Integrated STEM education in the Thai secondary schools: challenge and addressing of challenges

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Abstract. In response to the development of technology and to advance global competitiveness, many nations now face a shortage of a suitably trained STEM workforce. To develop the STEM workforce, STEM education has been integrated into the curriculum, which presents a range of challenges for teachers. Thailand is also in the process of integrating STEM education into their educational system. This paper aims to review the integration of STEM education in Thailand, focusing on the challenges of this implementation. Results from the literature reviewed suggest the challenges of STEM integration in Thailand consists of students’ low engagement in learning in the STEM disciplines, challenges in integrating engineering, and teachers’ knowledge and skills in teaching STEM integration. It also provides a review of possible solutions to each including engaging students by using questioning techniques, using the engineering design process (EDP) as a method to integrate engineering, and support teachers in professional development and collaborative partnerships.

1. Introduction

It is undeniable that the development of nations is significant contribution from the improvement of innovation. As the results many countries have put efforts to promote people who work in research and innovation that enable them to be more competitive in the global economy. Especially in science, technology, engineering, and mathematics (STEM) [1–3]. Opposite from the demands, the number of people who work in STEM fields seems to be decreasing [3–5].

Not only the decreasing trend in the number of STEM workforce, many countries have been faced with the problem of students’ low performance in international test such as PISA and TIMSS [1]. This trend is concerned because these international tests assess young generations’ 21st-century skills which are the essential for today workforce [1]. The literature mentions that the problem of decreasing of STEM workforce are caused by the caused by a range of reasons such as young people are not interested in STEM subjects and some of STEM graduates not working in STEM areas [6,7].

To promote the STEM work force, STEM education has been introduced in several countries with an aim to promote young people’s interest in STEM disciplines and to work in STEM areas. Moreover, to enhance students’ 21st century skills which are crucial workplace skills [1,8,9]. To gain high benefits from implementing STEM education, teachers are required to teach STEM in the integrated ways. This
is because the problems in STEM fields do not occur separately. Teaching integrated STEM disciplines with real-life problems could promote students to develop their interest in STEM subjects and the essential 21st-century skills needed in modern economies [1,3,10]. Currently, STEM education is now implemented in several countries including Thailand [11–13].

In Thailand, STEM education has been introduced and taught in schools since 2013 which aims to promote young people to interest in STEM disciplines and continue study in STEM areas [13,14]. However, the result of the implementation of STEM integration in Thailand has shown both successes and difficulties, with some teachers struggling to teach integrated STEM education [13,15–17].

Previous studies conducted in Thailand found that the challenges of teaching integrated STEM in Thailand include 1) Students’ low engagement in learning in the STEM disciplines, 2) Integrating engineering and, 3) Teachers’ knowledge and skills in teaching STEM integration [12,15–17]. As the importance of teaching integrated STEM education, this study aims to conduct a review of the current situation of the integration of STEM education in the Thai secondary school context. This will present challenges and the addressing of challenges will be studied.

2. Method
A critical literature review was employed in this study to investigate previous research about STEM education in Thailand and other countries on the topics of teaching, and to address the challenge of STEM integration in Thai secondary schools. Peer-reviewed research from 2009 to 2020 was analysed. The data were categorized into challenges and methods of addressing the challenges.

3. STEM education
STEM education was first introduced in the United States referring to the integration of science, technology, engineering, and mathematics [1]. The aim of implementing STEM education is to promote students’ interest in STEM subjects which could encourage them to continue work in STEM areas. STEM education is now widely implemented in many countries. The definition of STEM is varies among educators. However, a common focus in the literature is the combination of some or all of the STEM disciplines and connection with real-world problems or authentic situations in order to develop the essential 21st century skills in students [1,18,19]. Bybee [1] mentions that the importance of implementing STEM education depends on the context in which the STEM education is being used. STEM education should contribute to the integration of science and mathematics with emphasize on technology and engineering toward the real-life challenge, promoting STEM literacy, and essential 21st century skills for student [1,2]. Thus, among a variety of STEM education’s definitions, the focus of promoting the integration of STEM subjects with real-life problems, students’ 21st century.

4. Integrated STEM
To gain the benefits from STEM education teachers are required to teach STEM in an integrated way. However, there are some confusions among educators about the best method to integration of STEM subjects. For example, Moore [18] mentions that integrated STEM can refer to “Integrated STEM education is an attempt to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems”[10]. Another definition of integrated STEM was defined by Nadelson & Seifert [19] which is “The seamless amalgamation of content and concepts from multiple STEM disciplines. The integration takes place in ways such that knowledge and process of the specific STEM disciplines are considered simultaneously without regard to the discipline, but rather in the context of a problem, project, or task” [19].

It can be seen that, the concepts of integrated STEM are various depend on the person. However, a common focus of STEM integration definition is that literature point the combination of some or all of the STEM disciplines and connect with real-world problem or authentic situation. Therefore, in this
study integrated STEM refers to the methods that teachers can use to conduct STEM activities by integrating two or more disciplines with real-world problems.

5. STEM education in Thailand

In Thailand, STEM is seen as the instrument to reform education in Thailand with more innovative and integrated teaching and learning approaches. One of the primary goals of STEM education in Thailand is to produce the competent human capital for the workforce which aims to help Thailand move beyond a modern developed economy [14]. STEM education is driven by the Thai government. The Institute for the Promotion of Teaching Science and Technology (IPST) is the organization that plays an important role in implementing STEM education [11]. IPST define STEM education in Thailand as “an educational approach that integrated science, technology, engineering, and mathematics by focusing on problem solving in daily life and professional undertaking”.

IPST states that STEM learning organization should 1) employ an integration approach for teaching and learning, 2) link multidisciplinary to real life and work, 3) focus on critically demanded twenty-first-century skills, 4) challenge for students, and 5) give opportunities for students to share their ideas. Moreover, STEM education is included in the Thai educational plan which is designed by the Ministry of Education [11]. Therefore, as the concept of STEM education from IPST and the concern of ministry of education, teaching integrated STEM in classroom is crucial.

6. Challenge of integrated STEM and addressing challenges of integrated in Thailand

After the introduction of STEM education, there have been some studies about how teachers in Thailand understand and teach STEM integration. Research has indicated that students’ low engagement when they study STEM subjects is one of the problems of teaching integrated STEM in Thailand [13,16]. The Integration of engineering is also seen as one of the challenges, teachers mention that integrating “E” or engineering in STEM is difficult for them [13,14,16,20]. Another challenge is that teachers need to have strong knowledge and skills to teach STEM in integrated ways [16,21–23].

6.1. Students’ low engagement in learning in the STEM disciplines.

Students’ engagement is crucial for effectively learning STEM. When students are engaged in learning activities, they appear to be more actively participate in STEM activities [16] Srikoom et al [13] states that students can be more engaged in the class when teachers ask questions that encourage students. This is opposite from the classes where teaches rarely ask students questions and invite discussion and participation in class activities. In addition, this study mentions that the classrooms that effectively engage students in STEM integration are where the teachers use inquiry dialog questions to encourage students to find answers and discuss concepts with their peers. In the classes that showed less students’ engagement, teachers had difficulty asking engaging questions. Related to this Faikhanta [16] mentions that, most of teachers struggle engaging students when they were participating in STEM activities. The study claims that teachers realized the importance of engaging students by asking questions to encourage students’ class discussion. However, teachers still found that design questions in STEM activities are a challenge for them. [16] Thus, to overcome these challenge teachers need to include effective questioning in their planning and teaching to better engage students.

Nevertheless, the previous studies did not mention how to create effective questions and the components of questions used in STEM classrooms. When questioning in integrated STEM activities, the content of the question is important [24]. Teachers can use real – world issues as topics to frame questions for students to start discussing. This is because when the issues are familiar to the students’ life, they are more likely to be engaged to answer and discuss with their peers [18]. In addition, in integrated STEM activities teachers could use issues related to environmental quality, health, energy efficiency, and hazard mitigation [1].

Choosing type of question to ask is also important. Different types of questions are suitable for different purpose of classroom activities [24,25]. Dialogic questions have the potential to encourage students in class discussion. This values students’ opinions so that they feel comfortable. Authoritative
questions are appropriate when teachers need to ask students about factual knowledge. That is to say, dialogic questions can engage students to while authoritative questions shape knowledge and opinions. This characteristic could help students to improve their communication skills which is one of the skills that integrated STEM class should impart to students \[1,18\]. Thus, to effectively engage students in integrated STEM activities, teachers have to design questions that are based on real-world contexts and use different types of questions in line with the aims of the learning activities.

6.2. Students’ low engagement in learning in the STEM disciplines

To effectively integrated STEM education, engineering appears to be one of the important parts. Engineering enables students to solve real-world problems by integrating scientific concepts, mathematics, and technology in a natural way with catalyst students’ scientific and mathematics concepts \[3,26\]. This is because in reality, the problems in STEM fields do not occur separately, but it requires students to integrate STEM disciplines to find the solutions \[10\]. Moreover, it also promotes students problem-solving skill, communication skills and teamwork which are the crucial parts for future STEM workforce \[10\].

However, integrating engineering in STEM activities is one of the main challenge for teachers. Teachers mention that integrate engineering is difficult for them and some of them have lack confidence to integrated engineering in learning activities. Similarly, in Thailand teacher found that integrate engineering is challenge. However, there is a limited study that implements EDP in Thai secondary schools. This can be because teachers lack experiences in integrating Engineering in STEM and the amount of content is heavy due to the Thai curriculum \[12,13\]. Different from other STEM disciplines, engineering is not a compulsory subject in Thai secondary schools. This subject is taught in a specific field at the university level \[12,13,20\]. As a result, engineering is seen by teachers as a difficult discipline to integrate into STEM. Although teachers realized the important of integrating engineering in STEM, they do not really know how to design and what should be involved in integrating engineering in STEM activities \[15\]. This causes teacher rarely emphasized engineering when they teach STEM integration. The reason is engineering is new for them and it does not include in compulsory curriculum.

To overcome the difficulty of integrate engineering, provide the activity that allows students to design artefacts based-on real world problem in learning activities is crucial. The activities should provide students a chance to define problem which based-on authentic problems, allow students to addressing problems, testing and refining their solutions \[2,11\]. One of the effective methods is using engineering design process (EDP). EDP can provide a method to integrated engineering with other disciplines into learning activities effectively \[1,8\]. To integrate EDP, using a design-based approach with EDP can help students to naturally apply engineering with the other three disciplines. Teachers can use project – based approaches to design STEM activities and encourage students to design artifacts \[27\]. Importantly, to promote meaningful learning in STEM integration, teachers have to encourage students to design solutions to real-world issues such as climate change, environment, and energy resources \[1,18\]. By doing this, students have chances to apply their knowledge in science and mathematics with appropriate technology through the EDP to design artifacts and enhance their scientific and mathematics contents.

According to The Next Generation Science Standards (NGSS) \[28\] the EDP consists of 1) Identify problems, 2) develop and use artifacts, 3) plan and carry out investigations, 4) analyse and interpret data, 5) use mathematics and computational thinking, 6) design solutions, 7) engage in argument from evidence, 8) obtain, evaluate, and communicate information.

Schnittka & Bell \[29\] used the engineering teaching Kit called Save the Penguins was to teach the concept of heat transfer for grade 8 students. Results indicate that EDP helped to promote students’ discussion, attitude, and conceptual knowledge. Other studies indicated that EDP can help to promote students’ in several dimensions. Chao et al \[30\] conducted study on the topic of environment by using computer-aided design (CAD) software. This study employed EDP as a framework for students to
design via CAD software. Result showed that student can develop scientific knowledge and engineering design after participated the in activity. This is in line with Purzer et al [31] suggesting that using software programs such as CAD can promote students engineering design and conceptual concept understanding. Moreover, when students had chances to trial and develop their artifacts, they possibly practice and improve their EDP [30,31]. That is to say, EDP could be the method that promoting the integration of E in STEM with several learning activities. It also contributes to the improvement of students’ conceptual knowledge and other essential skills.

However, to effectively integrate EDP in STEM activities the characteristics of content needs to be considered. This is because some content is difficult for students to apply through the EDP due to level of complexity, such as biology content in the higher grades [10]. Besides, Teevasuthonsakul et al [20] claims that teachers should carefully scope the contents that are essential for students. This is because the unnecessary content probably lower students’ interest and willingness to participate in activities [20]. Nevertheless, it is important to use EDP with appropriate content such as mechanics, genetic engineering and artificial organs. This is because EDP can promote students interest in STEM disciplines so they can possibly continue study in a higher level of STEM fields [10,25]. Therefore, using EDP with the appropriate contents as a tool to encourage students to design artifacts based on real-world problem can help teachers to present STEM integration in meaningful ways.

6.3. Teachers’ knowledge and skills in teaching STEM integration
To be more effective in teaching integrated STEM, teachers are required to have strong content knowledge and skills in the STEM disciplines. In Thailand, research indicated mixed results regarding teachers’ perceptions toward STEM. Some teachers have an awareness of STEM education. While some have no experience with STEM integration. the teachers who had the most concerns about STEM education were those who teach in the four STEM disciplines [13,16]. Most of teachers mentioned that teaching integrated STEM is challenging for them [12,13] Teachers realized the importance and objectives of developing integrated STEM activities. However, they did not clearly understand the processes and details involved in designing STEM activities [16]. In addition, Pimthong and Williams [17] stated that teachers knew about STEM education, but only a small number of them indicated they knew how to teach integrated STEM. Besides, none of them highlighted about preparing students for the future STEM workforce which is the main purpose that Thailand introduced STEM education. Corresponding to Manosuttirir [23] which mentions that teacher have lack experience in teaching STEM and require more time to understand. That is to say, most of Thai teachers still have less experience and skills to teach STEM in the integration ways.

It is crucial to support teachers in developing strong knowledge and skills to teach STEM integration. To do this, research suggests providing teacher professional development programs (PD program). This is because PD can provide guidance for designing and teaching learning activates [16,32,33] Although PD programs can promote teachers knowledge and skills in teaching STEM, teachers tend to revert back to traditional strategies when they teach in their classrooms [34]. This may be because teachers could not see the effectiveness of the strategies their gained from PD program.

To overcome this problem, designing PD programs that can help teachers to see the effectiveness of techniques is essential. The characteristics of PD for STEM integration should provide teachers appropriate time to learn and see the effectiveness of teaching techniques represented in the program [35]. Teachers should have a chance to practice both in students and teacher roles in order to reflect and learn from each other. Doing this may help teachers to realize the effectiveness as well as the weaknesses upon which they can improve [35,36].

In addition, real-world partnership is one of the methods the methods that can support teachers in integrated STEM. Schools can develop partnerships with organizations such as universities, industry and government authorities [10,18]. The partnership can support teachers and schools in many ways such as providing learning resources and suggestions in developing curriculum and real-world learning activities [18]. For example, Verma & McKinney [37] have created a PD program to support teachers in teaching integrated STEM. This study designed the Marine Tech curriculum and associated project-
based learning activities which involve university, marine industry and local schools to run the program together. The Results indicated that supporting teachers by providing curriculum, resources, and learning activities helped them to teach STEM more effectively and confidently.

Although collaborative work with partnerships can support teachers in STEM integration, there were some difficulties to be considered. When teachers work with partners such as university scientists, they have different point of views on designing curriculum. This due to different experiences and roles which may lead to some tension when they work together [38,39]. To diminish such challenges, effective communication is important, schools have to identify appropriate staff to effectively communicate with partners, such as teachers who have industrial experience [10,39].

Importantly, to implement what teachers learn from PD and to build partnerships, school leaders should support teachers. This is because school leaders can influence teachers to make decisions to apply their knowledge from PD to their school. For the partnership, school leaders can support teachers through co-working spaces, time for collaborative work, and resources to communicate with partners [9,40]. Therefore, to support teachers in developing their skills in STEM integration, PD programs and school partnerships seem to be the effective ways. However, teachers need to have support from school leaders to implement techniques from PD and run partnerships.

7. Conclusion

The main purpose of the STEM integration into curriculum is to promote young people to participate in the STEM careers. To achieve this goal, encouraging students to study in STEM fields, and promoting their attitude toward STEM disciplines is essential. This study has review a range of literature to evaluate ways to address the challenges of STEM integration in Thailand.

Firstly, teacher have to develop the STEM instruction that can engage and motivate students to participate in the activities. Engaging students is important because when students are engaged with learning activities they will be more motivate to learn which can contribute to be more interest in STEM disciplines [13,16,41]. In Thailand, teachers face to problem of engaging students in integrated STEM activities. To overcome the challenge, previous studies claim that using questioning techniques appears to be the essential methods [13,16]. However, the studies did not mention about the focus of questions used in STEM activities. The review from literature suggests that to engage students in STEM integration, the topic of question should related to real-world issue such as climate change, health, environment, and energy resources [1,9,41]. This is because students probably familiar with the real-world issues and they clearly provide students related to the STEM disciplines [1,9,41]. In addition, teachers have to choose an appropriate type of question to ask students. This is because different types of questions are suit to the different purposes of learning activities. Dialog question is appropriate when learning activities require students to discuss and share their opinions with peers. While, authoritative question is appropriate when the purpose of activities is to review students’ conceptual knowledge [24,25]. To do this, it can promote students to be more encourage and more participate in STEM integration learning activities.

Secondly, teachers need to have skills and knowledge STEM activities that can integrate with other STEM disciplines. Engineering provide the realistic way to integrate other STEM subjects with authentic problems [3,10,18]. However, the challenge found from several teachers is that teachers have less experience and lack of confidence when they have to integrate engineering in STEM activities. This resulted from the reason that in Thailand engineering is not included in compulsory curriculum and teachers do not familiar with this disciplines [14,16]. To diminish this challenge, literature suggests that using EDP as a method to integrate engineering is helpful. Teachers can employ EDP to integrate with real-world problems and encourage students to design artefact to solve the problems by applying the contents in science and mathematics with appropriate technology [1,8]. Moreover, EDP allows teachers to construct learning activities by using varies type of techniques such as learning kit and computer-based design. However, there are some issue to be considered when integrating engineering by using
EDP. Teacher have to carefully choose the contents and the amount of contents that they will use. This is because some contents are difficult to teach by using EDP such as biology in the higher grade. Moreover, the amount of content is needed to be concerned [10,27]. Unnecessary content can cause students to less interest in participating in learning activities [20]. Nevertheless, it is important to apply EDP in the appropriate content such as mechanic and artifacts organs because it can encourage students to be more interested in STEM disciplines. This possibly makes students to continue study in STEM field [10,26,27]. To sum, using EDP is the helpful tool to integrate engineering in STEM integration learning activities. Teachers should provide students to using EDP to design their artifacts based-on real world problems by encouraging students to design the artefacts and solve the real-world problem can help teachers to teach STEM integration in meaningful ways.

Finally, teachers' knowledge and skill to design and teach integrated STEM is important. Teachers play an important role to run integrated STEM learning activities. In Thailand, teachers found that teaching integrates STEM is challenge for them [12,16]. Most of teachers realized the important of STEM integration, but they did not clearly understand about the details and process used for conducting STEM integration [16,17]. To overcome this challenge, it is crucial to support teachers to gain strong knowledge and skill to teach STEM in the integrated ways.

Literature suggests that provide teachers PD program appears to be the essential way. The characteristics of productive PD program in STEM integration is it should be conducted with appropriate time that allows teachers to realize an effectiveness of techniques represented in programs [35]. This is because when teachers cannot see the effectiveness of the techniques, they may turn back to the previous methods they use before [34]. The PD should give chances to teachers to perform both in teachers and students roles. When teachers can perform as students they can reflect on the techniques they use [35,36]. To do these possibly help them to see the effectiveness of strategies they have learned from the PD and apply into their classroom.

Another method is collaboratively work with partnerships. Partnership such as industry, can help to support teachers to design integrated STEM activities [10,18]. Moreover, school partnerships have also shown benefits to support teachers and students in STEM education. The benefits for teachers is partnership can support teachers for advanced knowledge, skills, and teaching resources [10,18]. Moreover, working with partnerships has profits in developing the relationship between students and partners which possibly could result in student interest in working in the STEM areas [8,9]. Although working with partnerships can help teachers and schools in several way, there are some challenge to be concerned. The reason is people from other organization such as experts from university possibly have different point of view toward STEM integration [38,39]. This probably leads to some tension when they work together with teachers. To overcome the challenges, effective communication is important, schools have to identify appropriate staff to communicate with partners such as teachers who have industrial experience might communicate well with industry partners [38,39]. Thus, to support teacher in developing their teaching in integrated STEM, PD program and school partnership appears to be the effective ways. However, teacher need to have support from school and leader to implement technique from PD and run partnership.

Overall, this study reveals the challenges, and addressing challenges of STEM integration in Thailand. The findings can be used to help STEM teachers, educators, and others involved in STEM education in Thailand to gain ideas and develop teaching STEM integration. The application of this study might be lead to a different range of results. Thus, teachers should critically apply these finding in the appropriate ways according to their classroom context and schools.
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