Research Article

THAI SCIENCE PRE-SERVICE TEACHERS' IMPLEMENTATIONS OF STEM THROUGH A PHENOMENOLOGICAL MULTIPLE CASE STUDY AFTER EXPERIENCING BLENDED PROFESSIONAL DEVELOPMENT PROGRAM

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Abstract

Integration of STEM disciplines offers students an experience to learn in real-world, multidisciplinary contexts. Teachers play the key role in STEM education and it is important to attract high achievers with relevant backgrounds. To produce a generation interested and skilled in STEM one of the key factors are teams of teachers who work together in an integrated approach, based on cross- curricular teaching and learning. Therefore, this study draws upon classroom implementation though a team who supports the student teachers' practice. Phenomenological multiple case study was used as the framework to understand 5 science teachers' first-time experiences in implementing integrated STEM curricular units in their elementary and middle school science classrooms. Classroom implementation data and teacher reflective interviews were used to illustrate different degrees of integrated STEM instruction to understand the teachers' challenges and successes with these varying approaches. The findings indicate that pre-service teachers have a strong understanding of STEM implementation after they were provided blended professional development and continual school coaching. The results of this study indicate that the knowledge they have acquired provides them with a broadened scope on how to teach STEM in schools now and what they need for future teaching of STEM. Pre-service teachers were challenged to make clear connections between science, engineering, and mathematics while simultaneously maintaining a motivating and engaging context for their students throughout their instruction. Therefore, educational researchers, policy makers, and STEM educators should focus to foster new teachers to reflect across content disciplines for the first time. Continual teacher support for the learning of STEM content and pedagogical practices for integration across content disciplines.

Keywords: STEM Education, Science, Phenomenological Multiple Case Study, Pre-service Teachers

Introduction

STEM Education is an educational approach that integrates knowledge from four fields: Science, Technology, Engineering, and Mathematics. The role these four subjects play at multiple levels of society and a country's economy revolve around mathematics, such as, accounting, economics, functions and logarithms, and calculus. The advanced study of chemistry and biology supports new trends in medical research, and environmental efforts like sustainable energy and nuclear power are also involved in these sciences. It is clear that STEM fields affect virtually every component of our everyday lives. These subjects build the high-achieving citizen who will provide new direction to our country. STEM is essential to our education system, as school districts across the country strive to build a stronger curriculum around these subjects. In Thailand, teaching STEM in primary and secondary education is a way that teachers help students become interested in STEM careers and build a nation's STEM-educated workforce that can be used to meet the demands of business and industry in a complex and technology-driven economy. The Institute for the Promotion of Teaching Science and Technology (IPST) responses to developing STEM Education programs for the national curriculum of Thailand (IPST, 2013). A training program has been initiated and designed to provide teachers with opportunities to enhance advanced knowledge and teaching practice for a STEM classroom (Organization for Economic Co-operation and Development, 2016). Education for the twenty-first century demands skills in science, technology, engineering, and mathematics (STEM) to deal with challenging complex situations, and these STEM capabilities need to be developed from as early as primary school (National Research Council, 2014). Integrated approaches to teaching, learning, teacher preparation and development are the key aspects that need to be focused on to produce STEM teachers who are interested and skilled in STEM. According to Holmlund et al. (2018, p.12), a majority of the teachers and workers in STEM settings included "students" opportunities to develop twenty-first century skills" as a "salient" feature of STEM education. The students build these skills for constructing lifelong learning competences (OECD, 2018). It is important to attract high achievers and boost the rigor of STEM within pre-service teacher preparations and in-service teacher development. The proliferation model of STEM that existed and the associated lack of practical advice created general confusion about integrated STEM that requires classification, especially for teacher charged with implementing integrated STEM in classrooms (Bybee, 2010). The three largest hurdles preventing successful STEM integration are (1) a lack of curriculum materials, (2) the need for creating engaging experiences for students, and (3) the need for assessments in integrated STEM (Guzey et al., 2016; Moore et al., 2014; Roehrig et al., 2012). According to Moore et al. (2014), the role of the teacher in integrated STEM learning is to help students make abstractions and to decontextualize concepts for application in a variety of different real-world, authentic contexts. However, most teachers do not currently have the knowledge and/or equipment to bring integrated STEM to the classroom, finding the balance of developing problem-solving skills and teaching science content challenging (Dare et al., 2014). Therefore, it is necessary to discuss on how pre-service teachers' conduct their lessons which can be observed during a teacher internship program and how to enhance their knowledge that can influence their future instructional practices (Leung, 2018). Knowledge of teaching and learning is among the attributes of individual pre-service teachers that inform and influence the decisions they will make and behaviors they will exhibit as professional educators. One of the ways that we can provide support for the inclusion of integrated STEM Education in classrooms is through systematic and high-quality professional development (Guzey et al., 2014, pp. 139-149; Roehrig et al., 2012, pp. 31-44).

Rajabhat University is preparing teachers for the changes to the diversity of new knowledge and technology. Professional development (PD) experiences can facilitate learning opportunities for teachers to acquire knowledge about new teaching practices or content (Estapa et al., 2016, pp. 85-104). Teacher PD programs typically seek to increase teachers' professional knowledge, challenge beliefs, improve classroom practices, and foster students. When considering how to design PD (professional development) experiences that will develop skilled and knowledgeable educators who use technology to create engaging and effective classroom environments, researchers have found mentors and a good learning team to be useful in understanding the processes at work. However, most teachers do not currently have the knowledge to bring integrated STEM Education to the classroom, finding the balance of developing problem-solving skills and teaching science content is proving to be challenging (Dare et al., 2014, pp. 47-61).

Therefore, it is necessary to understand pre-service teachers' knowledge and practices of integrated STEM instruction during their internship. The challenge of preparing pre-service teachers and in-service teachers in how the STEM knowledge influences the teaching practices when they become professional STEM teachers. This study presents pre-service teachers' implementations of integrated STEM Education with their first experience in classrooms. The discussion of enhancing knowledge that influences pre-service teachers' and in-service teachers' future instructional practices focuses on how they conduct their lessons which can be observed during a teacher internship program. This 1 year internship (Professional Development Program) was designed based on Blended learning approach which combines online platform and opportunities for interaction online with traditional face to face methods.

Research Objectives

This paper will pursue the research question empirically: What are the pre-service teachers' implementations of integrated STEM education after they experienced the blended professional development program? And how does the Professional Development Program look like?

Research Methodology

This study employs a phenomenological, interpretive multiple-case study designed to develop an understanding of the nature of integrated STEM. The phenomenological lens used in this case study enabled us to better understand what implementing integrated STEM is like for these teachers, focusing on their experiences (Creswell, 2013, pp. 15-16). This was done through an examination of primary and middle school science pre-service teachers' experiences with implementing integrated STEM curricular units in their classrooms. The observational data additionally provided context regarding individual classroom implementations. Post-implementation pre-service teacher reflective interviews provided detailed information from the teachers' perspective about challenges and successes they experienced during their implementation.

Context

The study is part of a 5-year teacher education. The curriculum involves working between university and the school partners from K-12 levels to promote K-12 STEM integration in Grade 4-8. The goal of the program is to increase student learning of science and mathematics by using an engineering design-based approach for integrated STEM instruction to guide professional development and curricular design.

The Blended Professional Development Program

The professional development program (PD) was designed based on TPACK model of knowledge and to use Continuing Professional Development (CPD) strategy. Punya Mishra and Matthew J. Koehler's 2006 TPACK framework, which focuses on technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) was used as a knowledge framework. The STEM integration PD was designed as described by Moore et al. (2014) was used to guide teachers' learning during an intensive 4-month professional development. The course involves the integration of STEM disciplines to (1) deepen student understanding of STEM disciplines, (2) broaden student understanding through exposure to socially and culturally relevant STEM contexts, and (3) increase interest in STEM disciplines. During the first year of the project, 24 preservice teachers from the department of general science participated in a 4-month professional development program that was not in the curriculum. After the intensive training program, they were provided with the continually professional development (PD) which was designed through the framework that is presented as Figure 1.

Figure 1 The School Professional Development Program Framework

The school PD included partnering with instructional coaches in teams to collaborate on the creation of STEM integration curriculum units designed to address state science and mathematics standards in grades 4–8 within the context of an engineering design challenge. This professional development was designed to engage teachers in learning and participating in various activities as part of an integrated STEM curriculum. These teachers were provided the knowledge and practices of engineering design and understanding of bringing STEM to their selected science area (life, earth, or physical science). The teachers then created their integrated STEM curricula. These curriculum units were expected to include the six tenets of integrated STEM education (Moore et al., 2014, pp. 46-47) discussed in the professional development. Pre-service teachers were asked to include an engineering design challenge situated within a real-world, engaging context that addressed science content. The learning activities were created using active learning approach. After classroom practices, the teachers and their teams had reflective discussions for revising their lessons for their next class. Visual meeting was used as the discussion platform, such as Google classroom and ZOOM.

Research Participants

The twenty-four participants during the internship were primary and middle school science teachers. Of the 24 participants, 17 of these teachers taught 4^{th} - 6^{th} grade and 7 taught an advanced 7^{th} grade course. There were 5 participants who were selected to work with the researcher continually for 1 year using criteria of willing to collaborative classroom practice in order to study how they implement their STEM lessons at the school.

Data Collection

Multiple data sources have been used during the research process. Interpretive case study, classroom observation, individual interview, STEM literacy questionnaire, STEM-based lesson plan, written reflection, and group discussion are preferred to assess all teachers' knowledge with their thinking, actions, and reasons in the specific context and setting. For the 5 purposive selected participants, each teacher was observed during their teaching an average of 6 times and 4 individual interviews along with the 1-year internship. The researcher observed, and video recorded the implementations of the STEM curriculum units in the 2019 school year as their classroom coach. In total, 30 observations were conducted. Curriculum units ranged in length from 3 to 7 days. The length of the class period was typically around 50 min, with the exception of teacher Piyawadee (Pseudonym), whose school used 45-minute class periods. Field notes were taken during each observation and used to provide a context for follow-up interviews. Additionally, a digital teaching log was completed each day to indicate the length of time spent on science, mathematics, and engineering. This log included options to indicate time as follows: None, Less than 10 min, 10–20 min, 20–30 min, 30–40 min, 40–50 min, and more than 50 min. After each teacher implemented their STEM curriculum unit, they were interviewed by a researcher (university supervisor) using a semi-structured interview protocol; this occurred, at most, a week after the last day of their curriculum unit implementation. This interview was structured to allow participants to reflect on their implementation, and since the researcher had previously observed the STEM unit implementation, the questions were somewhat personalized to their implementation. Interviews were generally 1 hour in length.

Data Analysis

The empirical data used in this paper comprised of the pre- service teachers' integrated STEM lesson plans, thus entailing a documentary analysis. Content analysis was used to understand how these teachers implemented their STEM units in their classrooms. This limited the scope of the analysis to only examine interview content that was uniquely related to STEM integration. Each transcript was read and openly coded individually by the first and second authors (Corbin & Strauss, 2008). After reading and coding each interview for the given theme, individual codes were discussed to check for places of agreement and disagreement between coders before moving on to reading the next transcript. Codes repeated across individual interviews that allowed us to determine initial themes within each case before all transcripts were coded as presented in Table 1.

Table 1 Code and Theme

Code	Theme
S	Single Disciplinary (Science)
M	Single Disciplinary (Mathematics)
T	Single Disciplinary (Technology)
SM	Cross Disciplinary (Science and Mathematics)
SE	Cross Disciplinary (Science and Engineering)
ST	Cross Disciplinary (Science and Technology)
SME	Multiple Disciplinary (Science, Mathematics and Engineering)
STEM	Multiple Disciplinary (Science, Technology Engineering and Mathematics)

Once all transcripts in all three themes were coded as presented in Table 2, we used a constant-comparative method to examine and re-examine codes to collapse them into themes across all nine interviews (Corbin & Strauss, 2008). Once these themes were identified and refined, we further consulted the teaching logs and field notes to contextualize teachers' comments surrounding their classroom implementation.

Table 2 Frequency of instructional days with disciplinary integration

Theme	Synonym Name		S	M	T	SM	SE	ST	ME	SME	STEM	Single Disciplinary	Cross/Multiple Disciplinary
1	Kamon	T1	7	2	3	3	2	0	0	0	0	70.58%	29.42%
2	Napa	T2	4	0	0	6	3	3	1	1	0	22.22%	77.78%
	Piyawadee	T3	5	1	0	5	2	4	2	1	0	25.00%	75.00%
3	Sirod	T4	1	0	0	2	5	2	0	4	3	5.88%	94.12%
	Tekla	T5	1	1	0	2	4	5	2	3	2	10.00%	90.00%

Research Results

In the academic year of 2019, the blended professional development program was conducted through working with Collaborative Teamwork among science teachers, supervisors, mentors, students, research instructors and experts in the development of STEM activities. The team worked to design the lesson plans in the way of face to face and online. From the study it concluded that these 24 pre-service teachers had developed their knowledge and skills of STEM teaching. Based on data from semi-structured interviews, analysis of STEM lesson and reflective journal it was found that teachers had explained the engineering design as a process of solving problems or meeting various needs.

After analyzing the research data from 24 pre-service teachers as stated above, five pre-service teachers who were selected purposively identified three common themes across the three cases which serve to clarify the teachers' experiences in implementing integrated STEM: 1) the nature of integration; 2) choosing between science and engineering; and 3) student engagement and motivation. The nature of integration describes how teachers perceived their role in making connections between multiple disciplines, whether implicit or explicit. Choosing between science and engineering highlights the struggle that teachers felt in balancing science content while also engaging students in an engineering design challenge. Student engagement and motivation describes how teachers viewed their student's interaction with the curriculum units they implemented. From 5 case studies of pre-service teachers' practicum, their classroom STEM actions were categorized into 3 patterns. Therefore, this result presents three themes which were generated from research data using cross case analysis as follow:

Theme 1: Full-scale STEM learning: Full-scale STEM learning management in a multilayered integration level started by a pre-service science teacher with her lesson plans that emphasize students to learn about the content and practical skills of science subjects, mathematics, technology and engineering with a theme that the science teacher works together with other STEM subjects. Example of lesson; the WAGON lesson was drawn upon multiple disciplines throughout the course of their implementation.

"The teachers of all four subjects can work together to use a WAGON as the main topic in managing science, mathematics and technology as shown in Figure 3. For example, in the technology subject, the teacher can start introducing materials and design, suggesting that it is a simple technology created by humans for facilitating or responding to the needs of transportation, while science teachers provide the concept of force and friction and mathematics teachers using number and measurement to teach students about shape and allow students to find the surface area and weight."

(Kamon's Interview and Reflective Journal)

The WAGON STEM activity can increase students' understanding of the science content and their ability to connect their understanding to the design challenge.

Theme 2: Multidisciplinary Instruction: two pre-service science teachers have organized learning management of STEM Education that focuses on students to learn about the content and practical skills of at least 2 subjects together by linking the relationship of all subjects for students to see the consonance in each one. In this kind of learning management, science teachers and another subject teacher (mathematics) work together by considering the content or learning indicators so that they can design learning activities. The science teachers required students to conduct experiments, for example, high and low tides. The science teachers challenged students with moon phase and coastal tide phenomena. They were then provided with different data sets of tidal phenomena in different areas by the mathematics teacher. The students learned the concept and skill of data visualization and pattern analysis from tidal phenomena graph before students started experimenting in science. Afterwards, when students'experimental and data collection was completed, graphs were created to interpret experimental results in mathematics again as the teachers stressed the importance of graphing to their students:

"Graphing is also obviously a scientific competency, so I liked my students to transform data into another pattern which was really easy for the students to understand. But some data was not so easy to graph and understand. So, Mathematics and Technology teachers had the responsibility to coach my students to use suitable program to do graphing."

(Napa's Interview and Reflective Journal)

Theme 3: Transdisciplinary Instruction: is that pre-service science teachers have to manage the teaching that helps students learn to connect knowledge and skills based on science, mathematics, technology and engineering relating to real life. The learning goal these teachers mentioned during their interview was.

"Teaching science should fill up a gap of what we teach in Science, and what Learners Learn. After we provide the students learning experience, they should apply such knowledge and skills to solve real problems in their community or society and that they are to create their own learning experiences."

(Tekla's Interview and Reflective Journal)

These two pre- service science teachers organized learning activities based on their interests or on students'problems. The science teachers may define a framework or theme of a wide problem for students and reflect on. However, teachers must think of these 3 concerning factors as follows: 1) Questions that are of particular interest; 2) Indicators in various related subjects; 3) The original knowledge of students, problem management/project-based learning which is a learning management strategy (instructional strategies) with a similar approach to this integration. If considering the use of a Tsunami as the main topic in STEM study, science teachers can manage Tran-disciplinary Instruction learning by starting to define the framework of problems related to Tsunami as a situation, for example, how does a Tsunami affect local people? And how do we plan for the next Tsunami? After the science teacher presented the problem to students, guidelines must be implemented for solving problems via using scientific concepts and skills, mathematics and technology through engineering design processes which demonstrates the development of knowledge.

Research Discussion

As the results are presented, the finding shed light on how pre-service teachers who do their practicum at elementary and middle school implement and experience an integrated STEM curriculum for the first time. The cases that are presented above in themes 1 to 3 represent both successes and challenges faced by these pre-service teachers. Across all three cases, teachers believed that their students not only learn about engineering but were engaged to real life decision making. All these changes of pre-service teaching are built through professional development that was developing along with the study. It consists of 3 stages: **Stage 1**: The Student Teachers' Preparation Cycle in science and skills management for science teachers which students have studied at the 4^{th} year level; **Stage 2**: The Cooperating Teachers Cycle consists of 5 steps, namely Exploration, Preparation, Co-planning, Co-teaching, Self-reflection; and **Stage 3**: The Collaboration Cycle between cooperating teacher, pre-service teacher (student teacher) and supervisor through PD which is created based on the co-teaching model and the coaching system.

Findings also indicated that at the beginning these pre-service teachers and cooperative teachers value STEM education; they reported barriers such as pedagogical challenges, curriculum challenges, structural challenges, concerns about students, concerns about assessments, and lack of cooperative teachers support. From interview data presented the pre-service teachers felt supports that the blended professional development program fulfilled their barriers and improved their effort to implement STEM education including collaboration with peers, quality curriculum, district support, prior experiences, and effective professional development. Especially, when the science mentoring teachers and pre-service teachers joined the STEM Education development for a period of 1 year, this group of science teachers changed clearly in terms of attitude towards teaching and learning in STEM Education. According to the teachers' interview it was found that having a support team working together with experts as both official and online consultants helped these science teachers have productive time to fully develop STEM Education activities. Based on the development of understanding about STEM Education, it was found that the science teachers have a good attitude towards learning about STEM Education management which leads to developing knowledge of understanding how to implement STEM Education into classrooms which present engineering design process clearly through their STEM activity. Furthermore, the study also provides the guideline of how to create integrated STEM learning activity which can foster the students to have scientific competency. The contribution of this study is presented in the following steps of how to conduct this integrated lesson into real context: 1) Identifying a challenge is a step away that a problem solver understands what the problem in daily life is. It is a way to understand the problems or challenges; to analyze conditions or limitations of problem situations in order to determine the extent of the problem which will lead to the creation of pieces of work or methods in solving problems; 2) Data gathering and related information search is a collection of information and theories in science, mathematics and technology related to the problem solving approach and assessing the feasibility, advantages and limitations: 3)Solution design is the application of relevant information and theories. The design of pieces of work or problem solving methods, taking into account the resources, limitations and conditions of the situation; 4) Planning and development are a step-by-step method for creating work pieces developed for problem solving methods; 5) Testing, evaluation and design improvement of solutions to problems or specimens is a test and evaluation of the performance of the workpiece or method by which the result may be used to improve and develop the most effective solution; and 6)Presentation of problems solving solutions is a procedure of solving problems for creating workpieces or developing methods for others to understand and can suggest further development. Especially in the aspect of beginning the lesson with a real world situation that is aligned with the literature, the participants saw the importance of a context to engage students with real-world situations and problems that are authentic to engineering and illustrate connections to the real world (Cunningham & Lachapelle, 2014, pp. 117-142; Moore et al., 2014, pp. 51-57).

One of the major challenges of STEM classroom practicum is how to balance between science and engineering design process. The 5 pre-service science teachers' learning units were intended to include a full execution of an engineering design process, only 3 pre-service teachers could complete the cycle of engineering design process. They included an explicit redesign and re-test phases. Balancing the roles of each part of STEM was challenging with respect of time (Dare et al., 2018). Reflective meetings of continual Professional Development is an important strategy to help these teachers plan to balance STEM activities and also to provide them ideas that make their students have time to process the information and to complete their assigned tasks effectively.

They design their STEM activity through creation of real world, meaningful context. Their STEM implementations maintain student's interest and a realistic storyline to keep students attentive.

Conclusion and Suggestion

Overall, the results indicate three distinct themes of integration within the sample that represent low, medium, and high degrees of STEM integration throughout curriculum implementations. Interviews with teachers from each case revealed three themes that varied across teachers' experiences: the nature of integration, choosing between science and engineering, and student engagement and motivation. Teachers in all five cases were challenged to make explicit connections between science, engineering, and mathematics while simultaneously maintaining a motivating and engaging context for their students throughout their instruction. Further, it appears that the degree of STEM integration that occurs in instruction may be related to teachers' ability to make explicit connections between the disciplines through continual support by a coaching team. This work provides a window of how STEM integration can be presented in the classroom which focuses on more than just the sequencing of engineering unit (Crotty et al., 2017; Guzey et al., 2016; Dare et al., 2018). This research study also has been summarized with factors contributed to the development of school science teaching in having the school learning goals, which the school leader should integrate the 21st century skill, as learning framework and integrated instruction (STEM education) as a teaching direction. Science teachers should be encouraged to participate in the design of STEM Educational learning management with real-life context. Analyze knowledge in science, mathematics, technology and engineering from problems or real situations in life by choosing appropriate activities or contexts to adapt to STEM thinking. Science teachers, who participate in professional development, will have the ability to develop different activities completely due to differences in creativity and experience of problem-based learning management and technology experience. Teachers' technological knowledge has been developed through the support process of continuous training of other teachers, administrators, teachers, mentors, experts with knowledge, sharing, reflections, ideas, exchange of experiences, group operations, showing results and reflecting opinions on teaching practices and accepting different abilities. The importance for PD experiences to go beyond teacher content knowledge and support teachers in strategies for enactment of an integrated approach (Anne & Kristina, 2017, pp. 1-16). Given an opportunity for the teachers to engage in the activity first as a learner, and then work to implement in the classroom provides a stronger foundation for enactment. The promotion of learning management with STEM Education theory for science teachers, results in science teachers' developing in knowledge, integrating teaching methods, technology (Technological Pedagogical Content Knowledge: TPACK) and affecting the teaching of STEM Education of teachers in the classroom. While this phenomenological work is composed of teacher reflections on their experiences with STEM implementation, further research should continue to explore how these reflections relate to their teaching pedagogy during this implementation. Quantitative observational measures throughout the entire curriculum unit should apply to construct a picture of each teachers' evolving pedagogy and instruction as they implement a STEM integrated unit for the first time. A further study is required to understand how these themes of STEM implementation relates to student learning outcomes. The findings here suggest that teachers who engage in larger amounts of integrated instruction value authentic learning context that makes clear connections between disciplines and reflecting key components of integrated STEM education (Moore et al., 2014, pp. 51-55; Kelly & Knowles, 2016, pp. 2-11). Information about the amount of time dedicated to science, engineering, and mathematics, assessing the quality of this instruction could benefit administrators and evaluators in helping them understand the needs of teachers who bring STEM to their classrooms. Until that time, this current study can act as a resource to help future facilitators and leaders of professional development to understand the challenges teachers may face when bringing STEM to their classrooms. Including how to use technology (ZOOM, Google classroom, Webex) as a learning platform or in blended learning. As a result, the research can be summarized on the aspects that both pre-service and in-service teachers have developed in the areas of: meaning, definition, sources and the importance of STEM Education management; writing the purpose of STEM education study in relation to 3R -7C; design and planning of integrated science theory and concepts at different levels; design of science learning management that challenges students; stimulating the application of successful work applied in real world living; and full measurement and evaluation of STEM Education.

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