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Research Article:

Examine In-Service Teachers' Initial Perceptions Toward STEM Education in Thailand

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ABSTRACT

This research aims to examine teacher's initial perceptions of STEM Education. The participants in this study were 43 in-service STEM related subject teachers from the northeastern region in Thailand who were keen on participating in the STEM Education for Educators Module, Khon Kaen University. The data was collected through an open-ended questionnaire of Teacher's Perceptions of STEM Education (TP-STEM) prior to the process of professional development beginning. The aspects of TP-STEM included (1) STEM concept; (2) Experience implementing STEM; (3) STEM PK; (4) Teacher' competency for STEM education; (5) Assessment in STEM education; (6) Supporting STEM education in schools; and (7) Research in STEM education. An interpretative paradigm was implemented as a methodology to interpret qualitative data in this research. Research findings were discussed around seven aspects of teacher's perceptions of STEM education according to the TP-STEM questionnaire. The findings reveal that teacher's perceptions of the STEM concept goes around the term integrated STEM disciplines. Surprisingly, the majority of teachers had never implemented STEM education in their teaching and a number of teachers tend to separate STEM teaching into each discipline rather than link the disciplines for problem solving. Key PK in STEM education was emphasised on practicing, active learning, and integrated disciplines. Teacher's indicated PK (PK) as the most significant competency for STEM education, whereas partnership was also considered as a competency to support successful STEM implementation. Authentic assessment and formative assessment were emphasised as key features for assessment in STEM education. Teachers indicated good organisation and support from schools on resources, policy, and professional development for successful STEM implementation. Also, enhancing student's skills, and innovation were indicated as a focus for STEM education research. These findings could explicitly indicate the trail for professional development (PD) provided that teacher's ideas about STEM education are related closely to the STEM philosophy from the basic background to implications for a more efficient outcome for implementing STEM education in schools. Moreover, there were indications of the need for support from the Ministry of Education, school administrations, and experts from universities in order to produce effective STEM Education in Thailand. The paper has implications for STEM education professional development not only in Thailand but also for Asia Pacific countries.

Keywords: STEM education, teacher's perception, teacher professional development

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INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) education emphasises the development of knowledge of Science and Mathematics in Engineering and Technology processes. STEM education is connected to engineering design; design-based learning (Williams, 2019), and it is naturally linked to problem-solving activities in real world situations (Mooney & Laubach, 2002; Chesky & Wolfmeyer, 2015). The real-world problem solving is believed to enhance students' STEM literacy and 21st century competencies (Johnson et al., 2018; Dare et al., 2018; Gomez & Albrecht, 2013). Educational progress in developing innovation has to initially Emphasise professional development for teachers; schoolteachers have to be ready to implement STEM education in school settings (Bell, 2016). Providing in-depth problem solving through STEM education with authentic experiences requires teacher's special mindset and skills. Teachers have to obtain competency to create an educational environment to scaffold the student's problem-solving process (Roehrig et al., 2021).

The Thai government has put the effort into fostering an innovation economy which emphasises the significant integration of science, technology and engineering through a campaign called Thailand 4.0 (Yuenyong, 2019). There has been an attempt to develop teacher professionalism for STEM education; educational training has been delivered across Thailand by public and private organisations to assist schoolteachers to be ready to employ STEM Education in actual classrooms. However, regardless of the effort to develop teacher' competency in STEM education, teachers still lack sufficient knowledge and self-efficacy in implementing STEM in the classroom (Srikoom et al., 2017).

Therefore, it is important to understand teachers' perceptions on STEM education as teacher's perceptions can act as a filter and amplifier to the teacher's action (Gess-Newsome, 2015). It strongly shapes their instructional decisions on activity design, students' assignments, the evaluation of student learning, and the use of curriculum materials (Adadan & Oner, 2014). Teachers' perceptions of STEM, and teacher's self-efficacy is inherently connected to the efficiency of STEM delivery in their own classroom practice (Bell, 2016). At this point, how teachers view STEM education is significant in efforts toward understanding and shaping teacher professional development in STEM education (Bell, 2016; Dare et al., 2018). We need to focus and explore teacher's existing ideas on STEM Education as they could serve as a powerful map to build better understanding of teacher's professional development for STEM education. Hence, this study aims to understand what teachers know about STEM education by examining teacher's existing ideas about STEM education in order to provide information or guidelines for professional development providers on STEM education development.

METHODOLOGY

The objective of this study is to examine teacher's initial perceptions of STEM Education. The methodology regarding qualitative descriptive research design through interpretative paradigms was implemented to clarify teacher's perceptions of STEM Education (Taylor et al., 2012; Taylor & Medina, 2013).

Participants

The participants in this study were 43 in-service science and mathematics teachers from 11 primary and secondary schools in the northeastern region of Thailand, namely Khon Kaen, Surin and Nong Khai provinces. There were 26 female and 17 male teachers, age range between 23 to 58 years old with varied teaching experience from 1 to 36 years. The majority of teachers had degrees in education (science education, mathematics education), some of the teachers had degrees in science (physics, chemistry, biology, and mathematics). All participants are teachers who voluntarily engaged in teacher professional development in STEM education for Educators Module, Khon Kaen University. The method of teacher professional development was a one-year programme of on-the-job training through professional learning community (PLC).

The Open-Ended Questionnaire of Teacher Perception on STEM Education (TP-STEM)

In this study, we implemented the open-ended questionnaire as the purpose-designed instrument to examine teachers' perceptions about STEM education (TP-STEM). The open-ended questionnaire is believed to capture detailed information revealing teacher's mindsets on STEM education (Creswell, 2014; Cohen et al., 2000). The literature around aspects of STEM education was reviewed. The questionnaire items were validated through a panel of experts. There were seven aspects involving teacher's beliefs and understanding regarding STEM education in school settings: (1) concepts or definition; (2) experiences; (3) pedagogy; (4) teacher's competency; (5) assessment; (6) organising; and (7) ways of seeing research. First, we elicited teacher perceptions of the STEM concept as it is believed that how teachers view STEM education will lead to their action of implementing STEM education in their classrooms (Gess-Newsome, 2015; Chesky & Wolfmeyer, 2015). The second question intends to reveal teacher's perceptions on how they were involved in STEM education in their teaching experience (Adadan & Oner, 2014). The third question attempts to elicit teacher's understanding of pedagogical knowledge (PK) toward STEM teaching (Moore et al., 2020). The fourth question attempts to reveal teacher's perceptions of the significant competency in STEM education (Roehrig et al., 2021). The fifth question focuses on assessment, specifically for STEM education (Kimbell et al., 2004; Akiri et al., 2021; Shernoff et al., 2017). The sixth question attempts to elicit teacher's beliefs about how their organisation such as school or the Ministry of Education will support STEM teaching and learning in schools (Ejiwale, 2013; Shernoff et al., 2017). Question seven attempts to elicit teacher's ideas on STEM research (Sohsomboon & Yuenyong, 2021; Taylor et al., 2012; Taylor & Medina, 2013). The TP-STEM questionnaire was peer reviewed and revised according to the discussion. The TP-STEM questions were as follows:

1. Could you provide perceptions or definitions about STEM education from your point of view?
2. Have you ever implemented STEM in your classroom instruction? If yes, please elaborate further.
3. What do you think pedagogy in STEM education should be?
4. What competencies should teachers acquire for STEM education?

5. How should STEM education be assessed?
6. Is there anything that should be changed for organising STEM education in school settings?
7. What areas of research should be done on STEM education and using what methods?

Data Collection

Data collection was carried as a part of Khon Kaen University's programme in teacher professional development in STEM education. In the first section of the PD programme, the participants were asked to share their vision on STEM education on Google through Google classroom. The tool of interpretation was TP-STEM. The TP-STEM questionnaire was posted on Google classroom three days prior to the start of the teacher professional development programme. An interpretative paradigm was implemented to clarify teacher's perceptions on STEM education (Taylor et al., 2012; Taylor & Medina, 2013). The procedure of collecting data involving human participants complied with the Ethical Standards of the Khon Kaen University Ethics Committee in Human Research, Thailand. Reference number: HE643223 on the Declaration of Helsinki and the ICH Good Clinical Practice Guideline.

Data Analysis

TP-STEM questionnaire responses were read through in the first round, however, some answers from teachers were incomplete so those answers were not counted and classified. The responses from teachers were code as ST or MT followed by number such as MT01, ST02. ST indicates science teacher while MT refers to mathematics teachers, the following number indicated the ordinal number of teachers. Inductive analysis was employed, the responses were interpreted and categorised into corresponding groups. Each group was considered to frame concept, then theme (Creswell, 2014). Therefore, the data analysis was post determining data analysis. To validate the data analysis, the peer debriefing process (Cohen et al., 2000), where the analysed data was clarified and discussed with peers to verify trustworthiness was used (Lincoln & Guba, 2006). Discussion with peers focused on the sense of feeling and meaning in the statement from teacher's point of view, rather than literally looking at the meaning of vocabulary. The authors and peers tried to categorise that sense into harmonised themes again. More than that each theme was revised or redefined. During the final process of data analysis, the data was revised according to suggestions from peers, then clarified to the peers again. This process was repeated until a consensus of data analysis had been reached.

RESEARCH FINDINGS

The teachers' shared vision of STEM education could be interpreted as their perceptions on STEM education. These perceptions will, therefore, be discussed through each aspect as follows.

Teacher's Perceptions on the Concept of STEM Education

Teacher perceptions on the STEM concept could lead to action in designing or creating lesson plans, activities or assessment on STEM teaching and learning. Nearly all in-service teachers lean their perceptions on STEM toward the term "integrated disciplines". Their position of viewing STEM education as integration was in various aspects. Teacher's perceptions about the STEM concept are as shown in Table 1.

Table 1. Teacher's concept of STEM education

Category	Frequency
Integrated disciplines	13
Integrated disciplines for constructing knowledge	5
Integrated disciplines on practicing to enhancing skills, constructing innovation and solving problems in daily life	21
Process of learning	3

Teachers illustrate their STEM concept addressing the term integrated emphasised solely on STEM disciplines.

> Teaching and learning which integrated science, mathematics, technology and engineering. (MT06)

> A study which Integrated across subjects among mathematics science and technology. (ST40)

Teachers place value to STEM disciplines integration. The Term integration was addressed to the integration of Science, Technology, Engineering, and Mathematics with no further elaboration on the meaning or process of integration. As there is multidisciplinary, interdisciplinary, and transdisciplinary (Roehrig et al., 2021), knowledge integration is believed to be excessively complicated (Shernoff et al., 2017; Moore et al., 2014).

The term integration was emphasised and linked to the idea of the process of learning for constructing knowledge.

> Constructing knowledge through integrating Mathematics, Science, Technology and English. (MT37)

> Instruction process where learners are implementing Science, Mathematics, Design, and Technology for constructing knowledge. (ST07)

Teachers seem to perceive STEM education as the process of instruction emphasising constructing knowledge through integrating STEM disciplines. Although, teachers implement novice teaching strategies, they still focus their teaching and learning aim on attaining a body of knowledge. However, STEM education should not be simply viewed as an instructional method aiming to gain knowledge from STEM learning activities. STEM education emphasises promoting practical experience which involves STEM literacy through problem solving in real world situations (Tang & Williams, 2019).

The majority of teachers view STEM as integrated disciplines and link it to practicing for enhancing skills, constructing innovation and solving problems in daily life.

> STEM education (Science Technology Engineering and Mathematics Education) is a method of instruction which assist students to construct knowledge and to be able to integrate disciplines in Science, Technology and process from Engineering and Mathematics, and to ***link and apply that knowledge to solve problems in real life situation***s. Moreover, it includes enhancing process or new products along with developing 21st century skills. (ST12)

> It is an instruction method integrating knowledge and scientific skills, mathematics, technology and engineering design process for enhancing students' knowledge and skills for implementing ideas and process to ***solve problems or develop innovation with the aim of human needs*** or solve problems in daily life. (MT33)

Teachers obtain the idea of STEM education within the scope of the STEM philosophy through problem-solving. Teachers expresses the key significant terms of STEM education such as knowledge implications, problem-solving, real-world situations and human needs. Applying knowledge for problem solving or inventing new innovations is addressed in STEM education. The social context in everyday life, when we need to solve problems, there will be knowledge integration processes in the process of problem solving, we cannot use single knowledge to solve complex problems in the real-world situations. This view on STEM education seems to promote a philosophy of STEM education addressing knowledge implications through problem-solving in daily life (Chesky & Wolfmeyer, 2015).

Teacher's Experiences Implementing STEM Education in School Settings

Teacher's experience is believed to disclose the position where the teacher is located. This question intends to elicit how the teacher has been involved with STEM education and activities. STEM education has been in Thailand for more than decade (since 2013). Much attention has been paid from the government and private agencies setting up many projects for professional development to intensively develop STEM Education in schools in Thailand (Yuenyong, 2019). However, surprisingly, the majority of participants in this study stated that they had never had experience implementing STEM education in their classroom teaching. Moreover, it seems that teachers tend to focus STEM teaching on a single discipline. The aspects that teachers refer to as their experience of STEM education as shown in Table 2.

Table 2. Teacher's experiences implementing STEM education

Category	Frequency
Never	15
Organising learning activity related to a single discipline, either Science or Mathematics	8
Organising through themes	8
Organising activities regarding package activity	4
Doing experiment	1
Implementing through inquiry cycle	1
Implementing through engineering design	1
Organising integrated knowledge for problem solving	3

A number of teachers distinguish Science and Mathematics disciplines in their STEM teaching experience.

> Calculating ***cylindrical volume and cone volume***, requiring students to develop shapes then find the relationship of cylindrical volume and cone volume. (MT05)
>
> Create learning activity in ***heat transfer*** learning unit for grade 7. (ST34)

Teachers refer to theories of either Science or Mathematics, their idea about implementing STEM were detached into each discipline. Teachers seem to regard the significance of integration for their STEM concept at first, however, it appears that when teachers express their experience about STEM teaching, their STEM concept and experience were steered in different ways (not in the integration manner) (Dare et al., 2018; Honey et al., 2014).

Teachers mention organising STEM activities through situations leading to producing a product.

> Learning about making and playing ***"kite"*** implementing STEM in the process of learning. (ST35)
>
> I used to work with a science teacher on employing STEM to teach, assuming students were a rescue team, assigning them to ***design a boat*** for evacuation in a flooding situation. (MT31)

Teachers recalled their experience of assigning students to design things (Kite, boat). It seems that teachers connect their experience of STEM education towards a sense of implementing knowledge to solve problems employing engineering design processes of "making things" (designing kite). STEM education emphasises knowledge application for problem-solving through design processes or engineering design processes, which connect to making things (Moye et al., 2014; Honey et al., 2014).

Teachers stated that they implement ready to use teaching packages for STEM teaching in their classroom.

> Implemented provided package activity from IPST for adjunct lesson on Mathematics. (MT09)

> I used to implement package activity from IPST to teach grade 8 science process skills. (ST14)

Teachers refer to package activities for their STEM teaching. This situation probably implies that teachers had no induction on STEM teaching and learning at all as they only follow directions from ready to use teaching packages.

Teacher mentions experiment on their recalled experience about STEM activity.

> Planning experiment. (ST22)

Teacher related STEM education with doing experiments. STEM activity rather emphasises the significance of cultivating student's practical knowledge and skills which is probably different from following the experiment direction in the typical way of doing experiments in science.

Teachers recalled their experience about STEM teaching related to problem solving.

> In a Mathematics project, students were assigned to ***invent an altimeter and laser*** to shoot the objects employing principles of trigonometry. The main structure of that tool has to be assembled from PVC implementing algebra applets for calculations and employing scientific and static processes to calculate and ***test the efficiency of the tools***. ***Develop model of the tool from feedback and peer reflection***. Present and reflect the product. (MT18)

> I employed STEM in ***hydroponic planting***, asking students to integrate ***science knowledge*** in the topic of hydroponic plants, considering instruments and different items such as water, air and fertiliser for plants. Employing ***Mathematics*** in the topic of shape of materials or substances planting. Implementing ***Technology*** in term of searching for information on hydroponic planting, and knowledge about ***Engineering*** drawing on designing and inventing waste material from daily life for hydroponic planting. Moreover, Arts was integrated to make the product more colorful. (ST42)

Although, both teachers refer to knowledge for problem-solving. Teacher (MT18) tends to firmly stick to STEM teaching strategy and seems to address the engineering design process (testing the tool, develop model) (Roehrig et al., 2021). While teacher (ST42) seems to distinguish each STEM discipline, worrying how many subjects they combined in the activity. Whereas STEM education actually draws on knowledge integration it is not necessary to distinguish knowledge as whatever knowledge is needed for problem-solving, it should be in combined manner (Bybee, 2013).

Teacher's PK for STEM Education

This question intends to verify initial perceptions on PK for STEM education and whether their PK is in accordance with the STEM philosophy. Teachers seem to address STEM pedagogy in three aspects; practicing, active learning, and integrated disciplines. The responses have been categorised and shown in Table 3.

Table 3. Teacher's PK for STEM education

Category	Frequency
Emphasise practicing	9
Emphasise stimulating innovative skills	2
Active learning	10
Emphasise integrated disciplines/problem solving in daily life/ Engineering design process	16
Inquiry-based learning	4

The term practicing was emphasised as a key pedagogy on STEM education.

> A teaching method that supports students to gain knowledge from practicing. (MT24)

> Designed learning activities focusing students to practice, brainstorm, and analyse. (ST26)

The term practicing referred here probably links to "doing" such as doing science experiments or doing mathematics exercises. However, knowledge application in STEM education is probably best linked to problem solving real-world problems (Gomez & Albrecht, 2013; Willams, 2019; Roehrig et al., 2021). Chesky and Wolfmeyer (2015) state in the philosophy of STEM education that the initial strategy to place value of knowledge practicing for STEM education is to link with real-world problems. Doing science experiments or doing mathematics exercises is probably not linked closely to real-world problems. Moreover, the significance of making things or solving any problem has to be associated thoroughly with human needs (Roehrig et al., 2020). The teacher response in this category seems to focus solely on practicing without considering real-world problems and human needs. Therefore, the importance of human needs should be emphasised and linked for the engineering design process on STEM teaching and learning (Roehrig et al., 2021)

Promoting innovative skills or producing a product was considered as strategies to teach STEM.

> Promoting learners to attain innovative skills. (ST02)

> Provide learners to implement knowledge from science, technology, engineering and mathematics disciplines to create the product. (ST20)

Teachers refer to STEM as a strategy to promote innovative skills, and products. The terms "innovation" and "technology" were referred to as an outcome of STEM teaching and learning. In this sense teachers probably link their pedagogy to innovation as design and technology focusing on the object or material of the innovation. However, there was no sense in designing linked to human needs, hence this sense of making things link teaching expectancy to stimulate students to be a technician but not a designer. Teachers' idea of PK in STEM education should be more on designing things according to human needs (Roehrig et al., 2020).

Teachers refer to the term and the process of active learning as a strategy for STEM teaching.

> Teach students to be able to ***share their opinion***, and understand content knowledge integrated for STEM. *(MT11)*
>
> Provide activities to gain ***opportunities for students to learn***, ***to understand and to present by themselves***. (ST22)

It seems that the teacher refers to the process of active learning. Active learning that teachers referred to in this context is probably be in the sense of physically moving or thinking in a simply way. However, STEM education addresses knowledge application through a problem-solving process (Williams, 2019; Roehrig et al., 2021). Active learning as a strategy for STEM education, therefore, has to be when students have to be active and employing higher-order thinking to solve problems in real-world situations (Williams, 2019; Roehrig et al., 2021).

A number of teachers address the term "integration" for problem solving or for engineering design processes as strategies for implementing STEM in the classroom.

> An instruction method which integrated Science, Mathematics, Engineering, and Technology to solve problem in everyday life and work. (MT19)
>
> The integration of knowledge in Mathematics, Science and Technology to generate engineering design. (ST13)

Teachers were able to pick up key terms for STEM teaching strategies such as knowledge integration, situations in daily life, and engineering design. It seems that the term integration includes only four disciplines (science, technology, engineering and mathematics), however, sometimes there are some other kinds of knowledge involved in problem-solving such as social, arts or even languages. The arts have been embraced by STEM believing that the arts will cultivate not only creative thinking but also morality and ethics (Taylor & Taylor, 2022). The social aspect is actually embedded in STEM teaching as Chesky and Wolfmeyer (2015) stated that STS (Science, Technology and Society) could be fundamental to triggering problem-solving in STEM education as the starting point for problem-solving should involve social situations. In addition, teachers seem to connect the engineering design process with knowledge integration, whereas the engineering design process is viewed as knowledge integration for knowledge practice (Williams, 2019; Roehrig et al., 2020).

Teachers express inquiry-based learning as a specific strategy for STEM teaching.

> Students should be offered the opportunity to acquire knowledge and construct knowledge by themselves. (MT29)

> Students are an inquirer whereas teachers are coaches for assisting and guiding the way to gain knowledge. (ST14)

Term inquiry that the teacher mentions seems to focus on the acquiring knowledge process. The inquiry process in STEM education, actually, should not be focused solely on an inquiry process to gain knowledge, rather it should be considering taking the inquiry process, which contains knowledge, to solve the problem. Students need to have opportunities to engage in knowledge practices that require them to use their knowledge and skills to solve problems in inquiry and practice (Zhan et al., 2021).

Teacher's Competency for STEM Education

STEM education is indeed special, it is completely different from the traditional teaching approach, and it emphasises the integration of disciplines aiming to turn applied knowledge into practical skills (Williams, 2019; Bell, 2016). Therefore, teachers need special knowledge, skills, and attitudes, and so-called competency, in order to effectively organise STEM education. Not much of the literature emphasises teacher's competency for STEM education (Roehrig et al., 2021). Hence, it is essential to identify aspects supporting teacher's competency for STEM education. A massive number of teachers believed that PK (PK) is the important competency for STEM education. The teacher's initial perceptions on competency for STEM education are presented in the Table 4.

Table 4. Teacher's competency for STEM education

Category	Frequency
PK (PK)	21
Content knowledge (CK)	2
TK	3
Pedagogical Content Knowledge (PCK)	3
Obtain way of seeing research	1
Partnership	3
Attain 21st century skills and attitude toward STEM professional development	10

The majority of teachers address the importance of PK (PK) for STEM competency.

> The teacher be able to ***design and organize learning activity*** for learner to learn regarding STEM teaching and learning concept. (ST07)

> The teacher has to be able to ***design learning activities*** which are student centered, providing the opportunity for them to construct knowledge by themselves. (ST26)

The teachers focus on the method of teaching (PK) without connecting PK with specific content knowledge. Focusing solely on PK possibly implies that teachers were looking for ready to use teaching packages. Teachers should consider the significant connection of PCK rather than focusing on PK only. To implement effective STEM education, teachers have to obtain PCK for STEM education for designing learning activities, the significant of nature of each discipline, and school and society contexts have to be considered to create proper activities for different teaching and learning contexts (Shulman, 1986).

Teachers address the importance of Content knowledge (CK) as STEM competency.

> The teacher has to attain content knowledge, problem solving skills, and attributes in order to support the learners to achieve learning activities. (MT01)
>
> The teacher has to obtain fundamental knowledge of Science, Mathematics, technology and Engineering. (ST20)

Teachers state the significance of content knowledge. It seems that teachers consider and focus on knowledge transferring rather than leading students to construct knowledge through meaningful practice activities. Teacher's probably need to shift their mindset to constructivist theory (Honey et al., 2014; Stohlmann et al., 2012). Constructivist theory is believed to underpin STEM education as it stimulates students for the active construction of knowledge (Chesky & Wolfmeyer, 2015).

Teachers address the importance of Technological Knowledge (TK) for STEM competency.

> Teachers have to obtain creative thinking, up-to-date knowledge and be able to apply technology. (ST30)
>
> Teachers have to obtain digital competency. (ST38)

Technology in this sense seems to progress and teachers must be ready to use applications and digital knowledge. TK for STEM should be considered as means to integrate content and PK for STEM instruction knowledge of technology for combing to PK and CK known as TPACK (Technological, Pedagogical and Content Knowledge) for STEM education (Chai et al., 2019).

Teacher's partnership was viewed as important competency for STEM education.

> Open-mined and cooperation for public interest. (ST23)
>
> Working as a team. (MT29)

Teachers consider the importance of partnership as an aspect of supporting STEM teaching. A significant feature of STEM education is interdisciplinary integration, it is important to consider the importance of partnership for knowledge and practice integration to reach effective goals of STEM education as it is difficult for only one teacher to be able to effectively integrate all disciplines for STEM teaching and learning (Williams, 2019; Asghar et al., 2012; Lehman et al., 2014). Partnership in this context probably refers to partnership in teaching and learning, and knowledge integration. In this situation partnership could be teachers in the same school or experts from university working together to assist students for problem solving (Park et al., 2017).

Assessment on STEM Education

Apart from considering designing and creating STEM learning activities and environment, teachers have to consider the way to clarify the accomplishment of STEM Education through assessment. The terms authentic assessment and formative assessment have been utilised as important methods to assess student's learning in STEM education. The Teacher's initial ideas on assessment of STEM education is presented in Table 5.

Table 5. Assessment on STEM education

Category	Frequency
Focusing on evaluating ideas and product	8
Authentic assessment and formative assessment	23
Focusing on evaluating student's competency (Knowledge, Skills and Attributes)	4
Objectivist and summative assessment	3
implement various assessment tools	3

Teachers address the importance of final product on learning process.

> Evaluate from the idea and product. (MT05)
>
> Evaluate from the impact of the product for people needs and how they present their idea. (MT21)

It seems that teachers obtain the idea of evaluating the final product. Assessment in STEM education should be in a way to assess student's learning processes rather than memorizing a body of knowledge or focusing on the final product (Sohsomboon & Yuenyong, 2021).

The majority of teachers mention the terms authentic assessment and formative assessment as methods to assess the process of learning.

> ***…authentic assessment***, ***assessing process***, thinking skills, practicing, and problem solving through the PLC process. (ST26)
>
> ***…evaluate for development***. (MT16)

It seems that teachers recognize the important terms of assessment (evaluate for development, authentic assessment) for STEM education (Sohsomboon & Yuenyong, 2021). However, it is not certain that teacher's understanding on the process of authentic assessment and formative assessment as the detail was not elaborated on.

Teachers focus the assessment for STEM education toward eliciting student's competency.

> Evaluate skills and student's significant competency bonding from STEM teaching and learning. (MT33)

> The evaluation should cover various aspects such as knowledge, skills, and attributes regarding authentic situations. (ST36)

Teachers address assessment for STEM teaching on student's competency. There is no clarity about the definition of students' competency in STEM education in the teacher's point of view. The critical skills and practices that should be defined, practical competency in STEM education should be focused (Tang & Williams, 2019). It is interesting that teachers still refer to the traditional summative assessment idea, when evaluating student's knowledge on STEM teaching and learning. Evaluate from testing student's knowledge. (MT24).

Teachers addressing the final stage (doing experiments, doing mathematic exercises, and testing) of practice. It seems that their assessment method constitutes summative assessment.

Organising STEM Education in School Settings

It is worth noting that STEM education has a special philosophy and requires special strategies for teaching and learning. This probably requires special support or management to obtain the effective implementation of STEM teaching and learning in school settings. Good organisation and support from schools in resources, policy, and professional development are required. The view of teacher perceptions on organising effective STEM education in school settings is presented in Table 6.

Table 6. Organising STEM education in school settings

Category	Frequency
Gaining partnership and collaboration	6
Develop teacher's professionally	9
Well organized and support with teaching resources and policy	14
Focusing on student-centered activitities	4
Empowering STEM education in school settings	6
Enhancing understanding toward STEM Education	4

Professional development is believed to be essential to the successful implementation of STEM Education in school settings.

> Develop teachers professionally in acquiring knowledge and the ability to design and manage activities regarding STEM education. (ST07)

> Develop teacher's knowledge and understanding first (MT17) Teachers echoed that they desire support in STEM education professional development. It probably could be implied that teachers lack understanding or are underprepared for STEM practice implementation (Srikoom et al., 2017).

Teachers also believed that well supported policy and teaching resources are essential to steer STEM education in schools.

> Provide efficient ***resources, and time***. (MT06)

> Setting ***curriculum*** to conform to STEM trail. (MT11)

> Set ***schedule for STEM*** teaching and learning particularly, set STEM education rooms, and provide materials. (ST20)

Teachers echo needs of support on clear policy and resources, in order to successfully steer STEM implementation (Park et al., 2017; Johnson, 2006; Jho et al., 2016; Shernoff et al., 2017). It seems that educational change focuses on the theoretical rather than the applied level; it proceeds without links to the nature of STEM practice activities.

Empowering STEM education in school through supporting and monitoring STEM Education continuously was considered the way to enhance STEM education in schools.

> There should be regularly follow-ups of the supervision and expansion of STEM teaching involving teachers. (ST09)

> Stimulate STEM education on Science and Mathematics teaching consecutively. (ST22)

> Clear policy has to be set from administrators, strategies regulations also have to be set for teachers to abide by, addressing knowledge integration as clear and united aims employing PLC as a process to develop and support teaching and learning regarding the STEM concept. (MT33)

Teachers mentioned that support from government, policy makers or even administrators is necessary to empower successful STEM implementation in schools (Aslam et al., 2018; El-Deghaidy et al., 2017). It seems that teachers addressed the top-down approach in order to direct them to implement STEM education in their classrooms. Whereas the significance of STEM education was recognised, the intention of STEM implementation was dismissed.

Teachers and administrators understanding of STEM education is considered to be one of the essential factors developing STEM education in school settings.

> Teachers and school administrators have to open their minds toward STEM. (MT16)

> School administrators should acquire vision, consider the importance of STEM teaching and learning first. They should have meetings for instructing or clarifying all learning areas in order to find the way together for learning integration, and then proceed further in each teaching step. (ST42)

Teachers refer to school administrations vision on STEM education. As STEM teaching and learning is special, it seems that teachers reflect their desire for STEM education leadership from school administrators in order to develop STEM implementation in schools (Ejiwale, 2013; Shernoff et al., 2017).

Teacher's Ways of Seeing Research on STEM Education

Ways of seeing research address ways in which teachers recognise the function of research within STEM education. The majority of teachers address research on enhancing student's skills, and innovation. Teacher's perceptions on ways of seeing research in STEM education is presented in Table 7.

Table 7. Teacher's ways of seeing research on STEM education

Category	Frequency
Enhancing student's skills, and innovation	21
Developing pedagogy and learning activities	2
Examining student's learning achievement	3
Barriers of students' learning	3
Method of assessment for STEM education	1
Leadership for organising STEM education in school setting	3
Examine concept about STEM education in Thai context	10

Numerous numbers of teachers consider conducting research on STEM Education concerning enhancing student's skills and innovation.

> Research in the area of enhancing student's learning on STEM skills (***Problem Solving, Creativity, Critical thinking***). (ST13)

> Research in the area of enhancing student's thinking skills and problem solving. (ST26)

> Research in student's skills area, and student's ideas on innovative products. (ST25)

Teachers focus their interest in STEM research on improving student's skills and the idea of producing a product. Living in a technology and innovative era, students need to obtain skills for living well and future careers (Honey et al., 2014; Yuenyong, 2019).

Teachers mention their research interest in STEM Education in the area of examining student's learning achievement.

> Student' learning achievement. (MT06)
>
> Comparing learning achievement between STEM teaching and typical teaching strategies. (MT11)

Teachers highlight the need for STEM education research on student's learning achievement. Implementing STEM education in classrooms has to involve problem solving through the process of practicing (Williams, 2019; Roehrig et al., 2021). Ways of assessing learning achievement may not correspond to the nature of STEM education which addresses the process of problem-solving rather than the final product.

Teachers interested in doing research on improving students' learning in STEM teaching and learning activities.

> Research about student's learning behaviour regarding STEM teaching and learning. (ST22)
>
> Problems in student's learning. (ST23)

Teachers mention about improving students' learning through understanding student's learning barriers (problem in student's learning). It seems that the term "student's learning" refers to learning to obtain knowledge. However, as has been mentioned throughout this paper, STEM addressing knowledge application for problem-solving, the barrier on learning could be to do with implementing knowledge to solve the problem. Teachers should scaffold learning for students to help them overcome barriers in problem-solving, step by step (Williams, 2019).

Assessment for STEM Education is considered to be an interesting topic to study.

> Learning assessment regarding STEM education, evaluate student's knowledge skills and attribute according to authentic assessment. (ST36)
>
> The learning assessment instrument. (MT28)

Teachers expresses their interest in research on STEM education in the area of examining assessment in STEM education. Research on STEM education has been developed, however, not much attention has been devoted to the area of assessment in STEM education. I am inclined to agree with STEM education research on the topic of assessment. The traditional way of thinking emphasising crystalized knowledge, assessing a body of knowledge through examinations, both internal and external, rather than skills or processes in engineering practices (Zhan et al., 2021).

DISCUSSION

This work attempts to examine Thai teacher's perceptions of STEM education in order to provide a window into what we need to work on further to develop teacher professional development in STEM education.

The findings reveal that the term integrated STEM disciplines seem to be emphasised as the teacher's concept of STEM education. Unexpectedly, a large number of teachers had never implemented STEM education in their teaching even though STEM education has been introduced across Thailand, and numbers of teachers who have employed STEM education in their classroom tend to separate each STEM discipline rather than link the disciplines. Teachers appear to indicate that practicing, active learning, and integrated disciplines were the significant pedagogy for STEM teaching. (PK) was viewed as the most essential competency and partnership was also recognised as an important feature to support successful STEM education. The terms authentic assessment and formative assessment were emphasised as key features for assessment in STEM education. Teachers revealed that good organisation and support from schools in resources, policy, and professional development were important for successful STEM implementation. Also, enhancing student's skills, and innovation seemed to be important topics in STEM education research.

These findings are expected to be valuable information, not only for PD providers, but also for teachers, school administrators, and even policy makers to consider and provide support for successful STEM implementation in schools. The key findings and recommendations will, therefore, be presented as follows.

Concept of STEM Education

Teachers Emphasise the term integration when thinking about STEM education, and the term integration appears to connect to knowledge integration. However, in practice, involving STEM subjects, they have normally been organized in separated disciplines (Moore et al., 2014). Focusing on the term integration could lead to difficulty in attempting to clarify how to integrate and how many disciplines to integrate; multidisciplinary, interdisciplinary, and transdisciplinary (Roehrig et al., 2021). Teachers probably shift the focus to knowledge practicing or process to do things through a problem solving process as STEM education actually addresses the significance of knowledge application, rather than building up knowledge understanding (Williams, 2019; Chesky, & Wolfmeyer, 2015; Bell, 2016; Moye et al., 2014; Gomez & Albrecht, 2013). STEM activities provide opportunities for students to solve real world problems and the outcome of the problem-solving process could be a new solution or innovation (Capraro et.,2013). Moreover, it is worth noting that social and cultural aspects are also deeply relevant to potential solutions to the problem-solving process, and designing the process and product according to human needs. Therefore, human needs have to be emphasised in the problem-solving process and goals (Roehrig et al., 2020). This approach might initially help teachers establish a suitable mindset to set their pathway for conducting or creating STEM activities.

Experiences Implementing STEM Education

Teachers' experience in STEM education tends to be in a detached manner as the existing curriculums are still organised in individual disciplines which does not support an integrated approach (English, 2016). This situation could be a huge hindrance for teachers as STEM promotes knowledge integration.

However, "STEM Thinker" according to Reeve (2015) will be recommended to overcome this obstacle, which attempts to lead teachers to appreciate and realise the interconnection and impact of STEM integration on problem-solving in society. Simply put, the real-world situation is probably the trigger to allow teachers to have an understanding of knowledge integration through problem solving. Knowledge that feeds into the problem-solving process will come naturally in an integrated manner. Moreover, utilising Engineering and designing things as a designer, are considered as great strategies to support the effective integration of STEM instruction (Cunningham & Carlsen, 2014), as it represents what practitioners do as they engage in their work (Reynante et al., 2020). However, school teachers are not familiar with engineering content or processes (Nadelson et al., 2013). Therefore, it is crucial for teachers to embrace the nature of engineering for both pre-service and in-service professional development in order to support the effective implementation of STEM education in schools.

PK for STEM Education

Although teachers refer to the terms "practicing, active learning, and integrated disciplines", it seems that teachers relate PK for STEM education to ready to use teaching packages rather than considering the importance of PCK for STEM education.

STEM teaching and learning involves knowledge application through problem solving in real-world situations. Teachers have to develop a well-defined STEM philosophy and pedagogy for specific content; so-called Pedagogical Content Knowledge, PCK), teachers have to be able to implement this knowledge to thoughtfully design learning activities for particular content knowledge to reach learning aims (Roehrig et al, 2021). Shulman (1986) states that effective and rich PCK occurs when teachers can employ appropriate pedagogical strategies and contexts to illustrate particular concepts, and make connections between topics. Approaches that scholars suggest are appropriate for STEM education include problem based, project based, inquiry based, design based and engineering design processes. Through those approaches and processes students should be able to employ practical knowledge to solve real world problems and enhance skills (Williams, 2019).

Teaching and learning processes in STEM education could be compared to the Snakes and Ladders board game where players start at the same point and finish the game at the same point. However, during the process of playing the game, the players could go in different directions regarding their way of reaching the same goal (Williams, 2019). In STEM education students have to get into the problem and look for ways to solve it, then students have to get into the process to solve the problem by themselves in their own individual way. Whereas, in a typical experiment students have to follow the same instructions to get similar results.

Teacher's Competency for STEM Education

There were important aspects referred to for STEM education such as PK, CK, TK, PCK, assessment, research and partnership. This section will address the importance of partnership for STEM education. The aspect of PCK for STEM education has been already discussed in the previous section, whereas assessment and ways of seeing research will be discussed in the following section.

Partnership has been considered as an important factor to support effective STEM education; it seems that teachers focus on academic partnership or partnership for knowledge integration (Park et al., 2017). New ways of thinking about partnership for STEM education have to be generated. Partnership for utilising knowledge in practice, linking students to future careers or entrepreneurship should also be considered; the owner or specialist from the private sector provides their expertise, knowledge and skills to scaffold students' knowledge and practice, allowing students to engage in the authentic work of professionals (Ryu et al., 2018; El-Deghaidy et al., 2017).

Assessment of STEM Education

Teachers mention the terms authentic and formative assessment, and summative assessment as assessment methods for STEM education.

Authentic and formative assessment are believed appropriate for STEM education rather than summative assessment. As STEM education involves applying knowledge through practicing, the way to assess this teaching method should be about how students implement their knowledge for problem solving and to assist their process of learning. When focusing on the final product or body of knowledge, student's learning processes such as how students learn, how they manage to solve problems or how they overcome their failures, will be ignored; the sense of partnership will be overlooked. The significant feature of scaffolding in student's learning will also disappear. Student's understanding might not need to be evaluated through examinations, Kimbell et al. (2004) propose that the ideas that they think in their mind could be interpreted or illustrated through the means of expression and performances. While understanding student's learning processes is addressed in STEM teaching and learning, the process of students overcoming each barrier with their problem solving should not be overlooked (Williams, 2019). Failure is believed to be inherent in the engineering design process; students will learn to improve their design and find solutions (Dare et al., 2014; Williams, 2019).

The exam-oriented education system seems inconsistent with the nature of STEM education. There probably has to be paradigm shift to transform education for assessment in STEM education; teachers should shift to another paradigm, look at another window or obtain multiple lenses in their research (Taylor et al., 2012; Taylor & Medina, 2013). Assessment in STEM education should focus on how to scaffold students through the process of problem-solving in real-world situations (Roehrig et al., 2021). The specific criteria could be revised to match a holistic conception (Williams, 2019). Specific rubrics might help to guide the process of student's learning in order to guide a teacher's idea of student's performance levels for each student, and then organise the specific level for each learning process to match the holistic leaning performance. Feedback without grading is claimed to be an effective way to support student's process of learning (Williams, 2019; Sohsomboon & Yuenyong, 2021). Evaluation has to separate from testing, as when tested students tend to focus on scoring rather than improving from feedback (Williams, 2019). Through this evaluation process students may have the opportunity to make outstanding progress which means they could have chance to progress their learning more than judging them solely by the final product.

STEM education involves students in practicing knowledge through problem-solving in real-world situations, and that process is believed to cultivate crucial 21st century skills. Assessment in STEM education should focus on the nature of engineering; the process of problem solving, connected to real-world problems that support 21st century skills (Roehrig et al., 2021), as it is essential to learn how teachers scaffold students and how students develop to move from step to step in order to establish these skills through the problem-solving process (Williams, 2019).

Holistic assessment is more practical and appropriate for STEM education than atomizedassessment. Holistic evaluation will be able to comprehend a detailed process of learning whereas, the final product solely might not be able to inform the whole progress of the learning story (Williams, 2019). Williams (2019) recommended that formative assessment through port-folios could be the method of addressing student's process of learning in a holistic process. Assessment for development through reflective thinking on their performance will allow students to learn from their failures and get better in their performance and progress Student's performance regarding the aim of the task might be rated through specific rubrics (Sohsomboon & Yuenyong, 2021).

Organising STEM Education in School Setting

Teachers echoed needs for STEM professional development support from policy makers, district administrators, and school administrators. This was viewed as extremely essential to develop their confidence for effective STEM implementation. The need for STEM professional development has been continuously reported for nearly a decade (Ejiwale, 2013; Shernoff et al., 2017). STEM Professional development has to be seriously applied and continued. Teacher professional development was inadequate as it usually took teachers outside of the classroom (OECD/UNESCO, 2016). Effective professional development should be an ongoing process, intensive and connect to practice and school initiatives; and build upon strong working relationships among teachers (Wei et al., 2010). To put in a simple way, the PD process has to be on duty (in schools or classrooms, continuously, and a yearlong program (Herro & Quigley 2017; Margot & Kettler, 2019). There is a lack of practical advice for teachers implementing STEM education in classrooms (Bybee, 2010) leading to a number of obstacles for teachers in practicing STEM education in schools. Not only is there an unclear consensus of the STEM definition, the process of STEM integration and operation has also not yet been conceptualised (Roehrig et al., 2021). This point of view should be brought to the attention of authorities in Thailand in order to provide adequate support for teachers implementing STEM education in Thailand. Teachers must have a view of instruction aligned with the philosophy otherwise, teachers will not be confident enough to implement STEM education in their classrooms (Park et al., 2017). Effective STEM professional development could be able to enhance teacher's self-efficacy in organising STEM education in their classrooms (Stohlmann et al., 2012).

Thailand educational policy makers usually Emphasise the structure of new frameworks on policy and political action whereas serious action on implementation regarding a sociocultural approach is essential to be taken. When there is conflict between culture and educational change in Thailand, teachers probably resist the new implementation and potential misconceptions about pedagogies has a high potential to occur (Hallinger & Bryant, 2013). Policy makers, district administrators, and school administrators should gain vision and take serious action on supporting STEM implementation regarding the sociocultural approach (Ejiwale, 2013; Shernoff et al., 2017).

Thai culture that relates strongly to religion, mainly Buddhism, leads to obeying and respecting seniority as the norm. It is viewed as disrespectful if young people or people in lower positions argue with or challenge their superiors. This norm may not allow alternative or new ways of thinking, which could be viewed as restricting social actions and change. This aspect is believed to influence the Thai education system (Yuenyong, 2017). Administrators, and teachers serve a crucial role in supporting a positive impact for STEM implementation, School leadership has a strong and positive effect on teaching and learning. Thus, leaders and authorities have to understand about culture and the condition of STEM education in order to develop STEM in schools (Margot & Kettler, 2019). School leaders should consider its significance, and provide STEM professional development, collaboration and ecosystems for STEM teaching in schools (Waight et al., 2018). STEM education should be grounded as part of school culture; embrace a collaborative and supportive community through a professional learning community in schools (Margot & Kettler, 2019; Wei et al., 2010). The significance of entrepreneurship for STEM teaching and learning should be emphasised (Waight et al., 2018).

Teacher's Ways of Seeing Research on STEM Education

Teacher's ways of seeing research on STEM education appears to be rigid in a single paradigm on enhancing student's skills, and innovation and other traditional ways of seeing research such as learning achievement. The teacher's view of STEM education probably needs to shift to knowledge application through problem-solving in real-world situations (Chesky & Wolfmeyer, 2015; Williams, 2019; Roehrig et al., 2020). Multi-paradigm and transformative learning which is believed to be ways of scaffolding teachers to come out of a small single frame to see another frame (Taylor et al., 2012; Taylor & Taylor, 2022).

STEM should evaluate knowledge application through practicing. Student's learning should be represented in the sense of formative assessment which the teacher has to present in reflective thinking means (Williams, 2019; Sohsomboon & Yuenyong, 2021). Teachers should reflect progress through the learning process, likewise, the process of reflecting on student's learning could be viewed in a way as the teacher as a researcher. Ways of seeing research arouse self-evaluation for reflective practicing; a process in which teachers obtain the ability to systematically reflect on their own environmental and pedagogical activities (Cohen et al., 2000).

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

In order to support teacher's professional development in STEM education, teacher's existing idea of STEM education has to be considered in order to address the aspects that have to be prioritised and developed for teachers. Therefore, this work attempts to identify teacher's perceptions of STEM education as a window for STEM-PD to look for the precise area for practicing on teacher professional development.

These findings indicate that Thai teachers appear to be superficially familiar with the important terms involving STEM education such as integration, partnership, engineering design process and formative assessment. Therefore, grounded STEM philosophy probably has to be embedded in order to lead teachers to the track of implementation regarding the STEM philosophy which emphasises knowledge application through problem-solving in real-world situations (Chesky & Wolfmayer, 2015; Williams, 2019; Roehrig et al., 2021). Thai culture which links strongly to religion (Yuenyong, 2017) seems to impact on teacher's perceptions of STEM education. STEM education is believed to cultivate creative and innovative technology through the problem-solving process. However, Thai culture believes deeply in obedience which could lead to initiative and creative thinking being forbidden; this seems be a contradiction. At this point, authorities and people in education play a very important role in leading the direction of STEM education. Moreover, one of the most important factors in supporting successful STEM implementation in school is authorities, such as policy makers and district and school administrators who have to be deeply understand the context and sincerely and continuously support practicing and the process of STEM education implementation (Ejiwale, 2013; Shernoff et al., 2017).

LIMITATION AND RECOMMENDATION

Key information was interpreted from questionnaire responses in writing only. Although, the responses were gained through open-ended questions, it might not be possible to declare an in-depth and holistic idea of teachers on STEM education; teacher's perceptions should be further probed.

The findings on teacher's perceptions on STEM education and suggestions represented in this study might not be able to be generalised for teachers in western countries, as there are differences in culture, educational systems, curriculums, and teaching and learning norms. Thai education is dominated by a strong religious culture (Yuenyong, 2017). The results of this study could be guidelines for application in Thailand and countries in the Asia-Pacific region which share a similar culture.

The information in this study attempts to provide guidelines for PD providers to plan and design for STEM education teacher professional development. Countries in the Asia-Pacific region could establish and expand partnerships for STEM professional development.

The development of STEM education could be proceeded through teacher professional development, further studies might look for the development of a STEM PD programme to fill the gap in teacher's competency on STEM education regarding information from this study, and implementation of the programme.

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