Perceptions of in-service teachers toward teaching STEM in Thailand

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Abstract

While increased attention has been put on approaches to teaching science, technology, engineering, and mathematics (STEM), little has been reported on teachers' views, perceptions, and beliefs about teaching STEM. Such knowledge is needed to inform efforts to support innovative teaching of STEM subjects in classrooms. In this study, 154 in-service teachers of both STEM-related and non-STEM related subjects, were randomly selected from schools all over Thailand. Data on teachers' perceptions were captured through a three-part questionnaire including an open-ended question that asked for general background information and perceptions of STEM education and STEM integration. Descriptive statistics were used to analyzed data and content analysis was used to analyze open-ended responses. Research findings showed that the majority of teachers (85.5%) had never heard about STEM education and approximately 19% of in-service teachers could not provide a definition of STEM education, with 20.53% of the teachers viewing STEM as a transdisciplinary course or program. While teachers think that a STEM teaching approach is very interesting, both STEM and non-STEM in-service teachers have strong concerns about the engineering discipline within STEM disciplines.

Keywords: STEM education, STEM teaching approaches, STEM integration, teacher's belief, teachers' perception

Introduction

The development of science and technology and the increasing number of skills necessary to work in the twenty-first century have influenced an educational paradigm shift. Education today emphasizes high-level thinking skills, creative thinking, problem-solving, and critical thinking, as well as the development of communication skills and technological proficiency as tools of inquiry for learning and living. The integration of all subjects, both in the classroom and in real life, is the primary trend toward making education more meaningful for students. The intent is that students realize the value of their studies and apply this knowledge to everyday life, which can lead to broader job opportunities in the future, add more value, and in turn build up national economies (Moore, 2008; National Research Council [NRC], 1996, 2000).

Many countries must be strongly alerted to practice educational reform. In Thailand, for example, the 2007 Trends in International Mathematics and Science Study (TIMSS) found that in the average mathematics score of eighth-grade Thai students was lower than that of most countries. Similarly, the average score in science for eighth-graders was low and decreasing over time (Ross et al., 2012).To help students stay globally competitive in terms of innovation and invention, STEM teaching has become a priority in K–12 education because well-integrated instruction increases retention, improves problem-solving skills, encourages the use of higher-level critical-thinking skills, and provides opportunities for students to learn in more relevant and stimulating experiences (Stohlmann et al., 2012).

To prepare students for the twenty-first century, educational institutions in many countries have adopted and forced in support of an increased focus on STEM education in schools (Honey et al., 2014). Many organizations have similar concerns about the future need for more skilled workers, especially in STEM-related fields and a knowledgeable population trained in STEM areas (Zollman, 2012). These alarming trends have increased support for change and have led to the formation of an education reform movement by integrating science, technology, engineering, and mathematics into schools. Nevertheless, several solutions beyond this are necessary to better prepare students for their future because different regions may require tailored solutions to fit their specific circumstances.

While it is easy to offer definitions and conceptions of STEM putting STEM education into practice is much harder. Teachers play an important role in providing students opportunities to learn STEM activities. However, being a STEM teacher requires a different knowledge base than that of science teachers. The specialized knowledge of teachers, known as pedagogical content knowledge (PCK), plays important role in teaching quality. PCK is an amalgam of content knowledge and pedagogical knowledge that reflects a teacher’s ability to make specific content understandable for particular students (Shulman, 1986).

Teachers’ perceptions about teaching is considered one of the vital components of PCK and has a great influence on their practice. Therefore, on the success of any change in educational systems should take these into account (Bell, 1998; Pajares, 1992; Park & Oliver, 2008). Therefore, the first step toward developing teachers' PCK to teach STEM is to better understand how teachers think about the STEM approach as a starting point for change. Park and Oliver (2008) indicate that a teacher’s orientation, which is influenced by their belief and perception about learning and teaching, acts as a concept map for decisions addressing the other PCK components. Similarly, Gess-Newsome (2015) noted that teacher’s belief and perception can act as a filter and amplifier to the teacher’s action. This is the reasons why we need to focus on exploring and changing teachers’ perceptions urgently. A clear understanding of teachers' STEM perceptions can serve as a powerful platform sustainably build a higher and better quality of STEM professional development experience.

Nowadays, Thailand encourages the support of teachers to develop STEM-appropriate teaching practices via STEM education agencies put forth by the Institute for the Promotion of Teaching Science and Technology (IPST). The Thai government's intention to advance STEM education forward in the country (IPST, 2013) represents a major initializing period that will involve several research agendas to drive STEM education forward beyond a mere slogan among educators. Further research investigations are required to teach the country more about STEM education in all its dimensions in order to fill educational gaps and improve student competencies for the future. The purpose of this study is to explore in-service teachers' initial perceptions including understanding of STEM definition and integrated perception of the STEM approach. The research question guiding this study is "What are in-service teachers' perceptions about STEM education?"

Methodology

Teacher's Pedagogical Content Knowledge

Building on Shulman's notion of PCK, many studies have defined PCK as consisting of instructional strategies that incorporate representations of subject matter and a good understanding of specific student-learning difficulties and modes of thought across different subjects (Goodnough & Nolan, 2008; Van Driel & Berry, 2010). PCK is suggested to have the greatest impact on a teacher's classroom abilities (Gess-Newsome 1999). The orientations toward teaching is an important component of PCK and referring to teachers' beliefs and perceptions about the goals for teaching specific content at different grade levels (Grossman, 1990; Magnusson et al., 1999). Recently, Gess-newsome suggested that teachers' orientations toward teaching, belief, prior knowledge, and context can act as a filter or amplifier for teachers to approach the learning and application of new knowledge differently (Gess-newsome, 2015, p. 32). Also, teacher's perceptions strongly shape their instructional decisions on activity design, the content of students' assignments, the evaluation of student learning, and the use of curriculum materials (Adadan & Oner, 2014). Moreover, it is much evidences that teachers' use of strategies is influenced by their beliefs and perceptions about teachings. For example, some teachers resisted changing their practices to match those of an innovative approach because their beliefs differed from the premises of the new approach (Cronin-Jones, 1991; Mitchener & Anderson, 1989; Olson, 1981). Research also indicates, however, that teachers are likely to change when they become dissatisfied with their current teaching practice (Feldman, 2000; Fullan, 1993).

Teachers' Perception of STEM Education

Many studies on learning context and teachers' perceptions of teaching (e.g., teachers' awareness, prior experiences, understanding, concern, and interest) established a series of systematic associations linking teachers' approaches with students' perceptions, learning approaches, and outcomes (Biggs, 1999; Marton & Booth, 1997; Prosser & Trigwell, 1999). In this way, teachers' perceptions of the STEM approach are very important given that they can influence teachers' decision-making. Also, students' learning is related to their teachers' approaches to teaching (Trigwell, Prosser & Waterhouse, 1999). Cope and Ward (2002) summarized the associations of teachers' perceptions of teaching and the quality of students' learning outcomes in Figure 1.

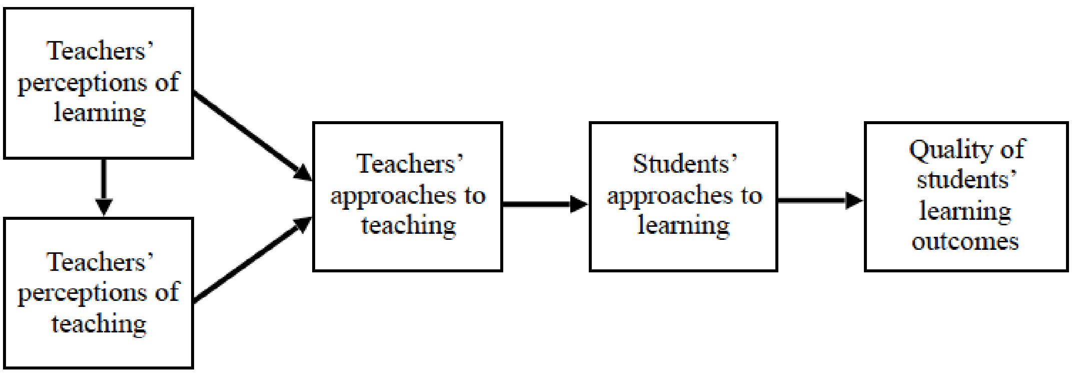

Figure 1. Teacher-student perceptions and quality-of-learning outcomes.

In terms of STEM education, the NRC (2007) argued that individuals begin to develop perceptions and knowledge of STEM prior to and during their elementary education, which increases the importance of teaching STEM at the elementary level. Teachers with negative attitudes-a part of perception-toward STEM tend to avoid teaching STEM (Appleton 2003). Since the attitudes of the teacher are frequently transferred to their students (Deemer, 2004), poor attitudes toward STEM may be initiated and enhanced by teachers. Besides developing robust teacher knowledge for teaching STEM, we insist that teachers' perceptions of the STEM approach should be considered. As STEM education becomes focus for an increasing number of schools and teachers, the term "STEM approach" needs to be clarified and better defined, because an uncertain definition may affect teachers' attitudes and views.

STEM Integration Perception

Although, educators are aware of the importance of STEM education, neither educators nor researchers agree on understand what STEM education should really be about in K-12 education. Currently, STEM disciplines are taught in silos, but the nature of the work blurs the lines between disciplines. Integrating STEM disciplines would be more in line with the nature of STEM (Wang et al., 2011). Because the nature of STEM is integration of the four subjects, many questions remain unanswerd in K-12 STEM education. One of the biggest educational challenges for K-12 STEM education is that few general guidelines or models exist for teachers to follow regarding how to teach using STEM integration approaches in their classroom. Thus, research needs to be done to look at teachers' understanding, perceptions, and implementation of STEM integration.

Bybee (2013) proposed that there are many different perceptions on STEM integration, for example, the view that STEM equal a quartet of separate disciplines and the view that STEM is a reference for science and mathematics (Figure 2). Both perceptions consist of the same four elements but the way in which each element interacts with each other is obviously different. In the first one, STEM is viewed as separate concepts with no explicit connection between them. This can represent a course that provides general content of the STEM disciplines or four separate courses, one for each discipline. In the second one, STEM is viewed as a course that emphasize only science and mathematics and may or may not mention engineering and technology. These are two examples of how integration can be viewed differently by each teacher. Even though STEM only consist of four major disciplines, it can take many forms, and we believe it directly impacts the teacher's decisions on instructional strategies. In this study, we proposed nine possible models that adopted and modified from Bybee's notions, constructed from many discussions, articles, reports, and projects. (summarized in Appendix A).

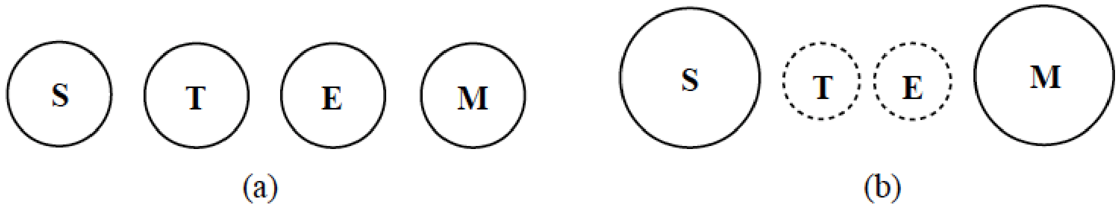

Figure 2. STEM equals a quartet of separate disciplines (a) and STEM as a reference for science and mathematics (b).

Teachers' perceptions can vary depending on job title, location, and teaching style. This can make it confusing for teachers trying to implement STEM-centric lessons into their classrooms. Bybee also pointed out that advancing STEM education presents several significant challenges. Use of the acronym and the associated ambiguity has served as a rallying point for policy makers and some educators (Bybee, 2010). When people come with different perceptions, they might come with different perceptions as well. Therefore, identifying teachers' STEM perceptions is one of the most important processes that science educators and other STEM-education stakeholders need to consider.

STEM integration can be viewed differently based on a person's background, attitude, and other factors. To advance STEM education into the classroom, we need to identify how teachers and students think about STEM education. While there is a continuing need to clearly define a theoretical framework for STEM integration, other issues including understanding curriculum for the classroom, and the goals for an effective STEM instruction still need to be discussed (Bybee, 2011; Breiner et al., 2012).

Method

Research Design

In this study, we used survey research design to examine teachers' perceptions about STEM education. We developed and applied the STEM questionnaire which comprises open-ended and closed-ended questions about teachers' beliefs and understanding regarding STEM education.

Participants

The participants in this study included 154 teachers from STEM workshops organized by IPST from March to May 2015. They came from both private (n = 12) and public (n = 27) schools all over the country, and included 26 kindergarten, 31 lower primary, 66 upper primary, 19 lower secondary, and 8 upper secondary teachers aged between 23 and 68 years old. Their teaching experience in schools averaged 13.7 years (minimum is 1 and maximum is 47 years). The majority of the teachers (85%) had a bachelor degree. Teaching assignments for this sample consisted of 90 STEM subjects, 60 non-STEM subjects, and 4 unidentified teaching subjects.

Data Collection

The data was collected using a survey questionnaire given before the STEM workshop, which included 3 parts:

Part 1 asked about the background information of the participants (e.g., age, education background, teaching experience).

Part 2, measured of teachers' awareness, prior experiences, understanding, concern, and interest regarding STEM education. It used a 4-point Likert-type scale ranging from 1 (not concerned) to 4 (strongly concerned). The open-ended question "In your opinion, what is STEM education?" was at the end of this part.

Part 3, participants selected their preference from several STEM teaching approaches, each represented by a diagram with brief description. Based on Bybee's notions, there were nine proposed STEM perceptions' diagrams (in Appendix A).

To check instrument validity before using instrument, a group of 55 science and mathematics in-service teachers were asked to comment on the readability of the items in the data-capturing tools. These teachers agreed that all items were relevant and should remain in the study.

Data Analysis

The participants' ages, years of experience in teaching, teaching level, and their perception of the STEM teaching approach, were analyzed using descriptive statistics including frequency, mean, standard deviation. We used the one-way analysis of variance (ANOVA) to determine whether changes in independent variables (i.e., age, teaching level, teaching subjects) had significant effects on teachers' concern about STEM disciplines.

To analyze qualitative data from the open-ended questions, the researchers used interpretive methods (Erickson, 1986), in which the participants' own meanings and points of view were sought. An iterative process of coding, memo writing, focused coding, and integrative memo writing (Emerson et al., 1995) was followed. All coded themes from the analysis were cross-checked by the research team. The open-ended question was analyzed in the first-level analysis. We gathered the teachers' answers about the definition of STEM education into the spreadsheet and noted the similarities and differences to categorize teachers' responses. In the second-level analysis, the data was coded and rearranged into the categories cross-checked by the research team. Table 1 provides an example of coding representing teachers' definition of STEM education. Codes were then grouped and refined to generate categories, for example, "STEM is an integrated teaching approach" and "STEM is a science teaching".

Table 1. Examples of codes and categories emerging from teachers' responses.

Codes	Categories
"STEM education is a teaching approach that uses the inquiry process to engage students' learning."	STEM education is an inquiry-based teaching approach
"STEM education is a science-teaching approach that mixes with other concepts to solve specific problems and find answers."	STEM education is a science-teaching approach
"STEM is a science- and project-based teaching and learning approach."	
"STEM education is a teaching approach in which students apply scientific concepts to solve problems."	
"STEM education is an approach that integrates several type of knowledge for learning."	STEM education is an integrated science, math, engineering, and technology approach
"STEM is an approach that focuses on integration and connection of STEM concepts."	

Findings

STEM Education Perceptions

The data indicates that, even though STEM education policy has been launched in Thailand in 2013, only 14% of participants had received information about STEM education before attending the IPST-STEM workshop and 85% never heard of STEM education through any media or other channels. Among those familiar with STEM education, the internet was the most accessible and powerful channel that allowed teachers to know about STEM education and become familiar with it.

Overall, teachers expressed moderate to strong concern about teaching STEM (2.44 to 3.16 out of 4). The discipline about which teachers expressed the most concern was Engineering (3.05 out of 4). Teachers expressed lower levels of concern about mathematics, technology and science, at 2.78, 2.63, and 2.64, respectively.

Teachers' concerns about teaching STEM, based on teaching subject, age, and teaching level . When we grouped teachers by teaching subjects, we found that teachers of STEM-related subjects had a higher level of concern for STEM education than teachers who teach non-STEM related subjects (Figure 3).

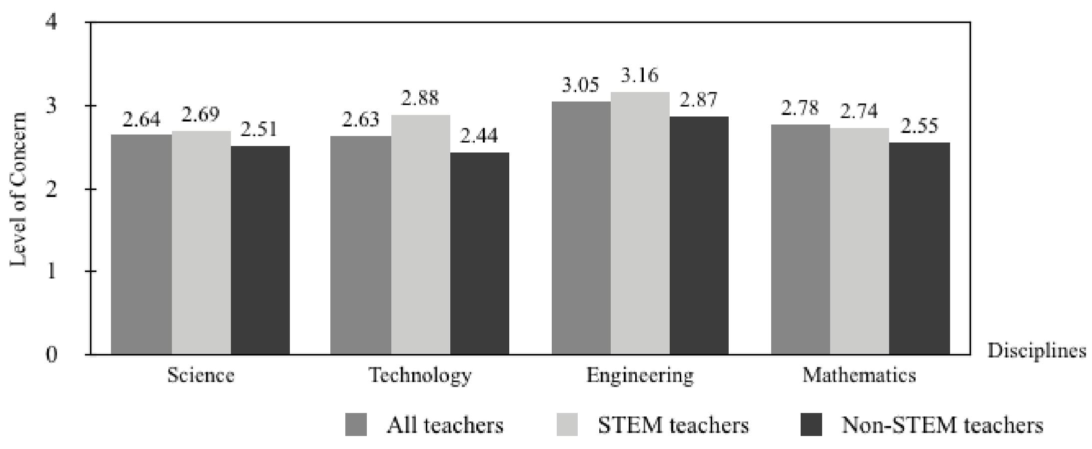

Figure 3. Teachers' concerns about STEM disciplines by teaching subject.

The age range of each group was analyzed using a one-way ANOVA to compare means. The results showed no significant differences between age groups ($p > 0.05$), however we noted some interesting patterns in the data. For example, teachers in the group aged 21–30 years old had stronger concerns about each discipline of STEM than other groups. In mathematics and engineering disciplines, teachers aged between 41–50 and those above 50 year old had lower concern than the groups of teachers aged 21–30 and 31–40 years old. However, teachers aged 31–40 years old seemed to have more confidence overall about all STEM disciplines except engineering (Table 2).

Table 2. Teachers' concerns for STEM education grouped by age range.

Age Range		Level of Concern			
		Science	Mathematics	Engineering	Technology
21–30 (n =35)	Mean	2.80	2.69	3.14	3.00
	Std. Deviation	1.02	1.02	0.85	1.00
31–40 (n=49)	Mean	2.53	2.65	3.14	2.65
	Std. Deviation	0.79	0.75	0.82	0.78
41–50 (n=25)	Mean	2.68	2.64	2.92	2.76
	Std. Deviation	0.95	0.70	0.86	0.97
Above 50 (n=37)	Mean	2.59	2.54	2.89	2.70
	Std. Deviation	1.01	0.96	0.91	0.91
Total (n=146)	Mean	2.64	2.63	3.04	2.77
	Std. Deviation	0.93	0.86	0.85	0.90

Additionally, teaching levels affected in-service teachers' concern level regarding STEM disciplines. Similar to age groups, the results showed no significant differences between teaching levels ($p > 0.05$). However, lower primary (grades 1–3) and lower secondary (grades 7–9) teachers tended to have stronger concerns. Lower primary and lower secondary teachers reported a concern of 2.93 and 2.95 for technology while kindergarten, upper primary, and high school teachers reported concern levels of lower concern level at 2.60, 2.69, and 2.63, respectively (mean = 2.78). All participants reported a strong interest in STEM education (mean = 3.93, SD = 0.385).

Teachers were grouped according to teaching subject: science (S), mathematics (M), science and mathematics (SM), STEM-related (e.g., agriculture, computer, and technology), and non-STEM. The findings showed that teachers of STEM-related subjects had a higher concern level in all disciplines of STEM (mean = 3.00 –3.63). While, science teachers held lower concern levels than the others (Table 3). However, a post-hoc pairwise comparison test did not show significant differences between the groups ($p > 0.05$). SM teachers indicated moderate concern in science, mathematics, and technology disciplines. All groups showed quite strong concerns in engineering (mean = 3.16). In contrast, science seems to be the discipline with the lowest concern level among discipline of STEM teachers (mean = 2.69).

Table 3. Teachers' concerns for STEM education grouped by teaching subjects.

Teaching Subject		Level of Concern			
		Science	Mathematics	Engineering	Technology
Science (n=44)	Mean	2.6	2.7	3.1	2.8
	Std. Deviation	1.1	0.9	0.9	1.0
Math (n=22)	Mean	2.9	2.7	3.1	3.1
	Std. Deviation	0.9	1.0	0.8	0.8
Science and Math (n=14)	Mean	2.6	2.6	3.4	2.8
	Std. Deviation	0.5	0.5	0.7	0.6
STEM-Related (n=8)	Mean	3.1	3.1	3.6	3.0
	Std. Deviation	0.8	0.6	0.5	1.1
Total (n=88)	Mean	2.7	2.7	3.2	2.9
	Std. Deviation	1.0	0.8	0.8	0.9

The findings show that 81% of teachers were able to articulate a definition of STEM, while 19% could not (Figure 4).

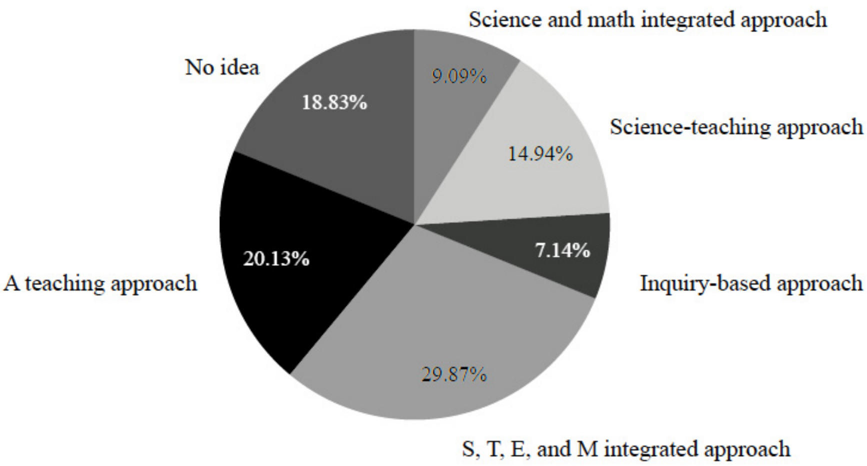

Figure 4. Teachers' understanding of what STEM education is.

About 30% of in-service teachers defined STEM education as an integrated STEM-disciplines course or a program to solve problems. The example of their ideas is as:

"STEM education is a teaching approach that integrates science, mathematics, engineering, and technology to solve real-life problem."

About 20% of the in-service teachers indicated that STEM education is an approach for teaching. The example of their ideas is as:

"STEM education is a teaching approach" and "STEM education is an approach that integrates several types of knowledge for learning."

Nearly 15% defined STEM education as an approach in which students mainly applied science (with or without other disciplines) to solve problems or find answers. The example of their ideas is as:

"STEM education is a science-teaching approach that mixes with other concepts to solve specific problems and find answers" and "STEM education is a teaching approach in which students apply science concepts to solve problems."

About 9% of in-service teachers defined STEM education as an approach that focuses on the integration of science and mathematics to guide students' learning. The example of their ideas is as:

"STEM education is an integrated science-and-mathematics teaching approach in which students learn from doing projects."

Around 7% defined STEM education as an inquiry-based approach that emphasizes learning by doing and finding one's own answers. The example of their ideas is as:

"STEM education is a teaching approach that uses the inquiry process to engage students' learning."

STEM Integration

Although there is not a single correct approach for STEM integration, we wanted to understand the perceptions that represent our context. In this study, we asked participants to select STEM-education perception models (defined by Bybee, 2013) that best match their perception. Teachers also could express their own ideas and models in addition to the given models. The findings, based on 302 responses, indicated that the majority (20%) viewed STEM education as a transdisciplinary course or program and only 2.32% viewed STEM as a teaching approach in which science is a core concept and other subjects are minor components. This indicates that teachers hold a verity of perceptions regarding STEM integration. The majority of teachers believe STEM concepts should be taught and as a transdisciplinary course in which science, mathematics, engineering, and technology concepts are integrated homogeneously. AT the same time, the same person can view STEM as overlapping across disciplines, such that the teacher must teach STEM concepts together via specific themes or activities. However, we strongly believe that more STEM integration perceptions remain, and we insist that more research should be done on teachers' beliefs and knowledge related to teaching practices in the context of the classroom. This sort of information will allow us to understand the connection between what teachers think and what they do.

Table 4. Teachers' STEM-perceptions models (details in Appendix A).

Integration Model	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9	Total
Frequency	33	39	7	36	41	28	13	43	62	302
Percentage	10.93	12.91	2.32	11.92	13.58	9.27	4.30	14.24	20.53	100.00

Discussion

In this study, Thai in-service teachers had limited awareness about STEM education (14%). This reflects the need to improve mass and official communication about STEM education through pathways such as social networks and online.

The finding regarding teachers' concern about STEM disciplines indicates engineering is the highest concern. This is an interesting point, because many studies indicate the importance of engineering in STEM teaching, specifically that the nature of engineering design provides students with a systematic approach to solving problems that often occur in all of the STEM fields. Also, engineering design provides the opportunity to locate between the STEM disciplines, which has been identified as key to subject integration (Frykholm & Glasson, 2005; Barnett & Hodson, 2001). Thus, a lack of understanding engineering probably impacts the quality of STEM integration in education. Engineering is difficult for teachers for several reasons. In this study, few teachers were knowledgeable about engineering in STEM concepts. Additionally, engineering is quite new to teacher and it was not seriously addressed in the science and technology curriculum. Regarding Gess-Newsome's notion, a teacher as a free agent has the opportunity to embrace, reject, or modify new knowledge, skills, and practices based on their perception and belief (Gess-newsome, 2015). Therefore, to enhance quality of teachers' practices we must measure and track teachers' perceptions on STEM education and integration.

We explored that there is no significant difference between teachers' background (e.g, age, teaching assignment, experiences) and their perceptions of STEM education. We believe teachers in all categories shared the same level of knowledge because STEM education was only established in Thailand a couple of years ago. Additionally, we believe most teachers' perceptions of the satisfying impact STEM has on students' learning has possibly created and reinforced positive attitudes. However, many teachers-especially science and mathematics teachers-tend to be concerned about how well their subjects will integrate with other subjects.

Regarding a definition of STEM education, some participants (19%) did not have any idea what it meant. This indicates the irrelevance of awareness and understanding; although most of teachers had never heard about STEM education they knew about STEM from other routes and some could provide a definition for it. Similarly, Heiden et al. (2016) have tracked STEM awareness since 2012. They report that STEM awareness was quite low (26%) in the first year of evaluation then rising to 49% in 2016 through strategical efforts. Thus, if we systematically emphasize public awareness, especially in school, then the resulting trend will be the same. The findings on categories of STEM definition indicate that teachers hold uncertain views of STEM education. This can be considered an advantage or a disadvantage. It's an advantage in that STEM can be flexibly applied in several forms into classroom and may reduce teachers' stress for enacting a new approach. It's a disadvantage in that teachers might suffer anxiety about STEM teaching due to uncertain views on the subject.

Similarly, teachers perceived STEM integration in many forms. This indicates that STEM can be used with different events and strategies. Some teachers may use technology or engineering design as the core of learning (Guzey, 2012), while some teachers view STEM as a problem-based learning activity grounded in the theoretical background of constructivism, where students are engaged in the diverse components of problem solving (Capraro & Slough, 2008; Clark & Ernst, 2007). However, teachers are required to understand and process STEM content in order to scaffold students' STEM learning and develop STEM literacy with regards to students' awareness and future skills.

In addition, teachers did not have a consensus about the integration model. This can be interpreted in two ways. The first is our given STEM-integration model represents all possible STEM-concepts integration. The second is that teachers might not understand well enough to conceptualize an integration model. However, we believe when teachers gain more STEM teaching experiences, they might come up with more ideas about integration.

Conclusions and Implications

This study examined teachers' perceptions of STEM education, which is receiving increased attention in educational reforms worldwide. It is important that we focus on teachers because they play a critical role in the success of new reforms. We grounded our work in the construct of PCK with a particular focus on teachers' orientations, which strongly shape their instructional decisions. The term 'orientations' refers to teachers' beliefs about the purposes and goals for teaching science at different grade levels. In this study, teachers' perceptions of STEM are considered to be related to their orientations. Our findings contribute to the field by characterizing the current state of teachers' perceptions of STEM education and by helping establish a baseline for further research about teachers' PCK for teaching STEM.

Our findings make several contributions toward understanding in-service teachers' perceptions of STEM. First, our study provides evidence that there is not a widespread awareness of STEM education among in-service teachers. The majority of teachers recognized STEM from online sources (e.g., websites and social media), colleagues, and related workshop events. That means we still need to invest more in communicating STEM education to the public by several channels, especially online and social network. Clearly, it is very important to start with raising the awareness and understanding levels of administrators and teachers to develop a common understanding of STEM education that can enhance collaboration between policy makers, school administrators, practitioners, and supporters to reach the same goal.

Second, our findings illustrate a lack of consensus among teachers about definition of integrative STEM. Most teachers described STEM education as an integrated-disciplines teaching approach toward solving real-life problems. Moreover, teachers often defined STEM education with the common phrases "solving problems" and "learning by doing". Therefore, the types of activity that harmonize with teachers' perception of STEM education are most likely problem-based, project-based, and inquiry-based approaches. These findings relate to teachers' STEM-integration perception, showing that a number of teachers viewed STEM approach as a transdisciplinary integration (all disciplines are planned and taught together) and interdisciplinary integration (all disciplines are planned and taught separately). Teachers viewed STEM as an approach that involves solving real-life problems with integrated knowledge. That is, real-life problems need to be infused in STEM lesson plans to connect lessons to everyday experiences. Based on the notion of Bybee (2013) and our findings, we still have no precise answers of which type of STEM integration is the best approach.

Third, our findings reveal areas of concern for in-service teachers about the STEM disciplines themselves. The findings also show that most in-service teachers have a higher concern about engineering than other discipline. Teacher confidence for teaching STEM is an important predictor of ability for teaching STEM-related content, and teachers that tend to have problems with content, especially engineering, can have a negative influence on student learning (Harlen & Holroyd, 1997; Ford, 2007; Jarrett, 1999). National education agencies such as the Ministry of Education and school administrators can apply this finding as baseline information toward making further steps to support STEM education implementation. Based on our findings, we suggest that educational resources materials and resources be designed to cover all common integration perceptions in order to serve all possible teaching styles. Moreover, IPST, curriculum, and teacher development agencies, can apply these findings and study methods to improve understanding about STEM perception and support teachers to develop better beliefs and attitudes about teaching STEM. For example, many teachers hold strong concerns about engineering, thus engineering-integrated curriculum and standards should be developed to support teachers' understanding, and teachers can use this curriculum as a guideline for enacting a STEM approach. Many scholars suggest that teachers' knowledge, beliefs, and perceptions about teaching and learning are tacit and tenacious and serve as filters for acceptable learning and teaching activity (Kagan, 1992; Pajares, 1992; Richardson, 1996; Gess-newsome, 2015). We suggest that emphasis on students' learning outcome and assessments must be included in teacher development process because students' learning is directly related to teachers' decision-making and selection of appropriated approaches to teaching (Trigwell et al., 1999).

The STEM perception survey developed in this study reveals science teachers' perceptions of STEM education. This data can be used to help science educators, curriculum developers, and others involved in teacher development as initial information or to provide ideas to develop professional development experiences concerning these factors. Everyone's perspective need not be the same, but we need to be clear enough about the perspective we hold because it can affect and shape our decisions. Thus, measuring STEM-education perceptions is important not only for teachers, but also the workplace, the community, and society.

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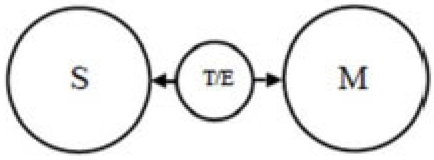
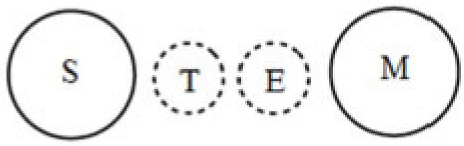
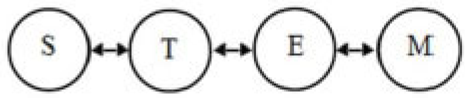
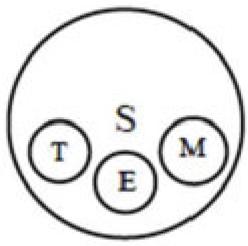
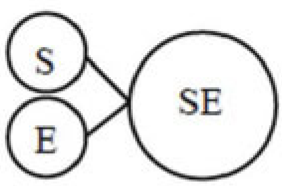
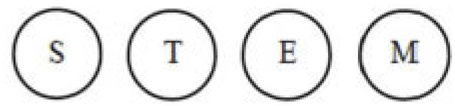
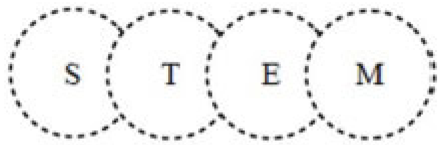
Appendix

Appendix A

STEM integration perspectives modified from Bybee (2013).

No.	Description	STEM Integrated Model
1	Single-discipline reference: STEM is Science or Math teaching approach.	
2	Science incorporated with Technology, Engineering, and/or Math: STEM is a teaching approach that Science is a core concept and others are minor components.	
3	Science and Math are connected by Technology and/or Engineering: STEM is Science and Math teaching approach that connected by concepts of Technology and Engineering.	
4	Quartet of separate discipline: STEM is teaching of Science Technology Engineering and Math separately and independently.	
5	Science incorporated with Technology, Engineering, and/or Math: STEM is a teaching approach that Science is a core concept and others are minor components.	
6	Combining two or three Disciplines: STEM is teaching approach that integrated a least two disciplines among Science, Technology, Engineering, and Math.	

7	Coordination across disciplines: STEM is teaching of Science Technology Engineering and Math separately with loose connection.	
8	Complementary overlapping across disciplines: STEM is teaching approach that teaches Science Technology Engineering and Math together by referring to specific theme.	
9	Transdisciplinary course or program: STEM is integrated teaching approach that mixed up all STEM disciplines homogeneously.