STEM partnership for design-based learning in PM 2.5 crisis for high school

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Abstract. This collaborative action research aimed to understand how a schoolteacher, science educator, mathematics educator, scientist, and engineer were able to work collaboratively in STEM lessons. All researchers took part in STEM activity through design-based learning in the PM 2.5 crisis for high school students in Bangkok. A content analysis approach was used to analyse how the partnership works together and how STEM integration occurred across activities, such as lesson plans, classroom participation, and reflective journal. The positions and roles of science teachers, science and mathematics educators, scientists, and engineers were addressed. Three themes emerged as critical success factors from the present research, namely students’ learning, STEM integration, and good practices in STEM partnerships. This research suggests proper advance preparation for the members of a STEM partnership.

1. Introduction

STEM is the integration of four disciplines: science, technology, engineering, and mathematics. STEM has its roots in the US, and it was started because of the crisis of shortages of engineers and scientists and the declining scores of US students in international tests in science and mathematics. Moreover, STEM is important for preparing 21st century citizens [1] STEM is important for everyone; therefore, it has been adopted as an educational goal of many countries [2]. STEM may help 21st century citizens to solve complex problems by integrating four disciplines [3–5].

Integration is a core idea of STEM. Because STEM is designed to support everyday life, it requires multidisciplinary knowledge and skills. It is basically the integration of knowledge and processes of science, technology, engineering, and mathematics [6–10]. STEM teachers must understand the nature of each discipline and how they are integrated because many studies have warned that teachers and preservice teachers have difficulty understanding and teaching STEM [11–13].

A STEM partnership is another way for people from a variety of disciplines to work collaboratively to plan and teach STEM. There are many forms of STEM partnerships: the triad of a classroom teacher, student-teacher, and an engineering fellow working together on an engineering design challenge to integrate STEM concepts in the elementary classroom [14]; a school-university partnership for scientific literacy development [15]; a partnership of experts, students, and teachers in
after-school STEM programs [16]; integrating a college neuroscience classroom and a high school to construct authentic science by integrating digital storytelling and social networking [17]; and the partnerships between scientists, teacher education students, teacher educators, preservice teachers, the STEM industry, and schools [18]. Most of the research literature has shown that a partnership from a variety of disciplines promoted students’ learning of STEM subjects and processes, and it improved their attitudes toward STEM and STEM careers.

As in many other countries, STEM education is promoted at all educational levels in Thailand. The fifth author of this research is a chemistry teacher in a large school in Bangkok. The chemistry project course for high school students has been assigned for Grade 12 students. The topic of this course was the PM 2.5 pollution crisis—the crisis we are all facing because of fine particulate matter in our atmosphere. We worked as a STEM partnership in which a science educator (first author), scientist (second author), engineer (third author), science teacher (fourth author), and mathematics educator (fifth author) worked together. We discussed and created the STEM instructional unit on the PM 2.5 crisis.

This research aims to examine how a high school teacher, science educator, mathematics educator, scientist, and engineer were able to work collaboratively in a STEM partnership.

2. Methods
This collaborative action was the joint effort of researchers from a variety of disciplines related to STEM [19]. The study aimed to help our community improve our STEM teaching practices. The researchers collaboratively developed a STEM instructional unit on the PM 2.5 crisis. The fifth author was the main teacher who implemented the 12-hour unit, while the other authors were co-teachers. Our team teaching was involving each co-teacher teach collaboratively with the main teacher while the activities were related to their discipline.

The data were collected from the researchers’ reflective journals, partnership meeting notes, lesson plans, and students’ work. A thematic analysis approach was implemented in this study to analyze the qualitative data. The themes of the result of STEM partnerships were identified.

3. Result and Discussion
The following three themes emerged from the partnership: good practices in STEM partnership, STEM integration and students’ learning. These themes show how the partnership worked together and how STEM integration.

3.1. STEM Partnership

3.1.1. Elicit and equip all parties with an understanding of STEM. When we started sharing our individual understanding of STEM among ourselves, we found that we had different levels of awareness and views about STEM. Therefore, we started holding weekly meetings to improve our understanding of STEM before creating the STEM instructional unit for a PM 2.5 detector. In addition, with various backgrounds and expertise, we offer different perspectives that help support student’s learning and different contributions to the partnership. At the beginning of the partnership, the researchers had difficulties working with each other because they came from different disciplines. For example, the science teacher said:

“I am worried because I am a little afraid of talking to different people outside my education field. I also worry about STEM teaching by myself because I expect that students’ solutions would require transdisciplinary efforts that are out of my expertise so it would be difficult for me to give them advice.”

It was found that the science teacher was worried about working with others from different disciplines and she was uncertain about teaching integrated STEM. The scientist and the engineer also showed some concern about working with people from the social science field. Up to this point, the science educator performed her role as a mediator who clarified STEM understanding and identified
each person’s role in the partnership. She explained that the transdisciplinary approach was the integration perspective in STEM for this research. Each person from the different disciplines needed to collaborate in planning, doing, and reflecting on STEM teaching practices. Besides her concerns about the nature of STEM, she was also worried about project management. Because this project involved people from different fields, it might be difficult for the team to manage their schedules to come to the class together.

3.1.2. Create STEM lesson plans for a PM 2.5 detector. As the diversity of S-T-E-M disciplines. The researchers needed to arrive at a consensus for each of their roles. The role of a science teacher was to give information about student backgrounds and schedules. She also organized timelines and provided learning materials and resources. She had an important role as the primary teacher for STEM lessons. The science educator also took the focal role of mediator to facilitate STEM understanding of the partnership. The scientist shared her views on designing the activities to promote scientific conceptions and inquiry related to STEM. She also performed as a facilitator during STEM activities to suggest and encourage students with solving problems and creating prototypes based on scientific concepts. The engineer was the most popular person among the students for giving them guidance about how solutions are related to engineering or technology. Her key contribution to this research was to provide the perspective of engineering and technology to the partnership and students about the lessons. Because engineering is not a discipline in the Thai curriculum, engineering was a key person of the partnership in terms of analysing and integrating engineering into science, technology, and mathematics. Finally, the mathematics educator had the important role of analysing the mathematics standards in the Thai curriculum and of integrating mathematics into science, technology, and engineering. The partnership had meetings for lesson planning and for finding research on STEM education, discussing our STEM understanding, and designing STEM activities. The STEM learning unit was presented to the experts, revised based on the experts’ suggestions, and implemented.

3.1.3. Team teaching. The science teacher was the primary teacher for this lesson, while the others took part in the class as co-teachers and participant observers. We arranged the roles of each person in the partnership based on their discipline. For example, the engineer helped the students to explain how laser beams worked and how the airflow system in the engine operated. Students also absorbed how the scientist and the engineer worked together and how they combined their different perspectives during work and in discussions with the students. Moreover, we found that we could promote students’ understanding of each discipline and STEM understanding. For example, the mathematics educator said, “We [researchers] are different; so we can help each other with STEM teaching. During the STEM activity, I saw that the students had some misunderstanding about the calculations for magnification in a microscope. I helped the students to solve their misunderstanding, and I suggested that the partnership incorporate some fundamental mathematical concepts on calculations into the unit. The partnership was responsible for correcting, giving feedback, and grading the students’ work. We developed and shared the criteria for assessing the students’ assignments.”

3.1.4. Reflecting on Our Teaching. After teaching the course, we reflected on our experience in terms of students’ STEM understanding, our roles in the partnership, and how to prepare for the next lesson. The partnership reflected on their teaching and identified the advantages of STEM partnership for promoting the students’ STEM learning. For example, the engineer said, “It is fun to work with this team. We are all open-minded and flexible, and we are all planning, brainstorming, and sharing our various abilities to develop the STEM unit.” The scientist concurred, saying, “Collaboration and argumentation will be the root of our success. It is good that we [researchers] come from diverse disciplines because we can share and complete each other.” Similarly, the science teacher said, “I love the way that the scientist and the engineer are teaching the unit because they have in-depth knowledge about the topic, and they can explain to the students in a way that I never could. I also like the way we
are working collaboratively. We share thoughts and opinions. With the different expertise and experience of the team members, we support each other and that helps to teach new equipment in class easier. For example, students were taught to use a camera microscope by a scientist who has experienced using it. This provides opportunities for students to learn from experts and plus helps the learning process of students and myself to be fast and easy. Otherwise, I may need to spend quite some time studying the instruction myself before teaching the class. Also, as I could not picture how we would teach in the class together, the picture of “we” are working in the class together became clearer to me when we share our availability.”

The science teacher strongly believed that she could not handle the class well if there was no support from the team members. Notably, in her opinion, because of the requirement of transdisciplinary knowledge, most schools do not have the readiness to implement STEM in class. STEM activity encouraged the students to learn from experts and learn from each other. Students’ inquiry skills were promoted during the lesson. They could search for data and solve a problem on their own. However, some students may miss opportunities to learn from other student groups when experts give feedback and guidance to each group. We saw that the students improved the project when they heard the comments their friends received. However, we had some problems regarding time management because all of us come from different institutions. Moreover, we found that we also needed to have more discussions about our individual roles in the classroom.

3.2. STEM Integration

The partnership found that we had integrated our knowledge and skills for lesson planning and teaching. We discovered that working collaboratively for STEM was better than working alone in a single discipline. Furthermore, the STEM integration was displayed not only in the way our partnership worked but also in the student’s learning.

Most students felt that the STEM lesson helped them to understand better and that STEM activities challenged them to use more than one discipline to solve common problems or to create something. Most students could understand and apply STEM to solve real-world problems and to design new things. We did not expect the students to demarcate which knowledge and skills they were using—whether it was science or technology or engineering or mathematics. However, we did encourage them to apply integrated STEM to solve a problem and create something new, which was the PM 2.5 detector. However, the students discovered for themselves that engineering was an unfamiliar discipline and the most difficult one for them. For example, as seen in figure 1, students created a PM 2.5 collecting device based on equipment for daily use, namely a balloon, a filter, and a fish flag. The students identified the knowledge they needed for designing the device, such as lifting force and the Pythagorean theorem. Furthermore, the students stated that problem solving was an essential skill to help them create the prototype.

Figure 1. Student work demonstrating the STEM integration to solve PM 2.5.
3.3. Students’ Learning
At the beginning of the lessons, there was a challenge that the Grade 12 students did not pay adequate attention to learning. Most of them were more focused on preparing themselves for the entrance examination. Some students said it would have been better if they had studied this unit in either Grade 10 or Grade 11. However, at the end of the unit, it was found that most of the students could use their creativity to design a PM 2.5 detector with an appropriate sensor. They followed the design process to solve the problem of how to detect PM 2.5 because the particles are too fine to see with the naked eye.

The students were given the required inputs to solve the problem of creating a PM 2.5 detector, and most students could improve their reasoning skills to explain how and why they created their PM 2.5 detectors. As a result, we saw a development in student’s device designs as shown in figure 2. The design was improved to adjust the airflow to make it stronger. It was designed to eliminate a problem student faced when they redesigned the first prototype.

Figure 2. First design and Second design of PM 2.5-related device.

Because of this research, their attitudes toward STEM were improved. The students loved to apply a variety of knowledge and skills from different disciplines to solve real-life problems. The feedback was that the project in this unit was fun for them and that they could apply such knowledge in their lives. Some students’ competencies and soft skills were improved during the unit, for example, interpersonal skills, communication and media, and information literacy.

4. Conclusion
From this research project, we found that we needed to have mutual understanding and shared values and goals to work as a partnership. All researchers had to participate throughout the process: in planning the lessons, teaching, and reflecting on their teaching to provide the required integration of the disciplines [14,18]. We also learned that considering we come from different disciplines, excellent interpersonal skills in building strong relationships are very important.

The STEM partnership helped us to develop many useful competencies and soft skills such as communication, collaboration, teamwork, empathy, and reflective thinking. However, there were challenges as well such as school and time management and the difficulties some teachers had with some STEM concepts and STEM pedagogy [14,18]. Moreover, the STEM information and the STEM community were required for Thai teachers.

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