Chapter 10
Preparing Science Teachers to Design and Implement Socioscientific Decision Making Instruction: Researcher's and Teachers' Experiences

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Abstract Providing students with the ability to make informed socioscientific decisions is important for being a scientifically literate person in today's society. However, many teachers still have an inadequate understanding of how to support well-informed decisions through socioscientific contexts, thereby leaving their students unable to improve their decision making abilities and make effective decisions about socioscientific issues (SSI). This chapter reports the researcher's experiences of helping two elementary school in-service science teachers to construct the knowledge and skills needed for teaching socioscientific decision making (SSDM), and describes these teachers' experiences in designing and implementing such instruction. Over a period of 15 months a series of supportive activities, such as reading professional literatures, questioning and reflection, mentoring observation, microteaching, and dialogues with experienced teachers and members in a study group, were provided for the teachers to enhance their profession awareness and practices. Qualitative data were collected and analyzed. The findings showed that two case teachers demonstrated professional growth in SSDM instruction, and how a mutually supportive partnership is necessary for in-service science teachers' professional growth and development. The study contributes to the understandings of researcher's and teachers' experiences in the project that supports in-service science teachers to develop pedagogical content knowledge (PCK) to teach SSDM in terms of forming a mutual support partnership. Implications for professional development of in-service science teachers are discussed and ways forward suggested.

Keywords In-service teachers · Decision making · Professional development · Socioscientific issues

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10.1 Introduction

Cultivating students as scientifically literate citizens is still one of the universal goals of science education in the contemporary world over the last 25 years (National Research Council, 1996; OECD, 2019b). A scientifically literate person is able to make an informed and deliberate decision when they take part in public discourse about socioscientific issues [SSI] (Gresch et al., 2013; Siarova et al., 2019). These student performances and behaviors have been valued in many countries, and also serve as one of the competence indicators in science curriculum frameworks in Taiwan (Ministry of Education of R.O.C., 2018).

Many science educators advocate that SSI can contextualize students' science learning for improving their decision making competence. Therefore, integrating SSIs into science curriculum and teaching can support meaningful and authentic learning (Kinslow et al., 2019; Zeidler et al., 2019). Previous studies have indicated that most students have a few disadvantages in making socioscientific decisions. Hong and Chang (2004) found that some students were inclined to use intuition rather than weighing solutions to make decisions. This represents a lower level of decision making (Eggert & Bögeholz, 2010). Hogan (2002) suggested that students usually made a quick decision about SSI. They ignored the fact that SSIs involved multiple perspectives, only narrowly considering one or two perspectives about SSI. Moreover, a few students lacked knowledge to develop criteria to select one of the alternatives for a possible solution (Papadouris & Constantions, 2010). Therefore, it is necessary for the teachers to enhance students' decision making (DM) abilities through appropriate SSI teaching.

However, before teachers can help students to develop their DM abilities through SSI teaching, the critical questions involved are: Are teachers fully equipped with the prerequisite knowledge and pedagogy to do it? Do they prepare well for teaching decision making in SSI contexts? Do they have sufficient understanding of how to design and implement SSI instruction? The current literature on SSI teaching would suggest that most science teachers do not have these competencies. The inclusion of SSI in the classroom is a challenge for science teachers. Hancock et al. (2019) pointed out that science teachers received little guidance and assistance in selecting and teaching SSIs. Some surveys of different countries have indicated inadequate help for science teachers to supporting them to teach SSI in class (EI Arbid & Tairab, 2020; Lee et al., 2006; Nida et al., 2020). A survey by Tidemand and Nielsen (2017) reveled that in-service science teachers were inclined to reduce SSI teaching to the introduction of scientific or factual knowledge instead of engaging students in DM involving discussion and resolution of controversy.

The science education community in Taiwan has encountered a similar situation, especially for in-service elementary school science teachers who have had few professional development opportunities to be educated for teaching SSI or teaching DM through socioscientific contexts when they were in their preparatory teacher program. Furthermore, SSI and DM has not yet formally appeared in the elementary school natural sciences curriculum and textbooks. Therefore, SSI and DM are relatively alien to most elementary science teachers in Taiwan. It is not surprising that most of them lack the knowledge and skills to teach SSI focusing on DM for students. This is why more research and development are needed to understand how to support in-service science teachers in developing pedagogical knowledge and instructional practices in teaching DM in an SSI context.

10.2 Purpose

This case study aimed at reporting how the researcher helped two elementary in-service science teachers to construct their knowledge and skills about teaching SSDM, and describes the two case teachers' experiences in the design and implementation of SSDM.

10.3 Literature Review

10.3.1 SSI Instruction Focusing on Enhancing Students' DM

An SSI is an authentic and real-world event, usually caused by the advancements of science and technology in today's society, such as genetically modified organisms, the utility of nuclear power, or radiation from cell phones. It often involves global, regional, or local issues in which conflicts happen among interest groups who have different perspectives about and solutions for the problematic issues associated with it (Levinson, 2006). Due to the nature of SSIs—controversial, ill-structured, value-laden, cross-disciplinary involving open-ended discussions (Zeidler, 2014)—many studies have advocated that integrating SSIs into science instruction and curriculum can bring students a lot of benefits for science learning, such as acquiring scientific concepts and knowledge (e.g., Sadler et al., 2016), understanding the nature of science (e.g., Estwood et al., 2012), developing moral sensitivity (e.g., Fowler et al., 2009; Westbrook & Breiner, 2019), argumentation (e.g., Lin & Mintzes, 2010; Nam & Chen, 2017), and decision making skills and competences (e.g., Garrecht et al., 2020; Hsu & Lin, 2017). In order to focus on what learning outcomes a science teacher wants students to achieve, the teacher has to consider what purpose, scope, and teaching strategies to adopt and what prior knowledge and abilities students have, while deciding how to design and implement an SSI. It is critical that a science teacher should avoid letting students feel a SSI is too difficult to learn to reduce the chance that they will give up on learning it. This is especially important for elementary students with limited knowledge and abilities.

SSI teaching should engage students in DM that is an important ability for negotiating SSI. In the practice of DM, students are expected to experience, elaborate, and follow a systematic process for rational thinking (Edelson et al., 2006). Ratcliffe (1997) indicated that making a rational decision in SSI involves several processes, including: identify a problem; develop possible solutions; formulate criteria for evaluating solutions; making a decision; and reflecting on the whole process. Fang et al. (2019) on the basis of a literature review suggested that SSDM consists of three phases. Phase one includes recognizing a problem and analyzing the information to find possible solutions. Phase two involves constructing criteria and strategies to assess different solutions. The DM strategy could be compensatory and noncompensatory. Eggert and Bögeholz (2010) described the compensatory strategy is to evaluate the advantages and disadvantages of each option in terms of decision criteria, then weigh and filter out the options. The noncompensatory strategy is to directly delete the options that do not match the criteria favored by the decision makers. The compensatory strategy is more elaborate than the noncompensatory strategy, but the noncompensatory strategy can reduce the number of options, such that there remain fewer options to choose from making it relatively more efficient (Böttcher & Meisert, 2013). Phase three puts emphasis on the review of and reflection on the DM process, in order to make more deliberate and better quality decisions.

10.3.2 The Problems for Teaching SSDM

Undoubtedly, in-service science teachers have to be effectively empowered by self-learning or other supports for teaching SSDM if they have no experiences on which to implement it. Previous studies have shown that there are many challenges hindering in-service science teachers' implementation of SSI instruction or DM. The first is that they are not familiar with SSIs, SSI instruction, the DM process, or DM strategies (Foulk et al., 2020). Nielsen (2020) pointed out that many in-service science teachers have limited content knowledge (CK) about these topics, which are new knowledge to them. Without appropriate CK, even if they have rich pedagogical knowledge (PK), they still are not able to form the needed PCK for implementation of SSDM instruction. Second, most in-service science teachers lack confidence to teach controversial issues they are unfamiliar with, even if they have constructed some of the CK and PK about SSI and DM (Saunders & Rennie, 2013). Most of these teachers still need supports from others to help them build confidence in teaching unfamiliar topics; especially if they lack this kind of experience. Third, many in-service science teachers have always struggled with the limitation of class time because of overloaded curriculum (Hammond et al., 2019). Many of them spend most of the class time on teaching science knowledge and skills that the school curriculum requires. If SSI or DM are not included in the textbook, it will lack priority and will be an extra load for them to teach.

Another problem is limited available activities for SSI or DM teaching (Kara, 2012). Although to design and develop activities regarding SSI or DM is one of science teachers' professional responsibilities, it requires time to find relevant materials to tailor and organize resources into a teaching unit. If there are teaching activities or units accessible to in-service science teachers, it would increase their willingness and motivation to implement SSDM in their science class.

10.3.3 The Approaches of Professional Development for In-Service Science Teachers

Continuous professional development (PD) can act as a catalyst for helping science teachers to update their understandings and skills on new issues and content, make better work efficacy, and deal with more work challenges (National Academies of Sciences et al., 2015). In-service science teachers need to have the opportunity for PD and advanced qualification graduate programs, in which they are able to engage in workshops and formal courses to enhance their CK, PK, and PCK. In formal courses, microteaching is one of the important strategies used for science teachers to improve their PCK (Boz & Belge-Can, 2020). They should be encouraged to join educational conferences, seminars, or visits to other schools to observe model teachers' teaching to revise their practices. Workshops and lectures focused on isolated simple tasks have been critiqued as having inadequate effects on teachers' PD (Flint et al., 2011), because PD should be a continuous process instead of only an event (Harwell, 2003). However, these activities can do a reasonable job of building CK and PK. In addition, authentic teaching is really needed for in-service science teachers to address PCK through reflection-on-action (post-teaching discussions and self-reflection), reflection-in-action (high level professional awareness, evaluation, and practices) and reflection for further action (Iqbal, 2017; Mälkki & Lindblom-Ylänne, 2012).

Another pathway of PD is to collaborate with science educators or university professors and join their curriculum and research projects, in which a teaching and collaborative partnership would be formed between practicing science teachers and experts. This kind of professional learning community enables sharing of common values and beliefs for all participants, and can offer deeper level teaching supports and research-based feedback (Jordan et al., 2013). Other informal approaches, such as to actively read articles published in educational magazines or on the internet, to engage in hearing other science teachers' experiences of implementation and sharing ideas with experienced science teachers, or forming a discourse network of teachers or a learning community, can provide opportunities for in-service science teachers to improve their PCK and classroom practices (Evans, 2019).

No matter what approaches in-service science teachers choose, the most important feature is whether the professional activities, courses, or programs provide a better quality of support for teachers' PD, whether these approaches meet the teachers' need for solving the problems and improving instructional practices, and whether they allow in-service teachers to feel satisfied and meaningfully engaged. The Organization for Economic Cooperation and Development [OECD] (2019a) pointed out that supportive activities for improving teachers' PD should be consistent with those they will apply to students, are expected to foster teachers' understanding of the relationship of research-theory-practice, and help them gain more confidence to face the challenges and solve problems occurring in the classroom. Specifically, if in-service science teachers experience professional benefits from these formal or informal activities, then they will be satisfied through gaining more confidence and abilities in teaching (Maeng et al., 2020; Murphy et al., 2007).

10.4 Research Questions

Two elementary school science teachers were invited to join the project that helped in-service teachers construct knowledge and skills about teaching SSDM. They formed a partnership with the researcher and three pre-service teachers. Two major research questions were formulated in this study:

- To what extent did the two case teachers experience professional growth in CK and PK after they joined the project?
- What experiences did the two case teachers have while engaging in designing and implementing SSDM?

10.5 Methodology

This case study of two elementary school science teachers specifically reported for their experiences subsequent to being invited to join the researcher's project of teacher PD. This focused on building the partnerships between the researcher and science teachers, and on helping the science teachers to implement SSDM teaching. The qualitative data were collected to reveal how the supportive activities the researcher provided assisted the teachers to construct their CK and PK to form PCK for the SSI implementation, and what consideration and adjustments they made during the preparation, design, and implementation phase.

10.5.1 The Participants and Contexts

The cases, Wu-I and Li-Chin (anonymized), are two female in-service elementary teachers with substantial teaching experience in science (16 and 13 years respectively). Both teachers had masters degrees in science education before they were invited to join this study that aimed at fostering in-service science teachers' PD in SSI teaching, with which they were not familiar.

Before these teachers agreed to be participants in this study, we met in a workshop about argumentation instruction that the researcher hosted several years earlier. They had expressed their interest in teaching SSI, but did not know how to do it. Their willingness, motivation, and attitude towards learning new knowledge and skills were strong and impressive. These attributes were why the author decided to invite them to be the participants of this study.

The two case teachers' self-reports of their teaching practices indicated a variety of classroom strategies. They suggested that in addition to doing experiments in terms of an inquiry approach, they also adopted lecture, questioning, and group or whole class discussion in their science classes.

The researcher formed a collaborative partnership with two case teachers and three pre-service teachers (graduate students) for conducting a project of teacher PD, in which all of the participants were required to design a SSI unit, and the two case teachers then implemented this SSI lesson plan in their science class. Only the two case teachers' data are presented in this chapter.

10.5.2 The Research-Based Activities for Participant Teachers

The project of PD for in-service teachers in SSI instruction for enhancing students' DM abilities was conducted in three phases, which consisted of the preparation phase, design phase, and implementation phase. Brief information about the three phases, including purpose, supportive activities, and time, are shown in Table 10.1.

Table 10.1 Purpose, supportive activities, and time allotments in the three phases of the PD

	Preparation phase	Design phase	Implementation phase
Purposes	Help teachers construct knowledge and skills about SSI, SSI instruction, DM process	Help teachers to design and improve their lesson plan	Teachers' implementation of lesson plan
Supportive Activities	• Reading and discussion of the position and empirical papers • Reflection on what I have learned	• Mentoring observation • Talks with two experienced teachers • Presenting the lesson plan • Microteaching • Reflection on improvements in lesson plan	• Implementation of lesson plan • Reflection on teaching practice
The period of time	Eight months	Five months	Two months

During the ‘Preparation phase’, the researcher, two case teachers, and three graduate students met together every two or three weeks, an average of two hours each time. We read and discussed a series of empirical and position papers regarding SSI, SSI instruction, DM, and DM strategies that the author provided for all the members. This phase helped all of the participants construct knowledge and skills in SSI and DM. Because paper-reading work and discussions were time consuming and the researcher did not want to put the case teachers under pressure, this phase lasted eight months.

The second phase was the ‘Design phase’ consisting of planning, evaluation, and reflection, in which the two case teachers and three graduate students were asked to individually design a SSI teaching unit that focused on improving students’ skills in making decisions. Before they designed their SSI unit, we discussed the factors influencing the teachers’ teaching or students’ learning in a SSI context. It reminded the teachers to think over the conditions of the following implementation phase. During the period of the five-month design phase, the researcher arranged for the participants to talk to a mentor and observed his SSI teaching. This mentor is an elementary science teacher with 25 years of teaching experience, and is a member of a local teacher guidance group in science education. He has designed and integrated SSI modules into his science class and attempted to enhance his students’ argumentation, DM, and evidence evaluation skills over time. Subsequently, the author invited two experienced science teachers to share their experiences of SSI teaching with the five participants, and to exchange ideas of design and implementation with each other.

After the teachers finished their design of SSI teaching, they then presented their lesson plan to the other members in the meeting. We then discussed the advantages and disadvantages of the teaching plan, and gave suggestions to the teacher for revising it. The follow-up microteaching was conducted, and each teacher briefly practiced teaching, then received feedback from the other participants and the researcher. The feedback included aspects of questioning, teaching representation, strategies, and sequence.

The third phase is the ‘Implementation phase’, in which two teachers implemented their designed SSDM instruction that extended from prescribed units of the school science curriculum in their science class, one hour each week, lasting in total four to five weeks, respectively. During the implementation, they shared teaching situations and problems with the researcher and the other teachers every two weeks, and then reflected on the teaching to make improvements. We also informally talked to each other by using APP Line or writing emails. After the end of this phase, we met regularly to reflect on and discuss the whole process of SSI teaching.

10.5.3 Data Collection and Analysis

Data included two teachers’ concept maps collected at the beginning of the preparation phase and the end of design phase, several retrospective interviews (individual and group), teachers’ reflective journals and lesson plans; dialogues in the meetings, and teacher-student talk in the classroom. Tape recordings of interviews, dialogues, and talk were transcribed. Then, each case teacher's two concept maps were compared to find the differences, categorized under CK or PK. The results represented two case teachers' knowledge construction about SSI instruction that focused on scaffolding students to learn how to make SSI decisions deliberately. Meanwhile, iterative constant comparison and inductive content analysis of transcripts, reflective journals, and lesson plans were utilized to identify the themes of their experiences in the three phases. The emergent themes included knowledge construction, selection of SSI and teaching strategies, the influence of supportive activities, successful experiences, and reflection on professional growth. These revealed the two case teachers' considerations and reflections in supportive activities during the period of three phases.

10.6 Findings

The results are organized to firstly present the two case teachers' knowledge construction and change concerning SSI teaching, followed by the teachers' consideration and experiences in unit design and the influence of supportive activities on teachers' implementation of SSDM. Finally, the two teachers' reflection on the process of teaching and professional growth are presented.

10.6.1 Preparation Phase

10.6.1.1 Prior Knowledge About SSI Instruction and DM

The two case teachers demonstrated their prior knowledge about SSI instruction and DM in the concept maps (Figs. 10.1 and 10.2) prepared during the first phase of the study, which indicated what CK and PK about SSI instruction they already have. The concept maps of Wu-I and Li-Chin respectively showed a few concepts and links that include specific SSI situations (zoo construction, petrochemical industry, energy utility, importation of exotic species, and construction of nuclear power plants) and two or three teaching strategies (discussion, role play, debate, and consensus vote), but lacked CK and PK about DM process.

10.6.1.2 The Process of Knowledge Construction

While reading papers, we only focused on the three parts of each paper—the rationale, the teaching design, and assessment, which would give the teachers an approximate picture of designing a SSI unit. The most important aim is that they could construct knowledge about SSI, SSI teaching, DM process, and strategies.

Fig. 10.1 Wu-I's concept map at the beginning of preparation phase

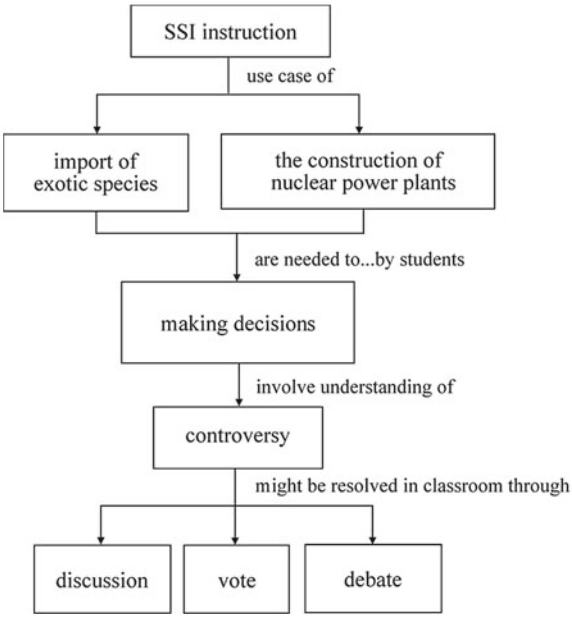

Fig. 10.2 Li-Chin's concept map at the beginning of preparation phase

During each PD meeting, one of the participants was responsible for presenting the outline of a paper and leading discussion of it. The researcher would help the teachers to elicit what they did not understand. Then we discussed the advantage and disadvantage of the design of SSI teaching in each paper, and considered if it was appropriate for Taiwanese science classes. If not, possible adjustments were discussed. This preparation phase required that the two case teachers devote effort to learn CK and PK evident in their concept maps. The preparation process stressed to them the practical aspects for the design of SSI teaching as illustrated in the following:

Wu-I [WI]: One cannot make bricks without straw. I am sure I lack a lot of content or pedagogical knowledge about SSI instruction and DM at the beginning. I became a learner and followed the pace of the study group to read and discuss papers. It really benefits me a lot for following task. [Interview]

Li-Chin [LC]: I liked the discussion atmosphere in each meeting…I also like the analysis of advantages and disadvantages of the teaching design showed in each paper. It reminded me of what points I can pay attention to in designing my teaching. [Reflective journal]

10.6.2 Design Phase

10.6.2.1 Knowledge Construction About SSDM Instruction

The case teachers' concept maps produced at the end of the design phase revealed relatively more complexity (Figs. 10.3 and 10.4) than those produced in the preparation phase. The concept maps and the comparison to the earlier concept maps showed

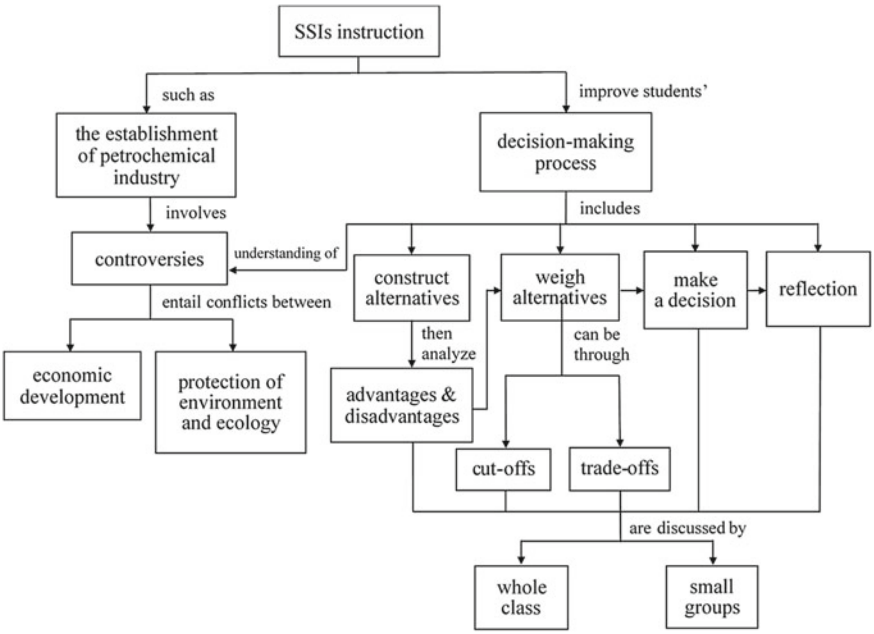

Fig. 10.3 Wu-I's concept map at the end of design phase

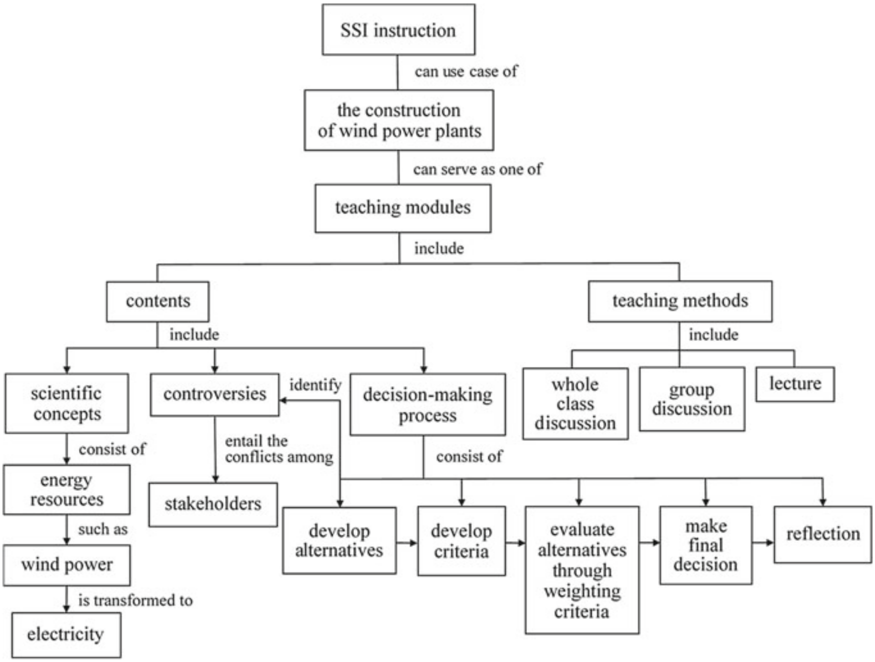

Fig. 10.4 Li-Chin's concept map at the end of design phase

that they not only have constructed more CK and PK about SSI teaching, but also have CK and PK about DM process and teaching strategies that did not appear in the earlier concept maps. Inspection of these concept maps revealed that these two teachers had many more concept nodes and some linkages between SSI attributes and DM attributes. However, the PK nodes are still limited and somewhat isolated for the CK nodes, which likely limited the teachers' insights into the combined understanding of CK and PK as foundations for later development of PCK about SSI and DM. The teachers' statements about their growth and understanding of SSI and DM support the claims flowing from the analysis of the concept maps.

LC: Now I understood DM process and strategies, and how SSI teaching can benefit students. These are really new to me … If there were no reading and discussion activities, I [would] have no idea about this knowledge. [Interview]

WI: The readings broadened my understanding of SSI, SSI teaching, DM and DM strategies…cut-offs and trade-offs … That is why I am able to draw down more concepts, relationships and cross-links in the second concept map. [Interview]

10.6.2.2 Select SSI and Teaching Strategies

Both case teachers indicated that it was possible to overcome the limitation of class time and to address students' motivation towards learning SSI by extending the unit of the school science curriculum and connecting it to what happens in the lives or surroundings of their students. Hence, Wu-I chose ‘the establishment of petrochemical industry’ [EPI], which could be extended from the unit ‘Environment and Ecology’ at grade six. Li-Chin selected ‘the construction of wind power plants’ [CWPP], which could be extended from the unit ‘All Kinds of Energy’ at grade five. Both SSIs are relevant to students’ lives.

WI: One of advantages is to make use of the scientific knowledge and topic background introduced in the unit of science curriculum to serve as a bridge to SSDM teaching …’The establishment of petrochemical industry’ had even been an issue several years ago in Taiwan. The selected location of it was near my school. [Interview]

LC: Many wind power mills have been set up in the neighborhood of my school. It has caused some problems in making low-frequency noise and in environmental conservation. I hoped ‘the construction of wind power plants’ could rouse the attention of students to it [this issue]. [Interview]

As for the adoption of teaching strategies, the teachers mostly considered students’ previous experiences and abilities.

WI: If I adopted a teaching strategy, such as role play, which my students are not familiar with, it would require them to spend time getting used to it. I do not think I have time to do that, even if the ‘new strategy’ allows students to better understand an SSI controversy that involves different stakeholders with different perspectives and alternatives. [Reflective journal]

LC: My students have weak abilities in evaluating information and reading comprehension. I plan to look for information that has different opinions of the SSI for students, and lead them to read through it. Then, I would let each small group discuss the advantages and disadvantages of each solution by themselves. [Interview]

Meanwhile, both of them knew their students were unfamiliar with developing criteria and weighting solutions. Therefore, based onto these reflections they decided to provide more scaffoldings and chances for their students to practice.

LC: My students did not have any experience in making decisions on SSI, not to mention to develop criteria and use criteria to weigh options. Therefore, I decided to slow down my teaching pace at this point, and provided more examples and time to them.

WI: I agree with LC. My students have the same situation as LC’s students. I plan to use buying a car or clothing to explain what criteria are, how to use them, and what cut-offs and trade-offs are. [Dialogues in meetings]

10.6.2.3 Influence of Mentoring Observation and Talking with Experienced Teachers

Two important supportive activities for the teachers are to observe their mentor's SSI teaching and talk with the other two experienced teachers. The two case teachers not only gained a lot of shared experiences, but also exchanged ideas in teaching SSI with each other.

WI: The experiences the mentor and two experienced teachers shared with me are greatly helpful for me to design and implement SSDM instruction. It stimulated me to think over what problems and difficulties my students might have and what solutions I can have. [Interview]

LC: It was really inspiring for me to implement SSDM teaching after we had the chance to observe mentor's SSI teaching, and talked with him … I know at least, it is not difficult for me to implement SSDM instruction. [Reflective journal]

10.6.2.4 The Experiences of Presenting Lesson Plan and Microteaching

The two case participants became more confident in implementing SSDM instruction after presenting their lesson plan in the PD meeting, and practicing microteaching to develop their teaching experiences. The reflections on their microteaching and the shared comments of the other PD participants help them realize that the new teaching approach was possible.

LC: Microteaching is one kind of trial and error for me. Although it is brief, it gave me a chance to practice, to increase my teaching experience. Moreover, much feedback came from the other teachers [who] also helped me to revise my teaching plan, and gave me more confidence to implement SSDM teaching. [Interview]

WI: Even as my teaching experience reaches 16 years, I still felt nervous to teach what I was not so familiar with … These supportive activities really made me become more confident to teach better in the following implementation. [Reflective journal]

10.6.3 Implementation Phase

10.6.3.1 The Successful Experiences of SSDM Implementation at the Beginning

The feedback and encouragement from the other teachers and the researcher gave the two case teachers stronger self-confidence to implement their teaching. After finishing the revisions of their lesson plans, Wu-I's and Li-Chin's SSDM instruction extended the unit from the textbook by four and five hours, respectively. At the end of the first two hours of implementing SSDM instruction, Wu-I used APP Line to message the researcher. She said:

> I never expected that my students would show more interest in discussing the controversy of EPI, but they did! After I introduced the background of EPI, and I asked them if the location of petrochemical industry was here, do they agree or disagree? They took turns speaking their opinions, including pros and cons…

Obviously, Wu-I felt a little surprised about the active and abundant replies of her students. Likewise, Li-Chin also shared her successful experiences in the meeting:

> I used a series of questions to lead students to understand the controversy of CWPP. Hereafter, I asked each small group to raise three solutions to solve the problem of low-frequency noise made from wind mills, then showed their solutions to all [the] students.

10.6.3.2 Dialogues in the Class for Developing and Weighing Criteria

The two case teachers guided students to learn the concept of 'criteria' and how to use criteria to weigh and evaluate options at the third or fourth hour of the extended instruction. They used teaching strategies, such as questioning, demonstration, or providing examples, to scaffold students to learn step by step. For example, in the third hour of Wu-I's SSDM teaching, she led the students to review and develop criteria, and learn how to use the cut-offs strategy:

WI:	Do you remember last class I asked if you want to buy a piece of clothing, what criteria would you consider?
Students [SS]:	Size, style, cost, quality, color…
WI:	Great!! If we want to buy a bicycle, then the criteria could be…
SS:	Cost, size, demand function, heavy or light.
WI:	Heavy or light, we call it …
S:	Weight.
WI:	Excellent! What you just mentioned are all criteria for buying a bicycle. Now, look at [the] blackboard, I present four styles of bicycles here, numbers 1, 2, 3, 4. And I also show their cost, color, size, weight, demand function, accessories. If I only have NT 3000 dollars, which bicycle do I not need to consider?
SS:	Number 3, 4, because the cost of them is higher than NT3000.
WI:	Right! We call this strategy 'cut-offs'. It means we use criteria to delete some options and reduce options to make [the] following decision. Let's practice one more time. If I want a small size of bicycle, the rider height is under one meter and the price is lower than NT5000. Which bicycle will we delete first?

Wu-I used examples that most of the students experience in daily life to teach the concepts of 'criteria' and 'cut-offs'. It helped students learn the concepts more easily. She explained in the interview, 'I tried to make learning of DM meaningful because I anchored the concept to their experiences'.

10.6.3.3 Reflection on the Process of Teaching and Professional Growth

At the end of the implementation phase, the two case teachers reflected on what they could revise if they had the chance to teach SSDM again. Issue selection and more time for students to discuss are the two main points mentioned by these teachers.

WI: I will change the issue to a simpler one. 'EPI' seems a little complex for grade six students. Some of them had difficult in constructing solutions to the issue or they made a naïve solution that is impossible to implement. I know it is just a practice in this teaching, but another issue may work better and give students better learning experiences. [Interview]

LC: I will give students more time to discuss. No matter the development of criteria, constructing alternative solutions, and making final a decision and reflection, all of these steps needed more time for students to think over and discuss in detail. [Interview]

The teachers also expressed a favorable experience of teaching SSDM and reflected on their gains after they joined the project. They pointed out that a mutually supportive partnership in teaching is a crucial base for professional growth for them.

LC: I enjoyed the interaction with students in SSDM teaching. If I have the opportunity, I will implement it again … Moreover, the form of teaching partnership is really special for me. We worked together and inspired each other … A supportive environment lets me feel safe and friendly to learn. Without the supports and encouragement from the study group, I think I cannot overcome the challenge alone.

WI: Each activity the researcher arranged for us is so important. It helps us to develop knowledge and abilities to design and teach SSDM … I agree with what LC said, this study group is excellent. We luckily work [well] together and happily collaborate with each other. I like this supportive partnership very much. [Interview]

10.7 Discussion and Implication

There are two supportive features of the approach to foster professional growth of in-service science teachers in the context of addressing an unfamiliar issue and planning instruction around this. The first one was a series of supportive activities, including reading papers, mentoring observation, microteaching, dialogues with experienced teachers and members of the study group, and reflection on teaching practice, that were provided by the researcher for the two case teachers that helped them construct knowledge and abilities for designing and implementing SSDM instruction. Providing supportive activities that meet teachers' need for instructional practices is one of the important principles in designing PD to enhance in-service teachers' CK and PK (OECD, 2019a). CK and PK are core elements of PCK (Shulman, 1986) that teachers need to pay most attention to while preparing for teaching (Evens et al., 2018). The different supportive activities that address teachers' needs at different phases facilitated their knowledge internalization of SSI, SSI teaching, DM process, and DM strategies as a foundation for their PCK about SSDM instruction. Moreover, among these activities, the actual implementation of unfamiliar instruction is necessary for science teachers. It gives them a chance to reflect in action, then to adjust their teaching materials and strategies in order to match the learning needs of students. Even for these experienced in-service science teachers, classroom practice still plays an important role in fostering their PD (NASEM, 2015) and helping them to build the confidence to implement the next SSDM instruction (Maeng et al., 2020). Moreover, involvement in a series of supportive reflection and feedback activities led the in-service science teachers to develop a deeper understanding for teaching SSDM, and improve the subsequent implementation (Bardach et al., 2021).

The second supportive feature was the formation of a mutually supportive group in which a collaborative partnership, and friendly and non-stressful environment were created for a period of time to facilitate PD. This learning community consisted of the researcher, two in-service science teachers, and three pre-service science teachers who engaged in learning together and learning from mutual feedback. We trusted each other to maintain the atmosphere of mutual assistance that supports teachers' PD. However, how to sustain the supportive group to continue for a longer time beyond the end of the project presents a considerable challenge for the researcher. It involves problems concerning the in-service science teachers' continued commitment, the time each participant is willing to spend, and maintaining funding to support the group to run.

To sum up, if we can create a more supportive context, including supportive activities and building collaborative partnerships, it will engage more in-service science teachers in overcoming their hesitation to teach unfamiliar issues, and then their PD will be enhanced.

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