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Case Studies of the Development of Science Teachers' Practices of Socio-Scientific Issue (SSI)-Based Teaching through a Professional Development Program

Sasithep Pitiporntapin[1] & Suchada Srisakuna[2]

[1] Department of Education, Faculty of Education, Kasetsart University, Bangkok, Thailand

[2] Kasetsart University Laboratory School Center for Educational Research and Development, Bangkok, Thailand

Correspondence: Sasithep Pitiporntapin, Department of Education, Faculty of Education, Kasetsart University, Bangkok, 10900 Thailand. Tel: 668-5323-2155. E-mail: fedustp@ku.ac.th

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Abstract

This research aimed to assess three case studies of in-service science teachers regarding their practices of socio-scientific issue (SSI)-based teaching as they participated in a specially developed professional development (PD) program. Data were collected throughout the PD program from group discussions, observations, interviews, and the review of documents, and they were analyzed using within-case and cross-case analysis methods. The findings showed that the PD program had positive impacts on the teachers' practices of SSI-based teaching. There were some modifications that combined their old teaching styles and SSI-based teaching; however, they attempted to link the science content within a social context in a way that motivated student ownership of learning. They modified their roles as information providers to be learning facilitators. Their students were also encouraged to employ scientific evidence-based reasoning to address the issues under discussion. The three science teachers also added questions to enhance student thinking about the application of scientific knowledge in society. At the individual level, teaching confidence and teaching enthusiasm had powerful influences on their practices of SSI-based teaching. At the school level, the amount of teaching time and the lack of experts on SSI-based teaching in the school were found to be barriers to SSI-based teaching. The results of this study contribute to the growing body of knowledge about preparing science teachers to link their science lessons to the real world, and they also provide a framework for future studies.

Keywords: teacher practices, SSI-based teaching, and professional development program

1. Introduction

Under Thai educational reform, learners are regarded as being the most important stakeholders (Office of the Education Council [OEC], 2000). The content of teaching and learning at each educational level places emphasis on knowledge about the relationship between oneself and society, science, management, conservation, and the utilization of natural resources to ensure that the environment is balanced and sustainable (Office of the National Education Commission [ONEC], 2003). Therefore, teaching is viewed as a microcosm of society that relates to reasoning about socio-scientific issues (SSIs). Due to the characteristics of these issues, they are open-ended social problems with substantive connections to science. There are also many situations that arise from these issues in which individuals are required to demonstrate their scientific literacy (Presley et al., 2013). In addition, a lack of understanding of SSIs may lead to feelings of fear, anger, and distrust towards the scientific community (Hodson, 2008).

To be successful in SSI-based teaching, teachers should perceive that their role is not to be an authoritarian in their presentation of the issues at the beginning of instruction but rather should be related to what students learn to add to their prior knowledge (Presley et al., 2013). Eastwood, Sadler, Sherwood, and Schlegel (2012) claimed that the key to successfully culminating activity is student reflection. Teachers should provide scaffolding for students to engage in practices such as argumentation, reasoning, and decision making (Presley et al., 2013). Teachers can employ teaching aids, media, and materials in SSI-based teaching, such as articles from newspapers and magazines or reports and interviews from television, to make connections between what students are learning in class and what is happening in the world (Klosterman, Sadler, & Brown, 2012). In

addition, technology can be used in a variety of ways to enhance SSI-based teaching and has the potential to be a powerful tool in providing access to relevant social issues (Evagorou, 2011). Students can use computers and the internet to obtain considerable information about SSIs. In light of the learning assessment framework, assessments should include students' higher-order thinking practices, such as analysis of scientific claims and arguments (Kolstø et al., 2006). To measure student engagement in SSI learning experiences, teachers should employ formative forms of assessment and regular feedback to promote learning (Tal & Kedmi, 2006) and should provide opportunities for students to reflect on and refine their own ideas (Sadler, 2011). In addition, at the end of a unit or topic, teachers can utilize summative assessments to identify what a student has learned, to determine the quality of the learning, and to compare their performances against specific standards (National Research Council [NRC], 2001).

The Thai educational system places too much emphasis on technical knowledge and not enough on knowledge that helps students become knowledgeable and qualified citizens (Pillay, 2002). Moreover, the learning processes do not currently relate scientific knowledge to daily life (Ngamkeeree, 2006). Although some teachers need to attend PD programs, including workshops and seminars in line with educational reform (Kitkanjanat, 1999), schools lack the experts needed for professional development in their schools (Ponvijit, 2005). These problems suggest that teachers' professional development should be vital in the current Thai context.

In professional development (PD), teachers play important roles in effective educational reform (Jurawatanaton, 2003). The quality of teachers has also been a concern of every Thai government administration from the past to present, as reflected in the National Education Act in Chapter 7 (section 52-57). This act focuses on professional development as a key component of educational reform and affects all teachers in every field, including science. The institutions responsible for the production and development of teachers, faculty, staff, and educational personnel should be ready and capable to prepare new staff and continually develop in-service personnel (ONEC, 2003). A PD program is considered an effective way to promote teachers' perceptions of teaching as well (Loucks-Horsley et al., 2003).

To cope with the aforementioned issues regarding in-service teacher practices in SSI-based teaching, the researchers employed a specially designed PD program to develop in-service science teachers' practices in SSI-based teaching. The implementation of this program should result in the development of improved SSI-based teaching.

2. Research Questions

The research questions in this study are: (1) What changes in in-service science teachers' SSI-based teaching occurred as a result of participating in the PD program? and (2) What are the factors that constrain or facilitate their SSI-based teaching practices?

3. Theoretical Framework

3.1 SSI-Based Teaching

An important characteristic of SSIs related to society is that they are controversial social issues that have a basis in science that are frequently at the frontiers of scientific knowledge. SSIs involve forming opinions; making choices at a personal or societal level; are frequently media-reported with attendant issues of presentations based on the purposes of the communicator; deal with incomplete information because of conflicting/incomplete scientific evidence and inevitably incomplete reporting; address local, national, and global dimensions with attendant political and societal frameworks; involve some cost-benefit analysis in which risk interacts with values; may involve the consideration of sustainable development; involve values and ethical reasoning; may require some understanding of probability and risk; and are frequently topical with a transient life (Ratcliffe & Grace, 2003). SSI incorporates both scientific and social knowledge and concerns (Ratcliffe & Grace, 2003). Successful teachers of SSI-based teaching can use SSIs as a useful context for learning specific science content knowledge (Sadler, Barab, & Scott, 2007). Therefore, teachers can make appropriate connections between the scientific content and other areas of science or other disciplines. Therefore, Roberts (2007) indicated that SSIs can be used to promote scientific literacy (SL) by taking into account real-life situations that are scientific in nature but are influenced by other factors, such as social, political, and ethical issues (version II of SL).

Moreover, students should also have the opportunity to learn about the nature of science (NOS) themes in the classroom (Presley et al., 2013) because NOS issues reveal that varied epistemological views influence the way in which students select and evaluate evidence and are considered to impact their pre-instructional views of SSI (Zeidler et al., 2005). Teachers also should focus on higher order practices (Presley et al., 2013), such as analyzing and interpreting data, using evidence to participate in argumentation, and collecting, evaluating, and

communicating information, which is one type of scientific literacy and the focus of the Next Generation Science Standards (NRC, 2012).

3.2 Teachers' Practices in SSI-Based Teaching

Many researchers have examined teacher practices in SSI-based teaching. For example, Sadler and Donnelly (2006) indicated that teachers might face difficulties in SSI-based planning or teaching if they believe that lesson content and science curriculum objectives are the main evaluation foci. Moreover, many examples are related to issues with scientific content in textbooks provided after the instruction, which leads to missing the purpose of SSI-based instruction (Sadler, 2011). Some teachers were found to be concerned about the unavailability of related materials, the limitations of time for SSI-based teaching (Lee, Abd-El. Khalick, & Choi, 2006), multiple ethical identities, including cultural, ethnic, religious, and gender perspectives when they discuss SSIs, and the lack of the support and confidence to discuss SSIs in their classrooms (Saunders & Renni, 2011). The teachers also perceived that they lacked guidance, pedagogical knowledge, understanding of ethical frameworks for ethical thinking, and classroom resources (Levison & Turner, 2001). Moreover, teachers often were found to lack faith in their ability to conduct lessons in which the students engage in argumentation (Newton et al., 1999). Pedretti et al. (2007) found that in the early years of teaching, many teachers were confident in teaching controversial issues, but on the other hand, they were reluctant to do so. Furthermore, many teachers tried to use mass media for students to explore SSIs, but their use of frameworks aligned with SSI-based teaching was limited (Klosterman et al., 2012). Therefore, for any change in a curriculum focus to be successful, changes in teacher perspectives and pedagogical practices are required (Bartholomew, Osborne, & Ratcliffe, 2004).

3.3 Professional Development

For success in the development of pre-service science teachers, several educators have suggested that a professional development program should relate to individual needs (Darling-Hammond & Sykes, 1999), have sufficient time and on-going professional support (Radford, 1998), and provide necessary resources (Loucks-Horsley et al., 2003). Change in their knowledge and beliefs takes time and persistence (Loucks-Horsley et al., 2003). The process of change can occur when teachers are confident about the outcomes of teaching strategies (Bell, 1998). It also occurs when they recognize a need, make plans to improve, engage in improvements, and allow time to evaluate the effectiveness of the new practices (Boling & Martin, 2005). Sikes (1992) suggested that during the change process, teachers are continually required to alter their administrative and organizational systems, pedagogy, curriculum content, resources and technology used, and assessment procedures. Loucks-Horsley et al. (2003) proposed several strategies that focus on finding ways to improve their teaching and to examine their experiences in the classroom and student learning. These strategies include action research, study groups, lesson study, case discussions, and examining students' work.

4. Research Methodology

The interpretive paradigm is the methodological perspective of this research study. This perspective attempts to understand and explain human and social realities (Crotty, 1998). To obtain a thorough understanding of the phenomenon, the researcher's interpretation in this study is important to examine how the teachers changed their perceptions of SSI-based teaching as a result of participating in the PD program as well as the factors that either constrained or facilitated their perceptions.

4.1 Context of the Study

This research study was conducted in the context of a PD program in one public school in Bangkok. This program was designed to focus on teachers' prior knowledge and on promoting the construction of new knowledge (Bell, 1998), providing situations for teacher reflections on practices (Richardson & Placier, 2001), providing a follow-up phase to monitor teachers' progress (Fetters et al., 2002), using activities in the same ways as they teach in classrooms (Loucks-Horsley et al., 2003), and using more than one strategy for development (Loucks-Horsley et al., 2003). While participating in the PD program, in-service science teachers completed various activities, such as discussion, presentation, self-reflection, observation, interviews, and sharing ideas with guest speakers. There were three parts of the activities. In part I, in-service science teachers were given an introduction to SSI-based teaching during a one-day meeting. The content in part I included: 1) the definition of SSI-based teaching; 2) the characteristics of SSI-based teaching; 3) the strategies of SSI-based teaching; and 4) the learning assessment of SSI-based teaching. In part II, examples of SSI-based teaching were demonstrated to in-service science teachers who were asked to develop their lesson plans according to SSI-based teaching. In part III, each in-service science teacher was asked to teach their developed lesson plans in their classrooms. Before the implementation in the second semester of the academic year 2015, the program was approved by three experts, including a scientist, a science educator, and an experienced teacher. The researchers acted as facilitators

who asked questions to clarify any points that the participants did not understand. Typically, the discussion lasted at least one hour per meeting.

4.2 Participants

Mana, Piti, and Mali (pseudonyms) were the three case studies who were selected to participate in the PD program to promote SSI-based teaching practices. The three cases were selected for the study based on three criteria: (1) the teachers did not have any experience in SSI-based teaching before participating in the PD program; (2) they volunteered to participate in all activities in the PD program; and (3) they intended to link their teaching content to daily life.

Case I: Mr. Mana

Mana was a 37-year-old man. He was enthusiastic about learning new things. He graduated with a bachelor's degree (Science Teaching) and a master's degree (Science Education) from one of the public universities in Bangkok. He had fifteen years of experience teaching science at the secondary level. In the academic year 2015, he taught grade 10 Biology. The number of periods per week that he taught was six, and there were around 50 students in each classroom. Most of his students were quiet and did not ask questions in the classroom, but they always asked questions personally via Line application on cellphone and wanted extra points for external motivation. To use SSIs in his classroom, he sometimes talked about SSIs with his students but did not use it as the focus of the lesson. By participating in the PD program, he wanted to learn new teaching approaches, and he thought that his students would benefit from his new teaching practices.

Case II: Mr. Piti

Piti was a 31-year-old man. He was confident about his teaching. He graduated with a bachelor's degree in Secondary Education (Biology-General Science) and a master's degree (Science Education) from one of the public universities in Bangkok. He had five years of experience teaching science at the secondary level. At the time of this study, he was responsible for teaching Biology, particularly concerning biotechnology, to non-science grade 10 students. The number of his teaching periods per week was twelve. In each classroom, there were around 13 students. Most of his students paid attention during class and liked to listen to what he taught rather than having a discussion in his classroom. He had no prior knowledge of SSI-based teaching. Therefore, he needed to participate in the PD program to try new teaching approaches in his class and also to conduct research in the future. In addition, he thought that he could develop additional skills by receiving support from the experts in the PD program.

Case III: Miss Mali

Mali was a 34-year-old woman. She was not as familiar with education as most of the other teachers at the school. She graduated with a bachelor's degree (Mechanical Engineering) and a master's degree (Elementary Education) from one of the public universities in Bangkok. She had four years of experience teaching science at the secondary level. At the time of the study, she was responsible for teaching science to grade 9 students, particularly nuclear power science. The number of her teaching periods per week was five. In each classroom, there were around 34 students. Many of them were eager to ask questions and were talkative. The reason that she participated in the PD program was because of her need to develop her teaching skills and to conduct research in the future.

4.3 Data Collection

The researchers collected data from participants by employing various methods before, during, and after participation in the PD program. Before participation in the PD program in the first semester of the academic year 2015, Mana, Piti, and Mali were asked to complete an open-ended questionnaire to determine their prior knowledge about SSI-based teaching. The questions were related to the definition of SSI-based teaching, the characteristics of SSI-based teaching, the strategies of SSI-based teaching, and learning assessments in SSI-based teaching. After that, they completed activities in two phases of the PD program during the school break of the first semester of the academic year 2015, as mentioned in the context section of the study. During each meeting, they were asked to discuss their experiences on the specific topic based on the content of each meeting. The researchers also asked each case for permission to videotape during the discussion. In addition, the researchers conducted semi-structured interviews both before and after participation in the PD program to examine the change of perceptions on SSI-based teaching. The researchers also conducted informal interviews of around 25-30 minutes to clarify some of the points that the researchers did not understand.

During the classroom observations in the second semester of academic year 2015, the three cases implemented their developed lesson plans in their classrooms. Some of them were selected to be case studies. The researchers

focused on the ways that they implemented their developed lesson plans according to SSI-based teaching in their classrooms as well as any factors that constrained or facilitated their perceptions. To avoid inaccurate interpretations, the researchers recorded contextual details in field notes, such as the names of participants, location, duration, activities, and opinions. For the document review, the in-service science teachers were asked to write journals, develop lesson plans, and complete their worksheets. They were also encouraged to explain what they wrote and expand on their thoughts and ideas if the researchers needed to clarify any of the information.

4.4 Data Analysis

The data from all research instruments were analyzed using a content analysis. The researchers collated raw data to interpret and construct categories to capture the relevant characteristics of the content. The validity of the coding was endorsed by the panel of science educators. Furthermore, four criteria for trustworthiness were included in this study, as outlined by Lincoln and Guba (1985). The researchers increased dependability by describing and explaining the assumptions and theories behind the study and how the data were collected in detail. Moreover, dependability was verified by an independent audit process of the research by education experts. For conformability, the details about the data collection, coding, and analysis were examined and reviewed by experts to provide feedback to the researchers on their points of view regarding accuracy. To achieve transferability, the researchers provided precise details about their views and practices of SSI-based teaching.

5. Findings

5.1 The Changes in In-Service Science Teachers' SSI-Based Teaching Practices Occurred as A Result of Participating in the PD Program

The teachers attempted to link science content to social contexts in a way that encouraged the students' ownership of learning

Before participating in the PD program, Mana, Piti, and Mali did not use any SSIs in their classrooms; however, Mana was aware of the need to link science content to social contexts, as he stated during the discussion at the beginning of the PD program: *"I would like to link my teaching content to social contexts because it relates to students' daily life."* He emphasized inquiry-based teaching in his classroom, as he identified in his lesson plan that *"the teacher launches a lesson by using pictures to motivate students to ask questions about animals in the kingdom of Monera. Then, students do group activities to search for answers in each learning station provided in the classroom. When students finish their searching, the representative of each group presents what they found in front of the class."* Still, based on the classroom observation, he rarely discussed social issues related to science with his students, and he said to the researcher, *"Today I did not use SSIs in my student discussion. I used only inquiry-based teaching in my class. My students worked in groups to search for information at each learning station."*

Piti demonstrated his strong belief in lecture-based teaching on the first day of the PD program, and said, *"If my students have much knowledge, they could apply knowledge in daily life later."* Consequently, Piti intended to spend most of his time in the classroom teaching scientific content to his students, as illustrated by his lesson plan: *"Students write the main concept that the teacher presents in the PPT in their notebooks."* Similarly, during the classroom observation, Piti also taught according to his lesson plan. He always explained what he presented to his students. Sometimes, he stopped and asked his students questions, and he reflected after his practice: *"I think that my lesson is not SSI-based teaching because I did not bring any situation in my class for student discussion. I tried to explain and ask questions about concepts to enhance student understanding."*

Mali advocated lecture-based teaching, and she claimed before participating in the PD program: *"I used to learn with this teaching approach from my teacher. I understood what teachers taught easily, so I am quite sure that my students will understand what I teach, too."* During the classroom observation, her students always listened to her explanations of concepts before she allowed them to do step-by-step activities. Consequently, she rarely linked her lessons to any social context. This belief was confirmed in her journal entries: *"I do believe that teachers have to teach scientific knowledge to students."*

After participating in the PD program, all three teachers provided more opportunities for students to link their learning content to a social context. For example, in the case of Mana, he introduced an SSI about the red tide phenomenon, which was about a group of local people who sold fish in the market that had died because of this phenomenon in the Kingdom of Protista. In his lesson plan, it was stated that *"the teacher showed pictures of red tide phenomenon and told the students about the conflict in the community concerning the sale of dead fish to*

people. Then, the teacher asked the students to search for information about which group of people in Protista caused this phenomenon." During the classroom observation, his students not only had the chance to discuss and search for information, but they also role-played as stakeholders of society, such as marine scientists, the deputy chief executive of the sub districts administrative organization, and the Greenpeace group. The students made their claims and warrants. Moreover, Mana provided students with the opportunity to present arguments about whether or not to sell the dead fish caused by the Protista group. Finally, Mana reflected in his journal entry after teaching that his students had learned more science content related to the social context: *"My students had to share ideas as though they were marine scientists, the deputy chief executive of the sub districts administrative organization, local people, Food and Drug Administration (FDA) officers, and the Greenpeace group to local people about eating dead fish from the red tide phenomenon based on knowledge about Protista."*

Piti tried to link his teaching topic about biotechnology to a social context. He introduced issues about golden rice to his class to promote his students' understanding about genetic engineering, as illustrated by his lesson plan: *"the teacher elicited the students' prior knowledge about golden rice after showing them a picture. Students had to search for information and explain the process to make it."* During the classroom observation, he tried to motivate his students to explain the genetic engineering process related to golden rice in their own words. Moreover, at the end of his lesson, he also asked his students to make a decision regarding whether or not the government should encourage farmers to grow golden rice in their country. After his lesson, he told the researchers, *"I enjoyed teaching in this way. My students joined together to share their ideas instead of listening only to me."*

Mali also introduced an SSI about the construction of a nuclear power plant to link it to the concept of alternative energy. In her lesson plan, she focused on linking the concept of energy to social dimensions: *"Each group of students searched for information about the advantages and disadvantages of constructing a nuclear power plant in Thailand. Then, they presented their information in the classroom, and the teacher led discussions about the impact of the construction of a nuclear power plant on the environment, law, and education."* During the classroom observation, she consistently encouraged students to discuss the risks and benefits of the construction of a nuclear power plant. After her lesson, she reflected, *"I felt good when I saw my students trying to bring data, both good and bad, to support their ideas in the classroom like experts do in a real situation."*

The teachers reduced their role as information providers to be more like learning facilitators. Their students were also encouraged to use scientific evidence-based reasoning to address an issue under discussion.

Before participating in the PD program, Mana's teaching style focused on the delivery of scientific content to his students via PowerPoint presentations, and he also allowed his students to discuss some information from his presentation. After the lesson, he reflected, "*I don't have much time, so using PowerPoint presentations is a convenient way to teach. Students can learn many concepts in a short time."* In the same way, Piti focused on presentations and asked his students questions about what he taught via PowerPoint. In addition, he behaved as a tutor who always asked students to jot down new technical terms in their notebooks: *"Students! This term is very important for you, so you should jot down notes in your note book…This information is always on the examination. You should underline it, and don't forget."* In contrast, Mali allowed students to do hands-on activities related to electricity according to the lab directions in the textbook, but her students did not have many opportunities to discuss what they had learned. Because of the limitation of time at the end of her class, she had to conclude the lesson for her students. She reflected to the researchers, *"Time is too short for discussions! So I have to hurry to conclude the concept for my students."*

For practice with SSI-based teaching, Mana provided opportunities for his students to use scientific evidence-based reasoning to address the issue regarding whether or not to sell the dead fish affected by the red tide phenomenon. During the lesson, he asked his students to discuss the issue based on scientific evidence rather than emotion. He stated in his journal entry: *"Normally during discussion, my students always used emotion or intuition to support their claim. To cope with this problem, I designed a worksheet and activities in which my students had to use scientific evidence to support their ideas about the SSI."*

Piti served more as a learning facilitator than before because he was aware of the value of student participation in the learning processes. During a discussion in the PD program, he said, *"If students meaningfully engage in learning activities that are linked to real life, they will understand the concept easily."* In his classroom, he asked his students to search for data to support their ideas. He stated, *"At the beginning, I felt uncomfortable teaching because I tried to use questions to motivate them to discuss with reasoning. As a result, my students increasingly used scientific evidence to support their ideas, so I was pleased and understood the role of a learning facilitator."*

In the case of Mali, she also changed her role to be a moderator in student discussions rather than a knowledge provider. She identified her role in her lesson plan: *"Students worked in groups to write down their ideas about the construction of a nuclear power plant, and the teacher walked around the classroom to facilitate their group work."* During her lessons, she provided students with the opportunity to share their ideas, and she used questions to lead her students to the main scientific concepts. She seemed to be happy about student participation during her lessons, and she said, *"I am confused about student learning. I have always thought that students have to receive knowledge only from the teacher. Now I am happy to see my students use scientific evidence-based reasoning to address the issues about the construction of a nuclear power plant during a discussion."*

The teachers used additional questions to enhance student thinking about the application of scientific knowledge in various aspects of society.

As mentioned, Mana, Piti, and Mali focused their teaching on content knowledge. In the case of Mana, when he taught students about the Kingdom of Monera, he used questions to probe his students' understanding of the concept being taught rather than enhancing student thinking about the application of scientific knowledge in various aspects of society. In his lesson plan, he stated, *"Students answered the questions about which group the living things that they saw in pictures of Monera belonged to."* During his lesson, he asked his students the same type of questions. He reflected, *"I always used questions to examine my students' prior knowledge and to link it to my teaching content. The types of questions that I used were comparative questions, such as 'what are the differences between animals in this kingdom when compared to other kingdoms?'"* Similarly, Piti taught concepts about types of flowers. He also asked his students guiding questions to enhance his students' understanding of the concept, which was observed both in his lesson plans and his practices. For example, he asked, *"It's an incomplete flower, isn't it? ... because it doesn't have a pistil. Some flowers have only a pistil, don't they?"* Similarly, Mali focused on asking questions about content knowledge. Moreover, her lesson plans were adapted from the teacher's manual, which also focused on student understanding, and she indicated in her lesson plan that *"students have to answer questions about electricity 1) what is voltage? 2) what is electrical resistance? and 3) what is electrical current?"* In practice, she always used guided questions for her students. In a journal entry, she wrote: *"I used guided question according to the teacher's manual that related to the examination of student understanding of the scientific concept."*

Regarding changes in practices, Mana used questions related to social aspects, as illustrated in his lesson plan: "*Students link their understanding about animals in the Kingdom of Protista to society by answering the teacher's questions, such as 'Who will be concerned about the conflict of selling dead fish from the red tide phenomenon to people?'"* Similarly, he asked his students *"to reflect about what people should or should not do in society about the SSI or whether there are some people who have different ideas about how they deal with this."* These questions showed that he attempted to link his lesson to society. In the case of Piti, he used more questions that linked the learning concept to a real-life situation. His questions focused on the risks and benefits of eating golden rice as well as the law related to the issue of golden rice, and during a lesson, he asked, *"Are there any effects on people's health due to consuming golden rice for a long time? Do you agree with the law about GMOs in Thailand?"* Mali asked questions to encourage her students to apply knowledge when answering her questions about the appropriateness of the construction of a nuclear power plant in Thailand. Her lesson plan included the question: *"What are the effects of the construction of a nuclear power plant on Thai society?"* In practice, her students also had an opportunity to ask questions and discuss the topic together with Mali. She stated after teaching, *"My students always asked each other questions. The questions were interesting. I also used questions to motivate students to search for information."*

5.2 The Factors That Constrained or Facilitated SSI-Based Teaching Practices

There are four factors that could be divided into individual-level and school-level factors. They have the potential to influence the SSI-based teaching practices of the three case studies.

At the individual level, teaching confidence and teaching enthusiasm had significant influences on SSI-based teaching practices.

Before participating in the PD program, Mali did not feel confident using SSI-based teaching in the classroom because she did not have any experience. In addition, Mali did not graduate with a bachelor's degree in the field of education. She seemed to express concern about her teaching in her lesson plan, as she stated, *"I am not confident about teaching because I graduated in the field of Mechanical Engineering. During my experiences earning a master degree's in Education, I hardly ever created my own lesson plans. I focused on doing research. Up to now, I have only taught science for a few years."* In contrast, Mana and Piti graduated with both bachelor's

degrees and master's degrees in education. Therefore, they seemed to be more confident in planning their SSI-based lessons than Mali; however, Mana expressed concern as to whether his lesson plan was SSI-based teaching or not. Therefore, he always asked the researcher for suggestions. Finally, he increased his confidence in SSI-based teaching, and he stated, "*After participating in the first phase of this PD program, I was quite confident, but I needed more confidence when I designed the lesson plans and taught them, so I called the researcher to get some advice. Consequently, I found that some parts of my lesson were not based on SSI-based teaching, so I had to revise it."* For Piti, his master thesis was related to SSI-based teaching about scientific explanations, so he could adapt his knowledge about scientific explanation to his SSI-based teaching. He said, *"I did my MS thesis about scientific explanation, which I applied in my activities for students to create their scientific explanations about their claims related to GMOs."*

Regarding their enthusiasm to teach**,** Mana was always actively involved. He continuously asked questions during the PD program to apply the knowledge in his class. He tried to search for information about SSIs using various search engines to create his lesson plan based on SSI-based teaching, which made his lesson more effective. He reflected, *"My SSI-based teaching is effective because I always ask the expert to get some advice about my lesson plan and teaching. I think that the more advice I get, the more I improve my practices."* In the case of Piti, he also tried to create an SSI-based lesson plan by himself. In addition, he also needed to do research along with his teaching, and he said, *"I want to learn more about SSI-based teaching because I want to create unit plans on other topics and do classroom action research on SSI-based teaching."* Mali seemed to lack confidence, but she was quite enthusiastic to develop and practice SSI-based teaching by herself. She always sent her lesson plans to the researcher to receive feedback. Eventually, she perceived that her SSI-based teaching had benefits for her students, and after finishing the PD program, she stated, *"My activities provided opportunities for students and teachers to discuss topics together. Moreover, students could search for information to answer their questions about SSIs."*

At the school level, the amount of teaching time and the lack of experts on SSI-based teaching in the school were found to be barriers to SSI-based teaching.

Piti and Mali were concerned about the amount of teaching time being the primary constraint when using SSI-based teaching before participating in the PD program because there were several hollidaysdays off at that time. Piti stated, *"I think that my students needed more time for discussion and argumentation. If time is limited, this teaching approach would not be different from other strategies."* In addition, Mali also pointed that because of the number of activities in this school, there was not much time for teaching and that the problem was related to school management. She stated, *"I selected several activities for my students to have direct experiences from SSI-based teaching, but there was not enough much time. Therefore, I had to modify my activities to finish all of the teaching concepts before the end of the semester."* In contrast, this factor did not significantly impact Mana because he could manage his lesson time even though there were several days off. He used social media to enhance his SSI-based teaching. He reflected, *"I used Line application to support my SSI-based teaching. I posted what my students had to do concerning the lesson during the days off. My students could ask me questions if they did not understand something."*

Due to the lack of experts, the teachers needed to develop their SSI-based teaching before participating in the PD program. SSI-based teaching had not been implemented at their school because there were no experts at their schools. This constraint was also confirmed by Mana. He stated, *"I think that experts are important in supporting the sustainability of SSI-based teaching. An expert can give essential advice to me, and I can practice in the same way as SSI-based teaching."* In the case of Piti, he also perceived that experts at the school would help him create SSI-based lessons more effectively, and he stated, *"I have just learned about SSI-based teaching. It's good to have experts to give me suggestions about creating lesson plans and teaching that save me time in accomplishing the goals of teaching."* Similarly, Mali indicated that she would feel more confident if she discussed SSI-based teaching with experts; however, she could not find an expert on SSI-based teaching in her school. She stated, *"In my school, there were no experts in SSI-based teaching. An expert could give me some advice about how to create lesson plans and how to improve activities after actual practice, and that would make me more confident."*

6. Conclusions and Discussion

As a result of participating in the PD program, the three teachers changed their teaching practices to be more in line with SSI-based teaching. All three teachers attempted to link science content to a social context in a way that motivated the students' ownership of learning, and Sadler, Barab, and Scott (2007) found that successful teachers of SSI-based teaching can use SSIs as a useful context for learning specific science content knowledge. The

findings in this study also showed that the three cases reduced their roles as information providers and behaved more like learning facilitators. Their students were also allowed to use scientific evidence-based reasoning to address issues under discussion, and Presley et al. (2013) pointed out that teachers should provide scaffolding for students to engage in practices such as argumentation, reasoning, and decision-making. In addition, the three teachers asked questions more often to enhance students' thinking about the application of scientific knowledge in various aspects of society, and Roberts (2007) indicated that SSIs can promote scientific literacy (SL) by bringing in the context of real-life situations that are scientific in nature but are influenced by other factors, such as social, political, and ethical issues (version II of SL).

There were four factors identified in this study that either constrained or facilitated SSI-based teaching practices: teaching confidence, teaching enthusiasm, the amount of teaching time**,** and the lack of experts on SSI-based teaching in schools. Regarding teaching confidence, the findings in this study confirmed the claims of Pedretti et al. (2007), who found that in early years of teaching, many teachers feel confident in teaching content related to controversial issues, though they are also reluctant to do so. The teachers with enthusiasm seemed to be more successful in their SSI-based teaching practices than those without it. Therefore, any positive changes in their practices occurred when teachers recognized a need, made plans to improve, engaged in improvements, and allowed for time to evaluate the effectiveness of the new practices (Boling & Martin, 2005). Another difficulty in SSI-based planning or teaching was that some teachers in this study also faced time limitations in their SSI-based teaching, as Lee, Abd-El. Khalick, and Choi (2006) identified in their research. Regarding the inefficiency of SSI-based teaching, the three cases also pointed out that the lack of experts on SSI-based teaching in their school hindered them. Levison and Turner (2001) also found that some teachers perceived that they lacked guidance, pedagogical knowledge, classroom resources, and had little understanding of ethical frameworks for ethical thinking.

7. Recommendations

As the changes of the three cases in this study were positive, the researchers suggest that the PD program should be implemented on a larger scale. For the continual development of SSI-based teaching in schools, there should be at least one expert in SSI-based teaching who can provide good advice regarding teaching practices. For further studies, researchers should consider whether students' learning outcomes are affected by SSI-based teaching. Moreover, researchers should investigate three cases of SSI-based teaching for other scientific concepts.

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