S-T-E-M –SC22’s diagram as an example (Relationships among S-T-E-M shown using double-headed arrows, while single-headed arrows show that STEM originated from the relationships among S-T-E-M)

teaching within specific contexts. To consider STEM as teaching with some integration, this sub-theme showed not only that S-T-E-M is integrated but also the ways to apply STEM to teaching. An example of this theme is shown in Figure 5.

Theme: Complicated Relationship Between S-T-E-M

The sixth theme illustrated more specific relationships between S-T-E-M through ideas such as “Breeding”, “Science and Mathematics create Engineering”, “Technology relies on Engineering”, and “Math is a part of Engineering”. An example of this theme is presented in Figure 6.

The six theme showed students’ confusion regarding the relationship among S-T-E-M which resulted in complicated and unreasonable explanations.

From the ninth question (How are S-T-E-M integrated? Please draw a diagram to illustrate how you visualize this integration.), most of the diagrams represented ideas about the outcomes of integration (The first theme). However, most preservice teachers also tried to represent the relationship between S-T-E-M in various ways, but they were ambiguous.

The tenth question (When should STEM be taught?) was used to explore the participants’ ideas about the appropriate time for the teaching of STEM. Most participants

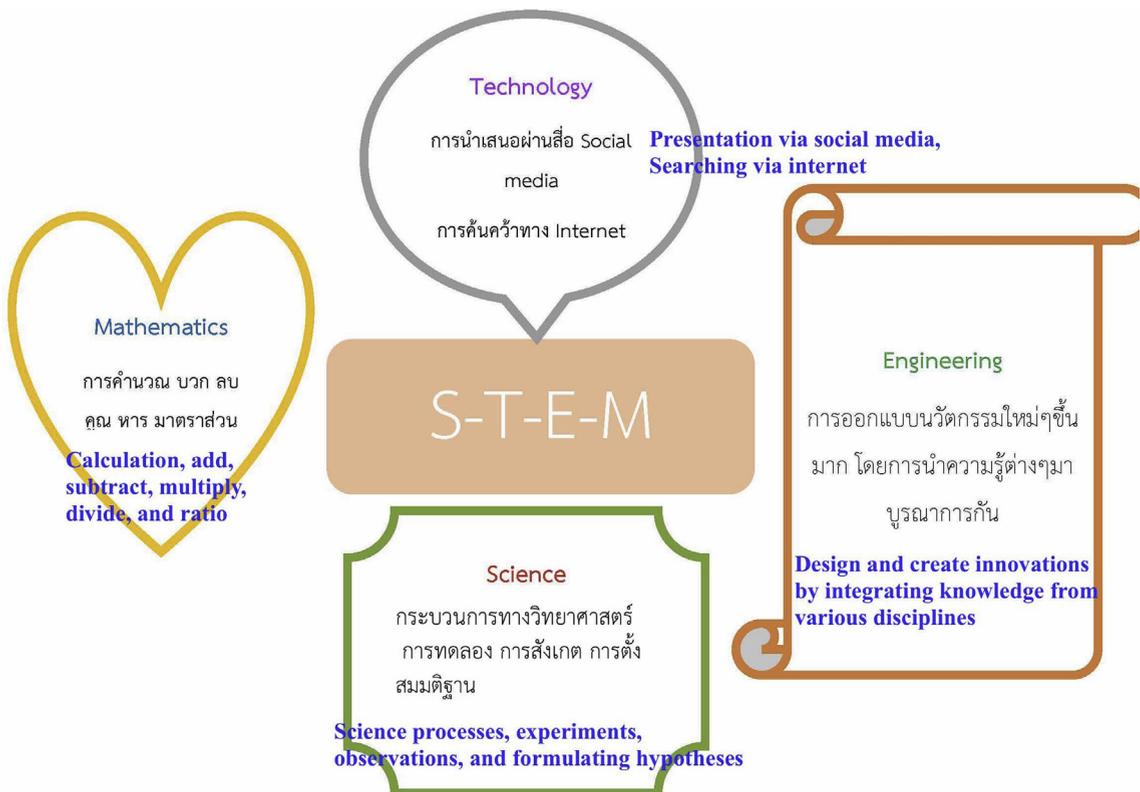


Figure 3 Separate S-T-E-M –C17’s diagram as an example (C17’s Thai text translated by the author)

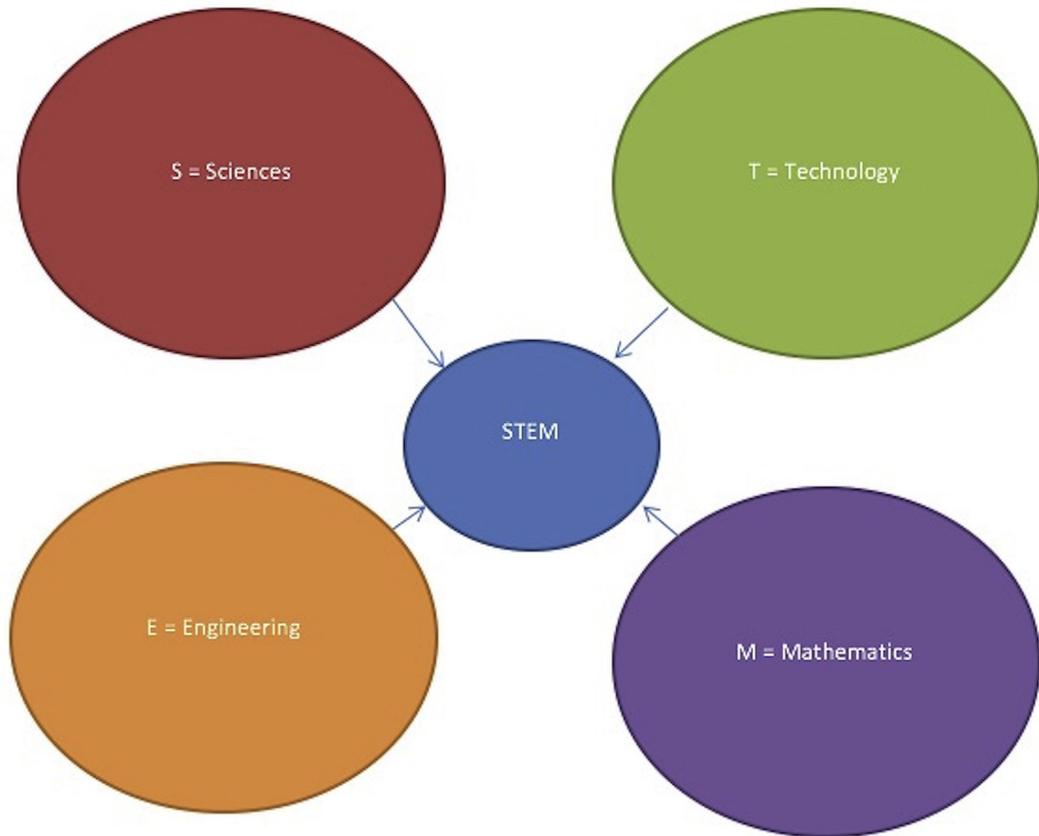


Figure 4 S-T-E-M = STEM –SC4's diagram as an example

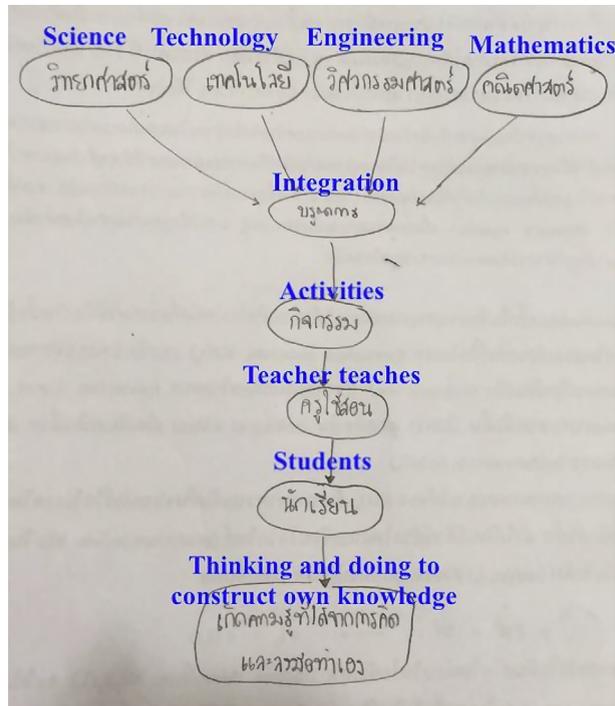


Figure 5 STEM as teaching with integration –SC23's diagram as an example (SC23's Thai text translated by the author)

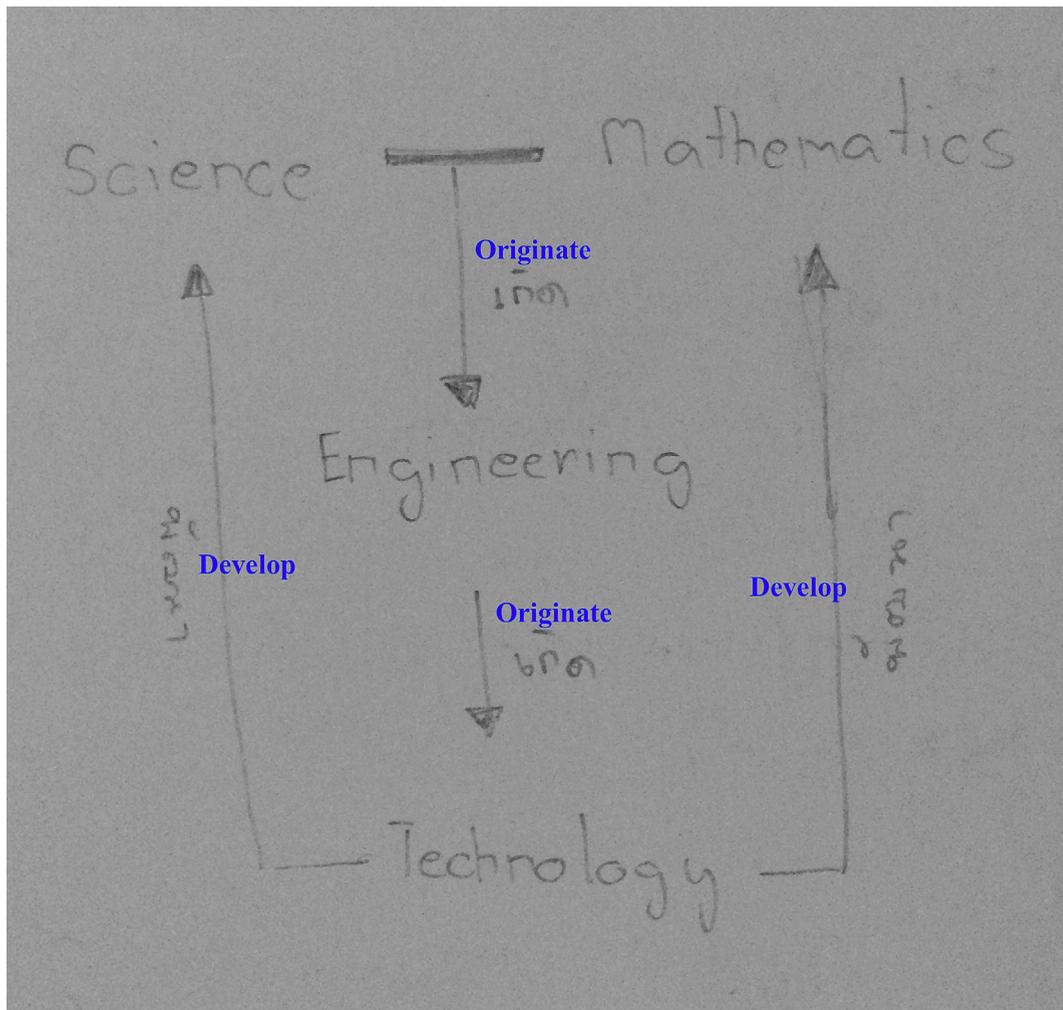


Figure 6 Complicated relationship between S-T-E-M –SC1's diagram as an example (SC1's Thai text translated by the author)

considered that STEM can be taught from the primary level. For example, HO13 responded that “The primary level is the foundation for developing students' understanding and thinking”. The last eleventh question (Which teachers should teach STEM?) was used to explore participants' ideas about the appropriateness of STEM teachers. Nearly three-fifths of participants (59.74%) felt that every teacher in every subject can teach STEM. For example, HE3 explained that “Every teacher who wants to emphasize practical work and 21st century learning” [should teach STEM].

Discussion

The results of this survey showed that most preservice teachers were aware of STEM and knew what STEM stood for. Although they mentioned integration, they did not explain in detail the nature of the integration. Most of them did not specifically answer the question of how S-T-E-M is integrated but focused on the outcomes of the integration. The results also indicated that some

preservice teachers emphasized the importance of each subject rather than explaining how those subjects are integrated, while some contextualized STEM within the processes of teaching. These results corresponded with [Bybee \(2013\)](#) and [Radloff and Guzey \(2016\)](#) in terms of the various perspectives of people regarding STEM. Although most participants responded that the purpose of STEM education is the ability to apply [STEM] to everyday life, their concepts of STEM were unclear. They did not mention STEM as an important literacy and a combination of competencies to prepare their students for joining the workforce ([Bybee, 2013](#); [Vasquez et al., 2013](#)). Moreover, the participants' ideas about the importance of STEM varied, based on their major area of study. Most were aware of STEM because they viewed their major as a part of STEM. This group of participants showed limited perspectives of STEM because their interest was especially on content knowledge in their own majors. The integration among S-T-E-M needs to focus on both the core content knowledge of each discipline and the interdisciplinary processes, so it is not just bringing these disciplines to

teach together (English, 2016; Sanders, 2009; Urban & Falvo, 2016). Moreover, most participants perceived STEM as a teaching strategy by accepting STEM as a compulsory area of understanding for all teachers. This idea might come from the many government campaigns for the promotion of STEM in Thailand. Up to this point, STEM teachers generally have a background in science and/or technology and/or engineering and/or mathematics because each discipline has a different nature of core content knowledge and processes. The STEM teachers should prepare opportunities for students to apply the integration of STEM concepts and skills to multidisciplinary situations which relate to real life (Bybee, 2010, 2013; Stohlmann et al., 2011). Bybee (2013) and Radloff and Guzey (2016) reminded stakeholders at all levels of the need to develop effective STEM education instruction for preparing quality STEM teachers who hold clear and reasonable STEM education concepts. These diverse ideas of STEM education concepts guide future research to discern the effective practices for STEM preservice teacher programs. So, building on these current understandings revealed in this survey, it is important to encourage preservice teachers to more deeply understand the nature of integration and the explicit connections among the disciplines (Pearson, 2017).

Conclusion and Recommendation

The findings of the study suggest the importance of promoting preservice teachers' understanding of the integrated nature of STEM and the connections among the disciplines. In the preparation of STEM teachers, the guides and activities need to provide opportunities for the development of STEM understandings. Firstly, STEM preservice teachers need to understand the concept of integration and how to teach S-T-E-M, not as a silo approach. Furthermore, the preservice teachers need to have some background in one or more disciplines in STEM, both content knowledge and processes, and the interdisciplinary processes which are developed from the four main disciplines. Secondly, the purposes of STEM education need to be clear for the preservice teachers, based on the educational goals. Finally, the STEM teachers' preparation program should be different from science teachers' preparation, technology teachers' preparation or mathematics teachers' preparation program because it represents the integration of disciplines. The preservice teachers need support to understand the ideas of integrated STEM as well as the identity of each discipline.

Conflict of Interest

There is no conflict of interest.

Acknowledgments

We would like to acknowledge the financial support provided by The Program to Prepare Research and Development Personnel, Science Education Division, Faculty of Education, Kasetsart University, Bangkok, Thailand and the academic support provided by the STEM Education Research Group, School of Education, Curtin University, Perth, WA, Australia.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.kjss.2018.07.017>.

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