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# Fostering Teachers' Competence of the Integrated STEM Education

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## Abstract

For the successful implementation of integrated STEM education, teachers' competence could be a key element. The purpose of this research is to identify necessary behaviors of competence for teachers' teaching integrated STEM subjects more efficiently and their desire for professional development courses. The qualitative analysis was utilized to examine teachers' competence and perceptions of effective STEM teacher professional developments (TPD). Semi-structure interview method with 15 teachers and survey method with 187 teachers were utilized to address our research questions in Vietnam. We found that teachers' competence in integrated STEM education consists of four components namely, awareness, designing, implementing, assessing and adjusting the STEM teaching plan. Based on the research results, we propose an essential structural model of teachers' competence to develop professional competence about integrated STEM education and some orientation for building the structure of the professional development program. Implications for effective STEM TPD were documented.

Keywords: Integrated STEM Education, Teachers' Competence, Interview Method

## INTRODUCTION

STEM education has become potential by introducing K-12 students to STEM concepts (Brown *et al.*, 2011; Barakos, Lujan and Strang, 2012; Yildirim, 2016). These concepts may lead the students to be interested in STEM subjects and pursuing STEM careers. Teachers play pivotal roles in enhancing students' STEM competencies (Rivkin, Hanushek and Kain, 2005; Lasley, Siedentop and Yinger, 2006; Elster, 2014; To Khuyen *et al.*, 2020). However, teachers are facing many obstacles in STEM implementations (Wang *et al.*, 2011; Bien *et al.*, 2019; Margot and Kettler, 2019; To Khuyen *et al.*, 2020). For example, science teachers face several obstacles in STEM implementation successfully, such as lacking STEM content knowledge, low self-efficacy, and shifting teaching practices (Cobern and Loving, 2002; Appleton, Ginns and Watters, 2005; Shernoff *et al.*, 2017). Still, technological pedagogical content knowledge and design-based learning approaches were considered as ongoing challenges with STEM teachers (Burns, 2002; Burghardt and Hacker, 2004; Culp, Honey and Mandinach, 2005; Asunda, 2017).

Many researchers proved the effectiveness of teacher professional development (TPD) in STEM education (Goldhaber and Brewer, 1997; Supovitz and Turner, 2000; Banilower, Heck and Weiss, 2007; Capps, Crawford and Constas, 2012; Fore *et al.*, 2015; Chai, 2019; Lynch *et al.*, 2019; Krause *et al.*, 2020). Effective STEM TPD could help teachers to increase innovative STEM knowledge (Fore *et al.*, 2015) and aligned subject matters (Chiyaka *et al.*, 2017). Teachers could shift preexisting teaching practices into project-based teaching or engineering design process while participating in professional development programs (Han *et al.*, 2015; Radloff and Guzey, 2016). Even teachers felt less difficult and more confident in STEM teaching after appropriate STEM professional developments (Aldahmash *et al.*, 2019; Bartels, Rupe and Lederman, 2019). Notably, this professional development is pivotal before and during the implementation in the STEM classroom. One can say that ongoing support is critical to the success of technology and engineering integration in the classroom (Wood *et al.*, 2005; Bien, 2016; Tsai, Chung and Lou, 2018).

In Vietnam, the application of STEM education to high schools makes significant sense, consistent with the current trend of reforming general education. However, most teachers do not yet teach STEM integration because they do not know how to build and implement STEM topics (Bien *et al.*, 2019). Accordingly, it is necessary to

identify professional competencies possessed by Vietnam high school teachers that could enable them to facilitate STEM education (Vietnam Ministry of Education and Training, 2018). Additionally, there are no studies in Vietnam that refer to the STEM integrated teaching competence. Therefore, we chose the research of teachers' necessary competence for fostering STEM education.

Teachers' competence was amply defined in research literate with the highlight of components and related elements to better implementation. (Hung, 2016) proposed that teaching competence in vocational education consisted of four components: competence for teaching design, competence for teaching implementation, competence for teaching test and evaluation, competence for teaching management, and identified 15 elements of four competence components. We found that elements in the component of teaching management competence are overlapped and have the function of the remaining three components. In the doctoral dissertation: "Developing integrated teaching capacity for Chemistry pedagogical students through a module of teaching Chemistry", (An, 2017) proposed the structure of integrated teaching competence for Chemistry students including three competence components: general awareness competence on integrated teaching, competence for design and organization of integrated teaching activities, competence for test and evaluation of integrated teaching and identified nine criteria of three competence components; but some criteria are not specific and are not fully mentioned integrated teaching competence. In the article: " Integrated STEM teaching in Korea: teachers' competence structure", (Song, 2017) built the structure of integrated STEM teaching competence consists of three competence components: awareness characteristics, teaching skills, attitude characteristics; and also identified 21 elements of three competence components. The elements fully show integrated teaching competence for STEM education, but many elements are not suitable for the competence of Vietnamese teachers in STEM teaching.

Similarly, we determined that integrated STEM teaching competence includes four components: competence for awareness of STEM education (Song, 2017), competence for design of STEM teaching plan (Hung, 2016; An, 2017) competence for implementation of STEM teaching plan (Hung, 2016); and competence for assessment - adjustment of the STEM teaching plan.

We need to identify the behavioral indicators of the four competency

components and some orientations for the professional development program.

Research questions; what the teachers' competence needed for STEM implementation successfully? and what are teachers' perceptions of effective STEM teacher professional development?

## METHOD

We utilized the qualitative analysis (Cohen, Manion and Morrison, 2017) to address research questions.

### Data collection and procedures

A semi-structured interview was utilized to address the first research question. Interview via video call from Facebook's messenger on some issues relating to STEM education. We try to minimize our control during the interview process to allow teachers to respond and talk about their feelings and experiences in the STEM teaching process. Based on the answers, we analyze and determine the behavioral indicators of the above four competence components to propose a structure of integrated STEM teaching competence.

Survey method was utilized to address the second research question. Teacher participants had an experience of participating in STEM education training sessions and; some of these teachers taught STEM topics in schools. We collected data using questionnaires with these teachers at the training session of the Ministry of Education and Training in March 2019 in Danang city. The questionnaire is designed based on the proposed STEM integrated teaching competency structure. Based on these studies, we propose an essential structural model of teachers' competence to develop professional about integrated STEM education and some orientation for building the structure of the professional development program.

### Sample

15 STEM teachers were interviewed from the North and the South of Vietnam to address the first question. 12 teachers from the North (Hanoi, Laocai, Ninhbinh) and three teachers from the South (Hochiminh city). They are seven bachelor's, seven masters, and one doctor specializing in the fields of Physics, Chemistry, Biology, Mathematics, Informatics technology, Engineering, currently teaching STEM in high schools or STEM Academy in Vietnam.

187 teachers from the central provinces of Vietnam to identify the necessary behaviors of fostering integrated STEM teaching competence and teachers' perspective about professional development courses on STEM education. They are from 18 secondary schools and high schools in five provinces: Namdinh, Nghean, Quangngai, Lamdong, Daklak.

**Interview protocol and the questionaire**

For the semi-structured interview, we use the question: What do teachers need to change for their best preparation in thinking and teaching STEM?

The questionnaire in the 187 teachers survey include:

1. How do the teachers evaluate the need for training on the following issues? (These issues are related to the behavioral indicators of the proposed STEM integrated teaching competency structure).
2. Do the teachers want theoretical or practical training sessions?
3. According to the teachers, how long should the training last?
4. Which methods of training do the teachers like best?
5. What activities do the teachers like during the training sessions?

## RESULTS AND DISCUSSION

### The structural model of teachers' competence to develop professional competence about integrated STEM education

These teachers expressed their views on the problem: "What do teachers need to change for From the recorded video data of the interview, we rewrote the teachers 'answers, then analyzed and coded the teachers' answers into point of views, arranged point of views as the four competence components can be seen in Table 1, Table 2, Table 3, and Table 4.

Besides, teachers 4, 5, 6 also raised a point of view that teachers need self-learning competence. Self-learning competence is the necessary one for each teacher when teaching any subject or teaching program, is the competence throughout the teaching process of teachers. We build the structure of integrated STEM teaching competence based on teachers who were qualified in teaching with professional standards issued by the Ministry of Education and Training. The competence behaviors of this structure are necessary to give to teachers who are teaching at high schools for their good skill of STEM teaching. Therefore, we do not put self-learning competence into this structure.

Studying the process of preparing and implementing STEM teaching hours; specifically, we find that opinions raised by teachers are insufficient. Therefore, we added some elements. Later, we use the Delphi method, including three Science experts and one Math expert to survey ideas for the proposed structure of integrated STEM teaching competence. Based on the expert method, we adjust and change the components following competence components. As a result, we have identified the structure of integrated STEM teaching competence, including four competence components and 18 elements that can be seen in Figure 1.

**Some orientation for building the structure of the professional development program**

To study the perspectives of teachers on the components of competence structure, we surveyed the perspectives of 187 teachers who used to take part in a STEM training session and STEM teaching in schools. The survey question is: How do you evaluate the need to give the following issues (only one appropriate level)? Survey results are shown in Figure 2.

Survey results show that the above issues are necessary and very necessary to train teachers for the preparation of integrated STEM teaching. Just a few options are selected as unnecessary. At the same time, when averaging the teachers' choice, we showed that four issues are the most necessary selected by teachers, including: How to assign tasks to students appropriately and interestingly; How to cooperate among teachers of subjects in developing STEM topics; How to organize activities to report discussion effectively; Select and design STEM teaching activities. In the training session for teachers, we need to pay special attention to the above four issues for best support to teachers during the STEM teaching process.

Analyzing the survey result, we find that there is no significant difference in the views of male and female teachers, or among teachers who only took part in one training session and teachers who participated in two or more training sessions on these issues.

Besides, we also study teachers' points of view on the training session. Among 187 participated teachers, 185 teachers find that it is necessary to strengthen practices, specific views on some training activities using in training sessions in Figure 3, Figure 4, and Figure 5.

The survey results in Figure 3, Figure 4, and Figure 5 show that most teachers want to practice the design of topics, teach designed topics, and to be discussed, consulted by experts on topics and teaching hours during training sessions. Thus, a training program should be minimized theory, strengthen practice, especially for strengthening three practice activities, which are the favorite of teachers.

Through the survey, we find that teachers like training sessions in a short time. The more timelines are, the fewer teachers' selection is (66.85% of surveyed teachers select training session in one week, 18.18% of surveyed teachers select training session in 1 month, 4.28% of surveyed teachers select training session in three months, some teachers want training session in few days). This is also important data for the arrangement of training time. Regarding the training model, teachers

have different views, but most teachers like gathered training (reach 67.4%). This training model enables teachers in learning and sharing with a colleague, spending full time on training content. However, other training models also have their advantages in some aspects such as time and work. Some teachers believe that it is necessary to combine training modes. A combination of training modes for the promotion of the advantages and disadvantages of each mode surely results in high efficiency.

Table 1. Point of view on the component of awareness competence for integrated STEM teaching.

| Elements & Teachers | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Understanding of STEM education | x | | x | | | x | x | x | x | | x | x | | x | |
| Design thinking | | | | | | | | | | | | x | | | |
| Scientific thinking | | | | | | | | | | x | | x | | | |
| Specialized teaching knowledge | | | x | | x | x | | | | | | | | | x |
| Passion, enthusiasm, dynamism | | x | | | | | | | | x | | | | | |

Table 2. Point of view on the component of planning competence for STEM teaching.

| Elements & Teachers | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cooperative skill | x | | x | | | | | | | | | | | | |
| Teamwork skill | | | x | | | | | | | | | | | | |
| Using modern teaching methods | x | | | | | | | x | | x | | | | | x |
| Information and communications technology | x | | | | | | | | x | | | | | | |
| Building STEM topics | | x | | | | | | | | | | x | | x | |
| Building teaching equipment | x | x | | | | | | | | | | | | | |

Table 3. Point of view on the component of implementation competence for STEM teaching plan.

| Elements & Teachers | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STEM theme organization | | | | | | | | | | | | x | | | |
| Teachers play the role of instructor and orientation in the teaching process | | | | | x | | | | | | x | | | | x |

Table 4. Point of view on the component of competence for assessment and adjustment of STEM teaching plan.

| Elements & Teachers | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test assessment in teaching | | | | | x | | | x | | | | | x | | |

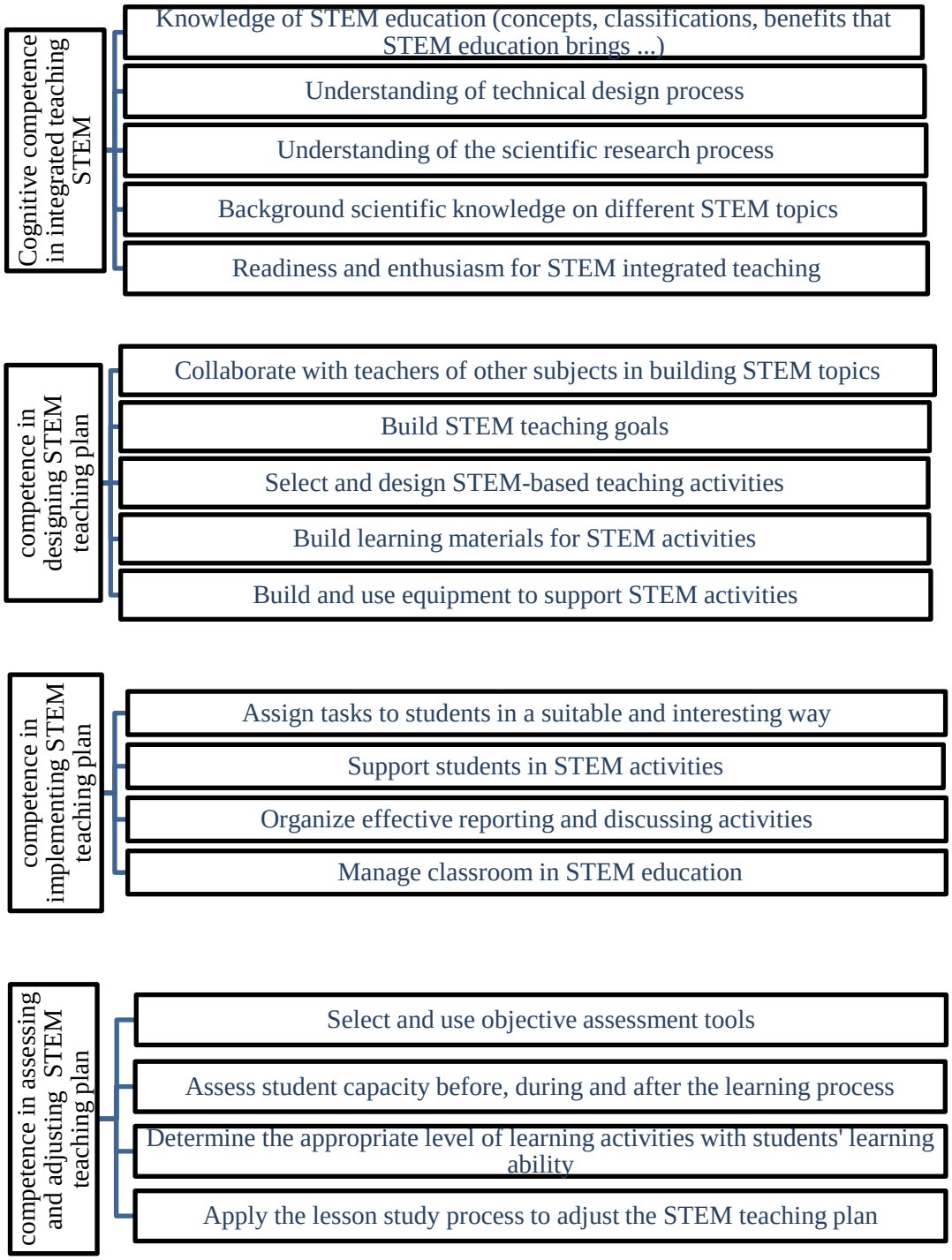


Figure 1. Model of essential competency structure for teacher training in integrated STEM education proposed

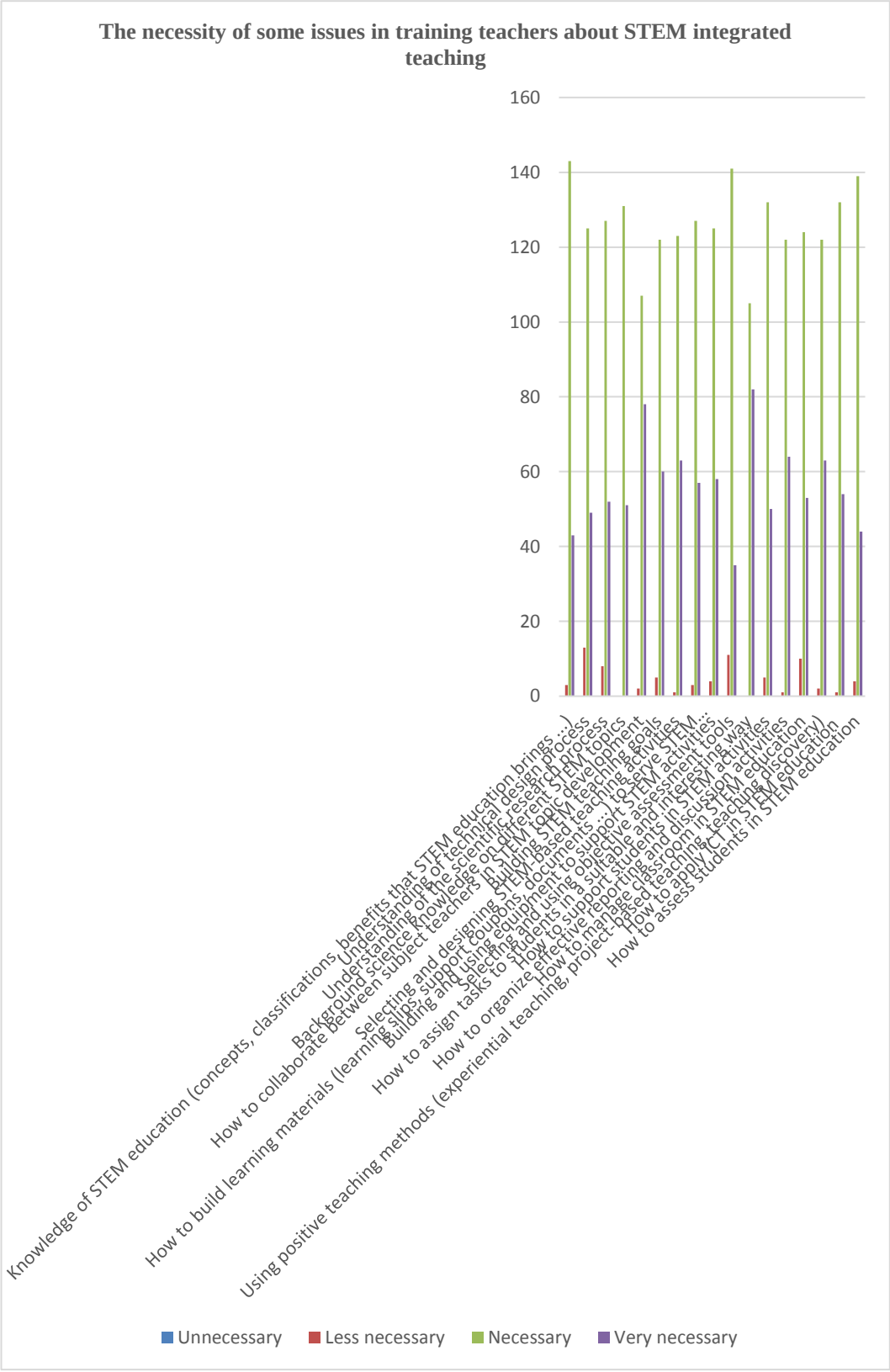


Figure 2. Teacher evaluation of the necessity of elements in the proposed competency structure

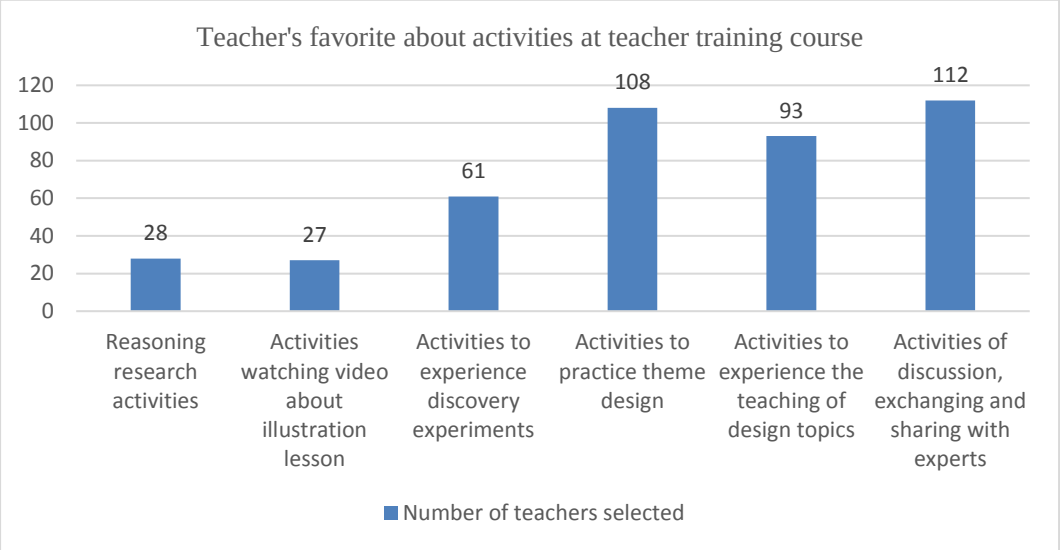


Figure 3. Teacher's favorite about activities at the teacher training course

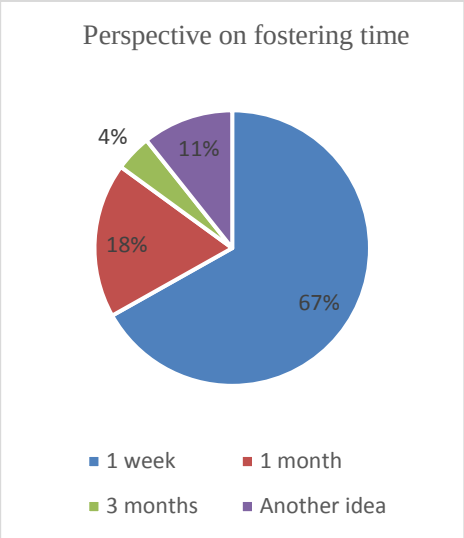


Figure 4. Perspective on fostering time

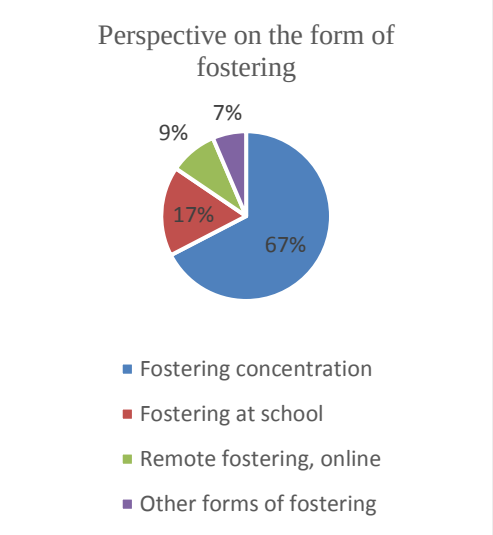


Figure 5. Perspective on the form of fostering

## CONCLUSION

Participating teachers in semi-structured interviews believe that their experiences help the improvement of STEM teaching quality. Each teacher has a different point of view which helps us to summarize general views on necessary competence components during the preparation and teaching of STEM topics. Experts also gave usimportant and effective ideas in building the structure of integrated STEM teaching competence. The teachers in the questionnaire survey thought that the following four issues were most essential in the STEM education training: How to assign tasks to students appropriately and interestingly; How to cooperate among teachers of

subjects in developing STEM topics; How to organize activities to report discussion effectively; Select and design STEM teaching activities. From the point of view of these teachers, it is necessary to strengthen practices in training sessions, especially training activities as follows: Activities to discuss, exchange and share with experts, Activities to practice theme design, Activities for getting experience from teaching designed topics. This research is an important scientific basis for us to build content of teacher training sessions on STEM education and identify some orientations of program, time, and teacher training mode. However, we think that it will be valuable to compare different cases and different points of view for the same issue raised in this study in future researches.

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