Science teachers’ professional development program for designing stem integrated lesson plan

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Abstract. With the increasing focus on integrated STEM into classrooms to develop learners to meet the needs of complex societies. Thus, teacher development is required to success that point. In this study, researcher provided STEM- focused professional development (PD) program to science teachers (n = 104). Then, teachers’ artifacts were examined to display the effects of the PD program through participants’ implementations. Descriptive statistic, STEM lesson plan analysis rubric, which developed in this study and content analysis were used to consolidate the findings. According to interventions and tools, the results indicate that STEM-focused PD supports participants to design varieties of STEM lesson plans, which categorized into five distinguished groups. Moreover, the effective and successful characteristics of professional development designing for integrating STEM into classroom were proposed to be developing guidelines’ principles and the challenges of instructing STEM lesson were pointed out as well.

1. STEM in National Education Reforms

Widely accepted that increasing the quality of STEM education is viewed as an important way toward creating an informed citizenry that will benefit policy decisions at the national, regional, and local levels [1]. In 2013, Thailand officially launched STEM policy, which mainly focused on integration of STEM into science units. Many educational agencies, for example, Ministry of Science and Technology, Ministry of Education, and private sectors, have been involved to encourage and support science teachers to teaching STEM in their practices.

After few years of continuing efforts by policy makers and educators to integrate STEM into K-12 education, significant progress has been made in including STEM in some school- based science curriculums. However, based on our previous survey indicated that many teachers (29%) still have no idea about “What is STEM education?” Even some teachers who have participated in several STEM education PD programs, which provided by several organizations, still be unclear about STEM education in practice. Researcher also found that teachers tended to concern about how to integrate four disciplines, especially engineering [2,3]. Therefore, those became our research questions, which are, firstly, what are the effective strategies that should consider to be the guideline principles of designing STEM education professional development? Secondly, what are effects of a professional development experiences to teachers’ implementations?

2. The Framework of the Study

In 2014, National Academy of Engineering (NAE) and National Research Council (NRC) suggested the design of effective integrated STEM education initiatives. Three key implications are 1) integration should
be made explicit; 2) students’ knowledge in individual disciplines must be supported; and 3) more integration is not necessarily better [3]. Based on Hurley [4] notions, STEM disciplinary integration can be divided into four categories: 1) Disciplinary integration: STEM disciplines are planned and taught separately in each discipline; 2) Multidisciplinary integration: STEM disciplines are planned and taught separately and sequentially, but referring to the common theme, 3) Interdisciplinary integration: STEM disciplines are planned and taught separately through an instruction, with explicitly connected; and Transdisciplinary integration: STEM disciplines are planned and taught together in a same setting theme of situation harmoniously. That means integration can be subjectively viewed in many instruction styles [3-4]. Our prior survey indicates that emphasizing on the nature of each discipline in professional development program is required. Particularly, engineering design, because typically, engineers employ multiple approaches and no single engineering design cycle exists. However, there are fundamental characteristics central to engineering design: (a) define problem, (b) plan and develop possible solutions, and (c) test and evaluate (redesign) [3, 5].

Moreover, researcher considers aspect integrating and infusing such an appropriated science content is necessary because science connections in an engineering activity can help students to design better engineering products and outcomes [6-7]. Without science or any content connections, engineering activities can become isolated, unrelated activities that depict engineering as tinkering or craft projects [8-9]. Researcher also highlights the fact that engineers usually work for a client, and therefore, their problems and solutions are intentional in that they are addressing the needs of that client that may be one of many different points between Science and STEM teaching [10]. Researcher also emphasized on setting STEM activities in a realistic context engages and motivates students to apply their learning to real-world problems.

3. The Professional Development
To supporting development of teachers, the study design strongly focused on design process model of professional development, which can create sustainable development. If the ultimate goal of improving teacher quality is also to consequentially improve student learning, it is imperative to evaluate the impact of professional development programs on student learning.

In this study, professional development design process modified based on the model of Guskey and Loucks-Horsley [8,11]. The framework for the structure of professional development and its impact on teacher change, and on this researcher’s firm belief that student learning should be the focal point of the educational system, a model for professional development was developed figure 1 [8, 11-12]. The professional development domain with 4 main phases:

- Setting Goals Phase that immediately started by formulating STEM education goals in terms of student learning outcomes, even though there may be other parallel goals such as building teacher leadership, improving teacher retention, solving their classrooms’ problem.
- Planning Phase where the professional development practitioners developed an action plan including professional development program, related activities, and documents.
- Acting Phase when the professional development program interacts with the teachers.
- Reflection Phase is a vital part of the professional development program because it is based on the actual results of the implemented professional development program on student learning and outcomes.
During acting and reflection phase, researcher scheduled the participants for classroom observations, reflection interviews to collect data that can use to triangulate other data sources. Additionally, researcher also used other strategies to support teacher changing such as, building professional learning community (PLC) for teachers to sharing experiences, and engaging teachers to do action-research in the work group based on their own questions or practical problems to help them improve their instructions [13-14].

**Figure 1.** Professional development framework in this study.

### 3.1 Face-to-Face Workshop

A 3-Day face-to-face workshop was designed focusing on construct and develop of participants’ knowledge and skills involved STEM teaching. The focus of Day 1 was on learning about STEM education, the nature of science, engineering design to investigate ways of integrating scientific and engineering practices into their content instruction and also focused on appropriated mathematic and technology application into STEM approach.

Day 2 focused on STEM activities that teachers experienced via learning through STEM activities and focused on analyzing of STEM unit’s necessary components based on given and searched STEM units to construct their own guidelines for designing STEM lesson plan. Afterward, each teacher selected, adapted, and/or designed their own draft STEM units.

After that, researcher gave teachers one month-period for STEM lessons development and presentation on Day 3, which focused on lesson plans’ presentation (some demonstrated) and discussion to get some feedbacks, suggestions and share ideas to improve STEM lesson plan as well. At the end of Day 3, researcher together planed about unit’s preparation, implementation, and possible action research topics.

| Day | Topics | Contents                                                                 | Main Objectives                              |
|-----|--------|--------------------------------------------------------------------------|----------------------------------------------|
| Day 1 | What is the future learning and teaching should be? Why STEM is important? | • Brainstorming about future learning and teaching  
• What is Science, Inquiry, and Nature of Science (NOS)? | • 21st Century Skills  
• STEM Literacy  
• STEM definition  
• Engineering design  
• Scientific inquiry |
3.2 Action Research in the Work Group

In the study, researcher designed to support teacher development by using action research cycle. By helping participants identified and constructed their research questions during several periods in professional development program. Afterward, researcher discussed and researched to find the way to figure it out or solutions to solve the problems such as suggestions, materials, and instruments [15].

3.3 Professional Learning Community (PLC)

During planning phase, participants were periodically gathered to discuss and share about implementation issues. Firstly, which is baseline data meeting for develop professional development program (PLC-A). Then, during implementation, they reflected what they learned, acted, and developed a professional learning culture in their schools (PLC-B and C). Finally, at the end of that semester, PLC-D meeting was provided for participants to reflect and share experiences about implementation of STEM lessons and how teachers deal with challenges that they faced. Each PLC meeting focused on participants’ reflections both reflect-in and on their actions about STEM teaching in their real classrooms. In addition, researcher also used social media application, social network tool (Facebook and LINE application), to reinforce relationship and increase communication channel.

4. Research Design

This qualitative research study used content analysis and case study approach to investigate teachers’ STEM teaching as they participated in a professional development program. The main unit of analysis was the STEM lessons that teachers applied and implemented as a result of participating in the STEM-focused professional development program by using STEM lesson plan analysis rubric [16-17]. 104 in-service teachers from 38 schools participated in this program. However, for implementing, six participants were voluntary selected to study in depth including classroom observations, individual and focus group interviews and the data of the interviews were analyzed and discussed in the future report.
4.1 Data Collection
The primary data sources that were used for this study included the teachers’ reflections in all PLC meetings while focus group interviews, about STEM design guideline principles, 58 STEM lessons were shared in the lesson plan development session. During implementation, all revised lesson plans and student artifacts (for example pre-and post-survey and worksheets) were collected.

STEM lesson plans, student artifacts, pictures, audio and video records were electronically collected by researcher and by in-cooperation support from district two supervisors. In particular, each lesson plan was analyzed of types, essential components and other characteristics by using STEM lesson plan rubric for tracking quality of lesson plan development. These data provided insight into STEM lesson implementation and presented additional evidence regarding teachers’ implementation of STEM in their classrooms.

4.2 Data Analysis
Fifty-eight STEM lesson plans developed by 58 in-service teachers (from 104 participants) and other source data were collected for data analysis. Teachers had a choice to highlight STEM teaching steps, including engineering design cycle, on their final lesson plans. Individually, researchers looked systematically for the codes in the data sources [18]. Researcher coded 58 STEM lessons, which were categorized by their adherence to the coding framework.

5. Findings

5.1 STEM Integration Lesson Plans
The STEM lessons were categorized by their adherence to the coding framework as 5 categories which are problem-based/project-based lesson, science and math incorporated with engineering design lesson, engineering design-based lesson, build-and-test-only lesson, and science activity lesson (see table 2).

| Category                                    | Description                                                                 | Frequency | Percentage |
|---------------------------------------------|-----------------------------------------------------------------------------|-----------|------------|
| problem-based/project-based lesson          | The lesson focuses on problem or project-based learning incorporates through a realistic context without any connection. | 8         | 14.29      |
| science and math incorporated with engineering design lesson | The lesson addresses science and math contents incorporated with engineering design process | 22        | 39.29      |
| engineering design-based lesson             | The lesson follows an engineering design process but is missing the address of appropriated contents. | 16        | 28.57      |
| build-and-test-only lesson                  | The lesson does not follow engineering design process, including only building and testing without needing to apply content information | 6         | 10.71      |
| science activity lesson                     | The lesson is a science activity, but is missing other disciplines connection | 4         | 7.14       |

Table 2. Categories of the STEM lesson plans.

Total 58 100.00
Most of the STEM lesson plans are lack of appropriated assessment tools. There are few STEM lessons (20.68%) provided assessment instruments or explicitly mentioned about how to assess students’ learning outcomes. Most of developed lesson plans addressed about students’ learning objectives but missing the clear measurement tools. However, researcher is still working on the effect of each category in multi-dimension issues, for example, the relationship between STEM lesson selection and teachers’ perception about STEM or the effectiveness of each category to student’ learning, especially STEM literacy.

5.2 Challenges for STEM Teaching
Researcher captured the challenges that teachers reflected through individual interviews, focus group interview, and reflection meeting. During implementation, some teachers struggle with the time constraints, for example, Herbal soap design activity includes two lesson plans that last two to three weeks for this activity. Teachers concerned about standard contents that need to be covered so it effects to contents, especially science, that they can select to be in STEM lesson. The participants also shared other challenges, which are summarized in table 3.

| Challenges                               | Frequency | Percentage |
|------------------------------------------|-----------|------------|
| time demanding activity                  | 23        | 31.08      |
| real world situation                     | 9         | 12.16      |
| assessment tools                         | 10        | 13.51      |
| standard coverage                        | 11        | 14.86      |
| teachers’ content knowledge              | 9         | 12.16      |
| student’s background                     | 6         | 8.11       |
| materials and resources                  | 4         | 5.41       |
| ICT integration and usage in instruction | 2         | 2.70       |
| Total                                    | 74        | 100.00     |

6. Discussion and Implications
As STEM education continues to make its way into K-12 classrooms, it is important to ensure that researcher is preparing and developing high-quality teachers in STEM fields. Researcher found that STEM education is difficult for science teachers for several reasons. Firstly, according to applying engineering design, few teachers are knowledgeable about or comfortable with using engineering design to teach content [19]. Many teachers think engineering is new and it is too complicated to insert into science curriculum. However, engineering design can be used as a context to teach science and students can apply science knowledge and scientific reasoning to solve engineering design challenges [6-7, 20-22]. In addition, many teachers think STEM lesson is such a time demanding lesson (31.08%). Thus, researcher might need to consider of how to create or support schools to create STEM lesson plans or even STEM curriculum that can reduce instruction time and cover the standards (science, math, and others) at once.

Second, it is challenging to teach all science or math concepts through engineering design challenges. Because many teachers do not clear about engineering, design based on STEM definition itself and firstly established of engineering in instruction. Some teachers also have problem dealing with other subject area contents in order to connect them together in activities. Thus, it is hard to design real world challenges in
which students investigate science, especially some concepts such as biology and life science. Moreover, teachers think some students may not familiar with this approach (8.11%) as well.

Third, all of lesson plans in this study were adopted (34.38%) and adapted (65.62%) from several sources indicates that researcher should not only focusing on develop and prepare teachers. Meanwhile, researcher needs to encourage all stakeholders to support and develop STEM focused educative materials (such as lesson plans, and media) to be a good supportive resource for teachers. Also, the assessment of students’ learning in the vital key of teaching STEM. Teachers probably changed and improved their instruction when they see students’ learning evidence [12]. According to Shulman (2009) asserts that "...assessment is a powerful tool for raising the quality of teaching and learning. It should be used diagnostically and interactively, not as a form of autopsy" [23]. These limitations in both measurement tools and the methodologies that currently dominate educational evaluation and research are contributors to the shortfalls in STEM education because without meaningful, iterative assessments, teachers, administrators, schools, and districts are lacking critical information and direction for improvement. Thus, researches that involving STEM assessment and evaluation tools are urgently required.

According to this study, I suggest that professional development requires to explicitly assisting teachers with recognizing and implementing quality STEM integration, especially engineering design. Research expects these findings may provide guidelines for in-service teacher educators on how to introduce STEM integration in teacher preparation programs so that teachers start developing their STEM practices early on. Based on our study, research proposes that STEM-focused professional development designer should consider these following characteristics:

- Clarifying STEM instruction that including science (scientific inquiry) and engineering practices (engineering design process);
- Focusing on contents’ integration (STEM and others) and cooperating through a realistic context;
- Providing a variety of categories of STEM integrated lessons;
- Emphasizing on students’ learning outcomes including contents, skills, and attitude; and
- Providing a suitable STEM lesson guideline that teachers can learn how to select those ready-to-use lesson plans that correlate with their goals (students’ outcome).

Finally, many questions about STEM education and teacher development are remain. Thus, I have been conducting to figure out about developing teachers’ pedagogical content knowledge for teaching STEM (PCK for STEM) [24], examining the effectiveness of STEM approach to students’ learning including contents, skills, and attitude, finding evidences about effectiveness of PD strategies that affect teacher development and school management for STEM instruction.

7. References

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