Pre-service mathematics teachers’ perspectives on STEM-based learning activities

Wanintorn Poonpairoonpipat
Department of Education, Faculty of Education, Naresuan University
wanintorns@nu.ac.th

Abstract. As STEM education is the learning approach which involves integration from various subjects, ambiguity and differences in the interpretation of the process among the users from different subjective backgrounds can occur, particularly the pre-service teachers who have less experience in teaching. They shall implement this teaching approach with confident in teaching mathematics which is one of the subjects in STEM education, this research has focused on mathematics teachers’ perspectives toward the STEM learning activities. The participants were 36 pre-service mathematics teachers in the academic year 2017. The research instrument used for collecting data was teacher reflective journals and lesson plans. The data was analyzed by content analysis, coding, generating themes and finding the associate frequency of pre-service mathematics teachers in each theme. The finding showed that most pre-service mathematics teachers learnt the concept of STEM education and could design learning activities based on STEM education. The difficulties in learning activities design were to create the integrated situations and to set the conditions related to engineering design processes. They wanted to revise their lesson plans to be more stressed in mathematical concepts and they still wondered if STEM education was suitable and applicable to every mathematical content.

Keyword: STEM education, mathematics learning, learning activities, pre-service mathematics teachers

1. Introduction
To stay globally competitive, many nations are calling for increased studies in the fields of Science, Technology, Engineering and Mathematics (STEM) at all levels of education. Teaching STEM in primary and secondary education can help students become interested in STEM careers and build a nation’s STEM-educated workforce that can be used to meet the demands of business and industry in a complex and technology-driven economy [5]. Today STEM is a popular acronym used in education. Many countries want to improve or implement STEM education in their countries including Thailand. Thailand also would like to reform curriculum that prepares students to be ready for the future workforce, the Committee of Basic Education Curriculum Reform, they initially agreed that the new curriculum should cover six groups of knowledge: (1) language and culture (2) STEM (science, technology, engineering and mathematics) (3) work life (4) media skills and communication (5) society and humanity, and (6) ASEAN and the world [1]. In Thailand, the Institute for the Promotion of Teaching Science and Technology (IPST) has initiated a new approach by emphasizing knowledge and skills which are suitable to professional life in a highly competitive economy and society as...
known as STEM education. STEM education is perceived as a learning innovation which engages learners in applying knowledge to problems in daily life, as well as finding new processes or solutions to benefit their lives and occupations through project-based, problem-based learning activities and engineering design process [3].

The promotion of definitions and concepts of STEM is widespread. However how to drive STEM education into practice is much harder. Teachers play an important role in providing students opportunities to learn STEM activities. Besides knowledge that regular mathematics teacher should have, being a STEM teacher requires various knowledge bases. Pedagogical content knowledge (PCK), plays important role in teaching quality. The teachers’ perceptions about teaching is considered one of the vital components of PCK and has a great influence on their practice [7], [8]. Therefore, the first step toward developing teachers' PCK to teach STEM is to get them motivated and adopting STEM approach as a starting point for change.

To teach mathematics effectively and to integrate it with the other areas to meet the STEM priorities, pre-service teachers in all phases of schooling must be prepared to have a good foundation of knowledge and use it with inspirational and confident manner [2]. The effective integration of mathematics into STEM education requires change in teaching and learning opportunity. The teacher’s perceptions of STEM based mathematics and their decision regarding how they approach mathematics education can affect student opportunities to experience and sustain STEM. Since pre-service teachers will become teacher in the system soon, their attitudes and perception may infer the possibility of sustaining STEM. It would be prudent to investigate how pre-service teacher conceive the relationships between mathematics and STEM. This research aimed to examine mathematics pre-service teachers perspectives toward the STEM learning activities. A clear understanding of teacher’s STEM perception can serve as a guideline to build a higher and better quality of STEM professional development experience.

2. Methodology

The introductory undergraduate STEM education training was taught as a part of teaching mathematics in secondary school course as one of instructional approach in the present. This course took place in the last semester before the pre-service teachers experience in school practicum.

The participants in this study were 36 senior undergraduate students in the Bachelor of Education with a mathematics major. All of them enrolled in teaching mathematics in secondary school course in the academic year 2017. There are 13 males and 23 females, and the age range is 22-24 years old.

The training program of STEM education consisted of 1-day workshop followed by weekly meeting in the class held every week in the second semester of the academic year 2017. The 1-Day workshop focused on developing participants’ understanding and skills involved in STEM education. The focus of morning section was on learning about definitions and concepts of STEM education, the position of STEM in Thai curriculum, STEM as an innovative teaching approach for mathematics teacher, engineering design process and other approaches such as problem-based learning, project-based learning as means and processes of integrating science, technology and mathematics into the STEM approach. The afternoon section focused on STEM activities. Designing catapults was an exemplary project that the pre-service teachers role-played as in real class scenario where some acted as teachers and some acted as learners. Following the role play, analysis of the lesson was conducted to construct guideline for designing STEM lesson plans.

After that pre-service teachers worked in group of three for a week to brainstorm STEM lesson plan. Then presented the draft of STEM lesson plan in class and received feedback and suggestions for improvement from peers and a researcher who acted as a facilitator of the course. At the end of meeting, all groups of pre-service teachers were asked to polish their lesson plans. The issues needed to be revise lesson plan were mostly about lacking the context of situations, having only one solution to the main situation problem, incomplete detain and mismatch of activities on engineering design process. However, there is a promising in STEM based mathematics learning design which every group emphasize on mathematics content in secondary school level.
Besides submitting the lesson plans, each group demonstrate STEM teaching as micro teaching for an hour per group. Totally, it takes 12 hours for micro teaching and 12 lesson plans were collected. After micro teaching, every groups were asked to reflect their teaching and obtain some comments, questions or suggestions from their classmate and a researcher. Then each group revised a lesson plan as a final version and all of them also wrote individually a reflective journal.

There were two sources of data for this study. The main data source came from teacher reflective journals and the second data source was a collection of STEM lesson plans design by pre-service teachers to support the written reflection. The reflective topics for pre-service teachers to express in journals included 4 parts: (i) what they have learnt from the training, (ii) what the difficulties they found in designing learning activities based on STEM education, (iii) what they wanted to improve the learning activities, and (iv) what they were unclear about.

The data from teacher’s reflection was analyzed by content analysis, decoding, generating themes and finding the associate frequency of pre-service mathematics teachers in each theme. While the data from STEM lesson plans design by teachers was collected as supporting documents for (i) and (ii).

3. Results
In the beginning of the training, the pre-service teachers were asked about STEM education, only 3 of them have heard about STEM education prior the training. The rest never heard of STEM education through any media or other channels.

According to the data analysis, four reflective topics were interpreted and extracted the core ideas, and data frequency in the term of the focus of the research: (i) what they have learnt from the training, (ii) what the difficulties they found in designing learning activities based on STEM education, (iii) what they wanted to improve the learning activities, and (iv) what they were unclear about.

3.1. What they have learnt from the training
The results from teachers’ written reflection were categorized in three aspects: views regarding designing STEM lesson plans, views regarding teaching experience through STEM activities, and views on the contribution of STEM to the student.

All the participants declared that they increase understanding STEM through designing STEM activities and lesson plans. The highest frequency, containing 31 pre-service teachers acquire the connection of the content and activities in particular the integration of secondary school curriculum into STEM activities. They understood and obtained insight from discussion among peers, constructing lesson plans, searching for more information and also from comments and suggestions to improve their lesson plans. The pre-service teachers were asked to design STEM lesson plans in group of three, therefore the total are 12 lesson plans and their STEM activities are shown in Table 1. They successfully created STEM activities and lesson plans with variety of mathematics contents. Whereas, one third of them stated about STEM learning context including setting up the real-life situation, given constraints, agreement and limitation. In addition, a few mentioned about time arrangement and students’ prior knowledge was very important to the success of learning from STEM activities.
### Table 1. Activities design by teachers.

| No. | Activities                      | Mathematics                          | Science                           | Technology                         |
|-----|---------------------------------|--------------------------------------|-----------------------------------|------------------------------------|
| 1.  | Young Pilot                     | Analytics geometry-ellipse            | Bernoulli's equation              | Software for design                |
| 2.  | Graph for prediction            | Graph-Spanning tree                  | Velocity                          | Internet searching                 |
| 3.  | Solar oven                      | Analytics geometry-parabola          | Law of reflection                 | Problem solving design and decision making |
| 4.  | Waxing and waning               | Trigonometry-unit circle             | Scientific mind                   | Internet searching                 |
| 5.  | Rubber band powered car         | Calculus- derivative and integral    | Linear motion                     | Application and graph calculator   |
| 6.  | Roller coaster                  | Analytics geometry-parabola          | circular motion                   | Internet searching                 |
| 7.  | Raise the bridge up             | Trigonometry-trigonometric ratio     | hydraulic press                   | Internet searching                 |
| 8.  | Tray garden design              | Graph-vertex degree                 | Astrometry                        | Technological process              |
| 9.  | Small boat sailing              | Calculus- derivative                 | Object motion                     | Creative product                   |
| 10. | Farm water system               | Graph-shortest path                 | Photosynthesis                    | Internet searching                 |
| 11. | electric circuit                | Logic-proposition and truth table    | Electrical circuit                | QR code                            |
| 12. | Young architect                 | Vectors-three-dimensional Cartesian coordinates | Weather phenomena                 | Google SketchUp                    |

For teaching experience, one third of them mostly reflected on gaining more experience during exchange idea with their peers and bring to cooperative working. Around one fourth of pre-service teachers expressed the improvement writing lesson plan skills and three of them can improve more teaching skill while a few of them can enhance their personality and can manage the classroom better. In addition, a few of them can reflect their weak point and strong point and a pre-service teacher said that creating STEM activities was challenge for mathematics teachers.

About one sixth of the pre-service teachers reveal views on the contribution of STEM to the student in the way of learning through STEM which are a chance for improve thinking skill, creative thinking, 21st century skill, problem solving skills and STEM is the way of meaningful learning.

3.2. What the difficulties they found in designing learning activities based on STEM education
Because each group was allowed to create a draft of STEM lesson plan draft and then present to get feedback and suggestions from their peers and a researcher. Once they finished their lesson plans, they reflected difficulties they found during to training in the process of designing STEM activities.

About half of pre-service teachers viewed the main difficulty relied on designing STEM activities which have mathematics as the dominant subject of STEM-based approach for secondary school. In the beginning, only two groups can set up STEM situation while the others designed STEM situation as same as the mathematical problems found in regular mathematics classroom. After all groups presented their ideas of their STEM lessons before extending them to be the lesson plans, the main problems of primary concept idea about STEM activities relies on the STEM context and the design process. This might be due to the fact that they do not familiar to the concept of STEM as survey in the beginning where students may find multiple solutions and learn through the engineering design process. Eventually all groups achieved STEM activities, but they still found that the major difficulty
was the integration mathematics content in secondary school into STEM. The sample of their idea are as:

“The nature of mathematics is often abstract therefore it is difficult to integrate mathematics into STEM and hard to find the appropriate situation”

“It is hard to design the product that have mathematics as dominant”

While a few of them concerned about the integration of mathematics and science content in secondary school into STEM as the reflective comments like “I want to design STEM activities which have mathematics and science as the dominant subject but I did not make it good”

Nearly one fourth of them define the difficulty on STEM learning context including the identification of a problem to solve and the specification of clear goals, or criteria, that the final product or system must meet, a variety of limitations, or constraints, when they engage in design. And although constraints place restrictions on a design, not all of them are permanent or absolute.

Around half of the pre-service teachers found some trouble in students’ engagement include the students’ prior knowledge and during the design learning process particularly in the step of Testing, Evaluation and Design Improvement.

A few of them get trouble in the learning material when some material or instrument are so expensive or have limited budget or harmful to use.

3.3. What they wanted to improve the learning activities

After implementing STEM lesson plans, the pre-service teachers were asked to reflect their teaching. With the question “if you have a chance to make a lesson plan better, what do you think on revising the STEM lesson plans”, they have got insight and address the area that they could have done better. Their views are shown in the Table 2 below.

| Codes                              | Frequency |
|------------------------------------|-----------|
| Integrating STEM context           | 15        |
| Engaging students’ role            | 15        |
| Specifying conditions, agreement and constraints | 12 |
| Integrated mathematics concepts    | 12        |
| Providing more equipment           | 6         |
| Improving Teachers’ role           | 6         |
| Time management                    | 4         |
| Providing more example             | 4         |
| Design of the activities           | 3         |
| Learning material                  | 2         |

This indicates that almost half of the pre-service teachers though that they could revise the STEM learning context and change student’s role in engagement in order to learn by themselves. However, one third of them needed to specify the clear goals, or criteria and the level of integration mathematics into STEM. One sixth of them required more equipment to create STEM products and have teacher as facilitators. While four of them thought about adjust flexible time for STEM activities, they emphasized that STEM activities need more time for design process and they wanted to show more examples of STEM products. Three of them wanted to change activities in the step of planning and development, and step of testing, evaluation and design improvement because they thought these steps are key idea of design process. Then they had to describe actions clearly and give students time to think. Only two of them expressed that the leaning material such as clip videos for engagement or connection to the real life should be more provided.
3.4. What they were unclear about

The views of the pre-service teachers regarding to the unclear issues about STEM activities which might lead to the applying STEM approach to their courses. Then they were asked what they still concerned. Most of them though that the concerns were clarified already through the STEM workshop and STEM lesson design process. The view like “what is the difference between content and concept” appeared. It could be implied that the big ambiguity was the suitability of mathematics content integrated into STEM activities and if STEM education was suitable and applicable to every mathematical content.

There are also interesting concerned issues as follows
- how to design the situation with many solutions
- if real life situation is necessary
- difference between STEM and STEAM
- how often we can use STEM in mathematics class
- how to conclude related contents in STEM
- if the process of STEM can be altered
- how to manage when students need more time
- the weakness of STEM
- how to give examples to guide students
- how to guide students
- teachers’ role

Some issues come from outside the scope of the training which they might obtain from other resources. However, all questions are valuable to take in account when designing the courses for teacher preparation.

4. Discussion and Conclusions

The purpose of this study is to determine the perspective of pre-service teachers toward STEM by means of workshop followed by in-class meeting procedures. The pre-service teachers have performed in group of three to design STEM lesson plans and receive teaching experience in STEM as micro teaching. In this context the perspective of the pre-service teacher were handled based on four categories: (i) what they have learnt from the training, (ii) what the difficulties they found in designing learning activities based on STEM education, (iii) what they wanted to improve the learning activities, and (iv) what they were unclear about and 2) STEM lesson plan designed by teachers. There were two main sources of data for this study. The first source for document analysis was the participant reflection journals. These reflection journals were also the main source of candidate data for this research the second source of data collected were obtained from lesson plans design by the pre-service teacher. Then 12 STEM lesson plans were created.

The pre-service teacher reflected that they learned STEM through design STEM activities and lesson plans. This can be inferred that only the description of the STEM did not enough for pre-service teachers to understand hands on activities and practice, the process with real experience still be important for teacher preparation.

On the other hand, pre-service teachers emphasized the difficulty in creating STEM activities which have mathematics as dominant subject. The course for mathematics teacher should pay attention on the supply of nature of mathematics and conceptualizations of mathematics of pre-service teacher. Likewise, Cooke and Walker [2] highlighted the exploration of experience that can enable pre-service teachers to revise how they see and interact with mathematics. It is crucial to initiate teacher preparation programs for good foundation of mathematics concepts and encouragement of using mathematics concepts. However, these might be unwanted if the pre-service teachers’
conceptualization of mathematics and their attitudes towards their use of mathematics in everyday life, numeracy in everyday life, and relevance of classroom mathematics to students’ everyday lives were not addressed. These issues must be considered if STEM education is to be realized [2].

Another result revealed the issues that pre-service teacher need to revise mainly in STEM context including situations and constraint, student’s and teacher’s roles, the level of integrated mathematics, and material involve in activities. The ideas are similar aspects of concern about STEM PCK obtained from the previous research of Srikoom, Faikhamta and Hanuscin [6] strongly believe that teachers who attempt to teach STEM lessons will need support to develop set of learning necessary for effective knowledge and skills that were extracted from four dimensions of practice: teacher’s role and instruction, STEM learning context, student engagement in design process and connecting to content [6]. Even the ambiguous issues reflected from pre-service teacher related to four dimensions and other point to teaching skills such as questioning technique, classroom management, conclusion approach. Besides, the last important aspect is student engagement in engineering design process.

Most teachers worried about design activities if they fit in each step of engineering design process - be iterative, allow for failure, allow refining ideas, and refine teamwork and communication. In a STEM lesson, students should be engaged in a design process [7]. Engineering design is a systematic process is both iterative and systematic. It is iterative in that each new version of the design is tested and then modified, based on what has been learned up to the point. It is systematic in that number of characteristic steps must be undertaken. Each proposed solution results from a process of balancing competing criteria of desired functions. There is usually no single best solution but rather a range of solutions which one is the optimal choice depends on the criteria used for evaluation [4].

Although, pre-service teachers were introduced multiple approaches that support STEM, but all group developed and implemented lessons using engineering design process. There lessons not following an engineering design process. For the results discussed regarding the implication of the data aligns with initial findings from teachers’ abilities to prepare for STEM content and pedagogy. The engagement with these hands-on strategies in these studies allow teachers to engage fully with STEM content, to expand current STEM definition, to increase more student-center pedagogies, and to improve attitude and confidence to try STEM-based learning again in the future.

To conclude, with content analysis of pre-service teachers’ real experience in STEM activities and lesson plan design, the result gives the meaningful feedback which can be used to develop teacher training of professional development program

References

[1] Assavanonda A 2013 New curriculum must ready students for the workforce. The Bangkok Post.
[2] Cooke A and Walker R 2015 Int. j. innov. sci. math. 23 35-46
[3] Institute for the Promotion of Teaching Science and Technology 2016 The Introduction to STEM Education in Primary and Secondary Education Level. (Bangkok: OWT Printing House) (in Thai)
[4] National Research Council (NRC) 2012 A framework for K-12 science education: practices, crosscutting concepts, and core ideas (Washington, DC: The National Academies Press)
[5] Reeve E M 2013 A Report Prepared for IPST
[6] Srikoom W, Faikhamta C and Hanuscin D 2018 K-12 STEM Education 4 313-330
[7] Srikoom W, Hanuscin D and Faikhamta C 2017 Asia-Pacific Forum on Science Learning and Teaching vol 18
[8] Yuenyong, C. (2019). Lesson learned of building up community of practice for STEM education in Thailand. AIP Conference Proceedings. 2081, 020002-1 – 020002-6.