Pedagogical and Epistemological Challenges of Pre-Service Science Teachers Teaching Socioscientific Issues

Based on the SSI-PCK Framework

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Abstract

To effectively address socioscientific issues (SSI), science teachers need to obtain a certain level of pedagogical content knowledge for SSI teaching (SSI-PCK). In this study, therefore, pre-service science teachers (PSTs) were provided an SSI teacher education program (SSI-TEP) based on the SSI-PCK framework and their development and challenges were carefully examined. Fifteen PSTs participated in the SSI-TEP over 15 weeks and had opportunities to design and implement an SSI lesson in a group. Data were collected through SSI lesson plans, fieldnotes, and group interviews. The results showed that the PSTs highly valued their SSI-TEP experience but noted several pedagogical and epistemological challenges. They were concerned about how to meet both the national science curriculum and students’ needs and how to reveal the nature of science and technology through the selected SSI scenarios. Additionally, they felt the need to obtain skills to facilitate and scaffold students’ participation. The challenges were often intertwined with SSI-PCK components.

Keywords

pre-service science teachers – socioscientific issues – SSI-PCK – SSI teaching
1 Introduction

With the rapid advancement of science and technology, unexpected social and ethical issues are constantly being reported by the media. In recent years, we have suffered from diseases due to the abuse of sterilizers, the danger of radon in beds and daily supplies, exposure to fine dust and microplastics, the construction of nuclear power plants, and other issues. Human beings have developed new science and technology with the intention of solving problems or easing discomforts in our lives. However, advances in science and technology, besides solving the original issues, have created new societal and global problems. This is the nature of science and technology in modern society (Lee & Lee, 2021; De Vries & De Vries, 2006; DiGironimo, 2011). Understanding nature would allow us to make more responsible decisions and to take action by exploring how to further the sustainable development of science, technologies, and human beings.

In Korea, the National Science Education Curriculum 2015 included messages on the necessity of socioscientific-issue (SSI) education (Ministry of Education, 2015). Specifically, one of the five core competencies that students should grow through the science curriculum is “scientific participation and life-long learning ability.” This refers to “the ability to continuously and independently learn in order to adapt to a new science technology environment while participating in decision-making processes with an emphasis on the social issues of science and technology so that one can act rationally and responsibly as a member of the community” (p. 4). Moreover, the National Science Education Curriculum 2022 further emphasized the goal of equipping students with scientific literacy as agents; that is, the ability to participate in collaboratively searching for scientific solutions on personal and societal issues and to willingly take action toward resolving the issues. Therefore, it is urgent for science teachers to understand SSI in order to enact the new ideas of the science curriculum in their teaching.

Previous studies, however, have reported many barriers that teachers often encounter when implementing SSI lessons. Zeidler et al. (2011) explained the reasons that SSI lessons require a “fundamental reconstruction” of traditional teacher-led science lessons. The concept of a fundamental reconstruction refers to various aspects of change. First, SSI lessons require changes in the type of content introduced in science classes. Whereas a traditional science class focuses on “knowledge in science,” as suggested in textbooks, SSI lessons also emphasize “knowledge about science” (Christensen, 2009). Knowledge about science involves understanding how scientific knowledge is constructed; discussing the meaning of science technology socially, politically, and economically; and
examining the effects of science technology in our lives. Furthermore, SSI lessons may handle how the development of science technology relates to human beings. Some science teachers feel pressure to include these social components in their science classes (Gray & Bryce, 2006; Kilinc, Demiral, & Kartal, 2017). Secondly, SSI lessons require a change in teachers’ epistemological beliefs about science. Many Korean teachers hold a positivist view of the nature of science regarding its inferential, social, and cultural aspects (Lee et al., 2010; Paik & Nam, 2010). However, SSI education requires a constructivist perspective, exploring the best solution through discussion and debate rather than finding a definite right answer. As such, uncertainty exists at all times in SSI lessons.

Third, the SSI perspective necessitates changes in instructional approaches. SSI lessons often utilize more progressive approaches such as debates, discussions, role playing, or student-led research. Teachers are encouraged to play the role of a metacognitive coach to assist students’ exploration rather than serving as the deliverer of information. However, many teachers who are used to teacher-directed lectures feel incompetent in implementing instructional approaches that differ from this approach (Pitpirontapin & Topcu, 2016; Saunders & Rennie, 2013; Simonneaux, 2014; Tidemand & Nielsen, 2017). Lastly, SSI lessons require changes in classroom culture. Because SSI lessons themselves are debate focused and critical, a collaborative atmosphere should be provided for students to freely discuss and argue with one another (Lee & Chung, 2013; Lee et al., 2020; Sadler, 2011). Overall, Lee et al. (2020) found tension in SSI classes because SSI lessons require changes in many of the rules that have been tacitly accepted in previous science classes, in the students’ and teachers’ roles, and in the types of classroom interactions.

For these reasons, many science educators and researchers have worked to support teachers implementing SSI lessons, but the teachers still have difficulty scaffolding students’ involvement in group work such as debates or discussions and positioning themselves between intensely conflicting opinions or to embrace opposing views (Gray & Bryce, 2006; Ekborg et al., 2013; Lee & Yang, 2019). For example, Ekborg et al. (2013) offered a teacher workshop for enhancing teachers’ understanding of SSI teaching. They guided teachers to design and implement SSI lessons using an SSI lesson manual. Similarly, Gray and Bryce provided a 1-week teacher training course focusing on bioengineering issues. Teachers participating in the above studies commonly admitted the educational potential of SSI lessons, but they still showed reluctance to address the non-scientific aspects of the issues (e.g., the social and ethical ramifications of science) in their classes. They also requested continuous support for SSI teaching. In order to supplement the limitations of the large-group training, Lee and Yang (2019) tried collaborative action research with two science teachers who
wanted to address SSIs. The two teachers also had difficulty scaffolding students’ involvement in group work such as debates or discussions and handling students’ struggles to choose between intensely conflicting views. Those studies have indicated that more specific support is necessary for science teachers to implement SSI lessons. Some researchers (e.g., Bayram-Jacobs et al., 2019; Choi & Lee, 2021; Lee, 2016, 2018; Presley et al., 2013; Sadler, 2011; Sadler et al., 2017) have proposed SSI lesson design guidelines to help teachers obtain pedagogical content knowledge (PCK) for teaching SSIs (SSI-PCK) with the expectation that such SSI-PCK frameworks and guidelines would diminish teachers’ difficulties in implementing SSI lessons and would help improve their confidence in teaching SSIs.

Therefore, in the present study, I adapted the SSI-PCK framework to design and examine the effectiveness of an SSI teacher education program (SSI-TEP; the SSI-PCK framework will be introduced in the next section). This is study follows the author’s previous one (Kwon & Lee, 2018), which focused mainly on quantitatively measuring the increase of pre-service science teachers’ (PSTs) SSI teaching efficacy through SSI-TEP. This study’s aim, however, was to see the details of changes in their understanding of and skills in SSI teaching and the challenges they encountered and overcame while attending the SSI-TEP. In Korea, PSTs normally learn about the interrelationship among science, technology, and society (STS) through methods courses, but have limited opportunities to apply SSIs into actual teaching practices. Thus, I implemented the SSI-TEP in a teaching methods course so PSTs could obtain more knowledge and skills for SSI teaching over a semester. The guiding research questions can be summarized as follows:

1. What kinds of understandings and skills did the pre-service science teachers develop through the SSI-TEP from SSI-PCK perspectives?
2. What kinds of challenges did they experience in designing and implementing SSI lessons?

2 Theoretical Framework for SSI-PCK

Previous studies on SSI teaching have reported that teachers experienced difficulties in developing SSI teaching materials, utilizing various teaching strategies, connecting to the suggested curriculum, and effectively delivering advanced knowledge of cutting-edge science and technology (Ekborg et al., 2013; Gray & Bryce, 2006; Lee et al., 2006). Because PCK is often domain or topic specific (Park & Oliver, 2008), science teachers may need to obtain a certain level of PCK, representing the nature of SSIs, to design and implement SSI
lessons (Bayram-Jacobs et al., 2019; Lee, 2016, 2018). For example, Bayram-Jacobs et al. introduced four SSI-PCK components based on the PCK model by Magnusson et al. (1999) that examined how teachers’ SSI-PCK improved and what kind of interaction types were observed among those factors. Their four components were knowledge of goals and objectives (GO), knowledge of students’ understanding of science (SU), knowledge of instructional strategies (IS), and knowledge of ways to assess students’ understanding (AS). Similarly, Han-Tosunoglu and Lederman (2021) suggested PCK-biological SSI (PCK-BSSI) and developed an instrument to measure teachers’ knowledge of subject matter, pedagogy, curriculum, student, and school to understand what teachers should know for their SSI lessons. PCK-BSSI can be considered an indicator of pre- and in-service teachers’ understanding of SSIs.

The theoretical framework of SSI-PCK applied in this study was suggested by the author of the study (Lee, 2016, 2018). The framework was developed based on the previous literature on PCK (e.g., Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1986; Tamir, 1988) and case studies of SSI teaching (e.g., Lee et al., 2010; Lee & Witz, 2009; Witz & Lee, 2009). The SSI-PCK framework is shown in Figure 1. SSI-PCK is related to content knowledge for SSIs (SSI-CK) in that a science teacher should be equipped with content knowledge
in order to teach science; namely, knowledge of cutting-edge science and technology and knowledge of the nature of science and technology. There are six components of SSI-PCK: orientation for teaching SSI (OTS), knowledge of instructional strategies for teaching SSI (KIS), knowledge of curriculum (KC), knowledge of students’ SSI learning (KSL), knowledge of assessments of SSI learning (KAS), and knowledge of learning contexts (KLC).

Orientation for teaching SSI (OTS) refers to the purposes and goals behind the introduction of SSI into a lesson, and it is the most influential component in teachers’ PCK construction (Lee & Witz, 2009; Witz & Lee, 2009). As in previous research on PCK, OTS carries out a guiding role in selecting teaching strategies, constructing and designing teaching/learning material, and conducting assessments of students’ learning (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008). Indeed, OTS has a significant effect on various components of SSI-PCK. In previous case studies of teachers who introduced SSI (e.g., Lee, 2008; Lee & Witz, 2009), individual teachers’ related experiences, faiths, value systems, and educational philosophies provided a foundation for OTS, which are naturally represented in SSI teaching. Following Magnusson et al.’s (1999) division of nine teaching orientations related to science teaching, I categorized OTS into six orientations: (a) activity-driven teaching, (b) knowledge and reasoning skills, (c) application of science in everyday life, (d) nature of science and technology, (e) citizenship, and (f) activism. Lee (2016, 2018) defined these orientations as follows: Activity-driven teaching aims to induce students’ interests and learning motivations for science lessons by introducing SSI, which can be used as a primary instructional tool or context for constructing a more student-centered environment rather than for exploring the nature of science and technology inherent in an SSI. Similarly, knowledge and reasoning skills focuses on cultivating students’ scientific knowledge as well as problem solving, decision making, argumentation, data collection, and interpretation skills through SSI. Application of science in everyday life emphasizes how science is applied in real life through SSI, which is very similar to science-technology-society (STS) approaches. The nature of science and technology orientation aims to help students perceive complexity and uncertainty while examining the social and moral connotations of science and technology, recognizing the value-laden nature of science, and understanding technology as a human endeavor. Citizenship aims to cultivate competencies and characteristics that citizens should obtain in a democratic society, including ethical and moral sensitivity, openness to diverse perspectives, critical views on science and technology, and participation in discourses on SSI. Finally, the activism orientation focuses on encouraging active and responsible participation in
solving the problems caused by science and technology. As Friedrichsen and Dana (2005) noted, the SSI teaching orientations are not mutually exclusive and are often combined in teaching (Lee, 2016, 2018).

Knowledge of instructional strategies for teaching SSI (KIS) refers to the instructional knowledge necessary for implementing SSI lessons. Unlike traditional science lessons that focus on providing definite correct answers, the nature of SSI demands that teachers be more knowledgeable on how to run a student-centered class. Knowledge of curriculum (KC) refers to familiarity with connections between the national science curriculum and an SSI, which teachers will naturally consider when introducing an SSI. Additionally, SSI are not limited to purely scientific content but involve social studies, politics, economics, technology, and engineering; therefore, it is necessary to consider their connections with other subject curriculums. Knowledge of students’ SSI learning (KSL) focuses on the characteristics of student engagement in SSI – not only the educational benefits of SSI lessons for students but also the challenges they might experience during SSI lessons based on their cognitive, psychological, and moral developmental stages. This category also includes knowledge of students’ informal reasoning patterns in SSI, which have frequently been analyzed in previous research. Such understanding of students’ viewpoints greatly affects the design of SSI teaching and learning strategies appropriate for students’ levels and characteristics. Correspondingly, many researchers (Tamir, 1988; Magnusson et al., 1999; Park & Oliver, 2008) have conceptualized knowledge of assessments of SSI learning (KAS) as a major component of PCK. It is clear that KAS is a crucial component in implementing SSI lessons, but it has been difficult to find any empirical evidence on which method is most appropriate and which targets to assess in SSI lessons. This lack of evidence is due to the newness of SSI: Teachers have not used SSI enough to view them as major assessment subjects. Even when they are introduced, teachers often consider SSI lessons special classes apart from conventional science courses, so they do not implement assessments at all (Ekborg et al., 2013). However, assessment is needed to consider how the dimensions that should be focused on and the methods can be applied in SSI lessons compare to conventional science learning. Lastly, knowledge of learning contexts (KLC) refers to the knowledge of the learning environment appropriate for teaching SSI. Few previous studies have mentioned the importance of knowledge of the context (e.g., Hashweh, 2005; Loughran et al., 2006), but KLC plays an essential role in teaching SSI because many science teachers are sensitive to how other teachers and parents in the school or the local community react to SSI classes (Presley et al., 2013). Moreover, SSI lessons often require flexibility in the school curriculum
and expanded resources such as local libraries, community centers, and organizations, further emphasizing the importance of teachers’ awareness of their surroundings.

3 Methods

3.1 Participants
Fifteen pre-service science teachers enrolled in a science method course at a women’s university located in Seoul, South Korea, voluntarily participated in the study. Following the guidelines of the IRB, I introduced the purpose of the research and benefits and obligations that they might have in the beginning of the course, and they agreed to join the study. They were mostly sophomores and their majors varied: 11 were in physics, three in biology and one in earth science. They had taken a theory course for general science teaching as a prerequisite before this course, but only two of the PSTs had had experience with designing SSI lessons in other courses. A few PSTs responded that they had had experience with taking SSI lessons in their formative school years. The PSTs participated in the SSI-TEP over 15 weeks (3 hours per week) in groups with each group consisting of 2–4 PSTs (six groups in total). They were guided to study theories of SSI education, to participate in SSI activities, and, ultimately, to design and implement SSI lessons as teachers.

3.2 Developing a Teacher Education Program for Teaching SSI (SSI-TEP)
To guide the PSTs to design and implement SSI lessons, previous literature on the SSI-PCK framework (e.g., Bayram-Jacobs et al., 2019; Han-Tosunoglu & Lederman, 2021) and SSI lesson design guidelines suggested by Sadler and his colleagues (Sadler, 2011; Presley et al., 2013; Sadler et al., 2017) was carefully reviewed. Specifically, Sadler (2011) suggested a framework for SSI-based education with four components: design, learner experience, classroom environment, and teachers. Later, Presley et al. (2013) reconstructed this framework into three categories: core aspects, classroom environment, and peripheral influences. First, core aspect includes a method of designing SSI classes (e.g., how to introduce a given SSI and how to provide scaffolding for students to think higher), learners’ educational experience through SSI lessons (e.g., reasoning, argumentation, and decision-making), and teachers’ knowledge, skills, and attitudes for SSI teaching. Second, the classroom environment includes positive expectations for student participation, a collaborative and interactive classroom environment, and an atmosphere of mutual respect. Peripheral
influences refers to supports for SSI teaching such as SSI lesson materials, flexibility of the curriculum, and instructional supports. SSI-TEP applied the design principles and made connections with SSI-PCK elements by explicitly introducing the steps and sub-steps discussed below (Table 1).

In Step 1, constructing SSI scenarios, the PSTs chose SSI in connection with the science curriculum and their own interests (KC). Considering the characteristics of the issues (e.g., diverse perspectives, moral and ethical aspects, and social implications; SSI-CK), they developed more specific scenarios that could lead students to be contextualized in the issues and attract them to be more actively engaged in class (KSL). Step 2, designing SSI lessons, focused on constructing the flow of the lesson by planning activities and strategies to

<table>
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<tr>
<th>Steps</th>
<th>Sub-step</th>
<th>Things to consider (Examples)</th>
<th>SSI-PCK components</th>
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<tbody>
<tr>
<td>1. Constructing</td>
<td>Choice of SSI topics</td>
<td>– Social-ethical aspects of science</td>
<td>SSI-CK</td>
</tr>
<tr>
<td>SSI scenarios</td>
<td></td>
<td>– Relevance to life</td>
<td>KC</td>
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<td></td>
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<td>– Curriculum connection</td>
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</tr>
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<td></td>
<td>Construction of SSI scenarios</td>
<td>– Characteristics of selected SSI</td>
<td>SSI-CK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Contextualization of SSI based on an analysis of students’ interests and level</td>
<td>KSL</td>
</tr>
<tr>
<td>2. Designing</td>
<td>Lesson goals</td>
<td>– Knowledge/competence (or skills)/attitudes and character, etc.</td>
<td>OTS, KC</td>
</tr>
<tr>
<td>SSI lessons</td>
<td>Flow of lesson</td>
<td>– Use of instructional models</td>
<td>KIS</td>
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<td></td>
<td>Learning activities</td>
<td>– Designing activities</td>
<td>KIS</td>
</tr>
<tr>
<td></td>
<td>Instructional strategies</td>
<td>– Questioning</td>
<td>KIS</td>
</tr>
<tr>
<td></td>
<td>Assessment plans</td>
<td>– Scaffolding</td>
<td>KSL</td>
</tr>
<tr>
<td></td>
<td>Rules for SSI lesson</td>
<td>– Teacher’s and students’ roles</td>
<td>KLC</td>
</tr>
<tr>
<td>3. Formulating</td>
<td></td>
<td>– Constructive and collaborative classroom environment</td>
<td>KIS</td>
</tr>
<tr>
<td>an SSI learning environment</td>
<td>Arrangement of resources</td>
<td>– Use of web resources</td>
<td>KLC</td>
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<tr>
<td></td>
<td></td>
<td>– Use of community resources</td>
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</table>
implement in the classroom (KIS). The PSTs set the goals of the SSI lessons in connection with the curriculum (OTS, KC), selected instructional models to achieve the goals if necessary, and planned activities in which students could actively participate (KSL). They also adopted instructional strategies (e.g., questioning and scaffolding) to promote students’ SSI learning and established assessment plans for the lessons (KIS, KAS). Last, in Step 3, formulating an SSI learning environment, the PSTs considered a learning environment and decided how to utilize the resources needed for the lesson inside or outside of school. For example, they discussed how to assist student internet searches, how to gather information using online platforms, and whether any local resources could be used (KLS, KIS). After completing all three steps, the PSTs conducted microteaching using their lesson plans with their peers as students (i.e., they were not implemented with actual secondary school students).

3.3 Data Collection and Analysis
To explore the challenges and conflicts that the PSTs encountered in SSI-TEP and the changes that they demonstrated in their understanding and skills for SSI teaching, I conducted focus group interviews with six PST groups (Group 1–Group 6). Each interview lasted 50–80 minutes and was audio-recorded. One interview with Group 4 was not recorded well due to a recorder malfunction, so I used notes and memos written during the interview for that group. The interview protocol covered the PSTs’ experiences and challenges at each step of the SSI-TEP. The questions included how the PSTs chose their SSI and constructed SSI scenarios, what they focused on when designing and implementing SSI lessons, what they found difficult at each step of the SSI-TEP, how they overcame the challenges, and to what extent they observed the development of their understanding of SSI teaching. In addition to the interviews, two to four informal conversations with the groups were carried out to check their progress, which lasted 20–30 minutes each. The PSTs brought their challenges and questions to the informal meetings as they proceeded through each stage of the SSI-TEP, allowing clearer understanding of their difficulties at each step. I took notes regarding their challenges and responses during these conversations without audiotaping and developed the notes into narratives right after the conversations. I also collected participants’ SSI lesson plans and created field notes during their micro-teaching on SSI. The observations of their micro-teaching with lesson plans were valuable resources not only for understanding how they actualized the ideas of SSI teaching but also for facilitating interviews to explore how they reflected on their experiences of teaching SSI and what kinds of challenges they experienced.
The interviews were transcribed for data analysis. After repeatedly listening to and reading the transcripts, I identified the common major challenges and concerns that the PSTs experienced by inductive coding (Miles & Huberman, 1994). Specifically, I created a guiding analytical framework consisting of two axes. The horizontal axis represented the steps of the SSI-TEP, and the vertical axis indicated the SSI-PCK components. I located the challenges that emerged from the interviews and observation fieldnotes on the plane. For instance, the PSTs felt difficulties in making connections with national science curriculum when choosing SSI, locating the challenge in the area of Step 1 of SSI-TEP and KC. This was very effective in helping me to visualize the PSTs’ concerns and challenges in connection with the SSI-PCK components. Through iterative analysis using this method, common themes were identified among the challenges and connections were made with SSI-PCK components. I simultaneously applied this method to and compared the themes with the informal talks with the PSTs and field notes of classroom observations to supplement my understanding. This process increased the credibility of the analysis (Lincoln & Guba, 1985).

4 Findings

The PSTs experienced various challenges at each step of the SSI-TEP. In the following section, I present their challenging experiences and describe to what extent their SSI-PCK developed through the SSI-TEP.

4.1 Balance Between Science Content and the Social Implications of Science: KC – KSL

One of the challenges the PSTs encountered in the construction of SSI scenarios (Step 1) was how to connect SSIs with science content in the national curriculum. This was a pedagogical challenge that required the PSTs to understand the curriculum (KC) and students’ interests and academic levels (KSL). When choosing SSIs, the PSTs examined to what extent the selected topics contained science content that they should cover, whether the content was beyond the grade-level curriculum (vertical consideration of the curriculum), and whether they could make connections with other subjects (horizontal consideration of the curriculum). As shown in Table 2, PSTs in Group 1 (PST-G1; analogous abbreviation used for the other groups), PST-G2, and PST-G3 selected topics that clearly matched with the curriculum but contained relatively fewer moral or ethical considerations in science and technology. PST-G4, PST-G5, and
### Table 2: Selected SSI topics and problem scenarios

<table>
<thead>
<tr>
<th>PST</th>
<th>SSI Topic</th>
<th>Curriculum connection</th>
<th>Example scenarios from lesson plans</th>
</tr>
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<tbody>
<tr>
<td>G1</td>
<td>Artificial retinal transplantation operation</td>
<td>Anatomy of eyes</td>
<td>The cost of the artificial retinal transplantation operation is approximately $200,000. Discuss in groups whether governmental financial support for patients who need this procedure is reasonable.</td>
</tr>
<tr>
<td>G2</td>
<td>Overuse of air conditioners</td>
<td>Change of phases</td>
<td>Examine how much CO$_2$ production can be reduced by combating the overuse of air conditioners and how much changing our habits can help slow global warming.</td>
</tr>
<tr>
<td>G3</td>
<td>Earthquake</td>
<td>Volcanos and earthquakes</td>
<td>(Provide cards showing various earthquake situations.) Discuss in groups how to behave when you cope with earthquakes in locations such as home, school, and subway. Research what severe impacts you might expect to see.</td>
</tr>
<tr>
<td>G4</td>
<td>Designer babies</td>
<td>Reproductive cell division</td>
<td>Discuss in groups whether you would choose to have a customized baby if you learned that your unborn baby had a genetic disorder (e.g., Down syndrome).</td>
</tr>
<tr>
<td>G5</td>
<td>Hazards of humidifier sterilizer</td>
<td>Chemical reactions in life</td>
<td>(Provide an overview of the recent humidifier sterilizer scandal.) Discuss in groups why this scandal happened and how we as citizens should deal with this situation.</td>
</tr>
<tr>
<td>G6</td>
<td>Use of weight-control supplements</td>
<td>Digestion</td>
<td>Jane, a ninth grader, is planning to start a diet to lose weight during break. She accidentally saw an advertisement for a diet supplement (Garcinia) on SNS. If you were Jane, would you buy the diet supplement?</td>
</tr>
</tbody>
</table>
PST-G6, however, selected topics that effectively highlighted social and moral aspects in science while being linked to the curriculum.

For example, PST-G1 chose the topic of artificial retinal transplantation because they could see a clear curriculum connection to the anatomy of the human eye. Specifically, they planned to introduce the structure and function of human eyes and compare them with artificial eyes. However, when they developed the topic into an example scenario, they found challenges in presenting the social and moral connotations of the technology: “How can I include ethical or moral aspects in this discussion?” Consequently, they spent a great deal of time finding debatable aspects of the issue:

We chose artificial retinal transplantation because the technology was interesting. We didn't think about the ethical aspect at first. So, it took time for us to combine an ethical or moral aspect with it… The part where we thought of it [the ethical aspect] was when we heard, “By the way, this surgery costs 200 million won! (US$200,000).” We all said, “Wow.” Usually, we only hear, “Congratulations, now you can see your family” in the news or other video clips [about the procedure]. We thought, “This could be something we can discuss.” (PST-G1)

After they searched the web, the huge cost of the retinal transplantation operation caught their attention, and they decided to develop it into a scenario. They recognized various stakeholders related to the surgery (e.g., the government, the families of patients who need the surgery, patients and families who struggle with other diseases, and citizens who pay taxes), and finally formulated the question, “What do you think about the government’s financial support for artificial retinal transplantation operations?”

On the other hand, PST-G5 first selected controversial issues and then experienced difficulties in linking them with science content. As they studied the selected SSIs, they discovered that it required an advanced level of scientific content knowledge. Specifically, they intended to address the humidifier disinfectant scandal during the chemical reaction unit. The following excerpt shows that PST-G5 struggled with how to present the issue at the curriculum level.

The humidifier disinfectant scandal is closely related to students. However, chemical reactions that we normally teach in science class are not as complicated as humidifier disinfectant. The chemistry of humidifier disinfectant is not like ninth graders’ science. So it was quite tricky [for us] to connect the two. So, we naturally talked about the consumer boycott or tried to make connections with society, not science. (PST-G5)
This conversation occurred at a time when most Koreans were very sensitive to the dangers of chemicals contained in household products such as humidifier disinfectant, toothpastes, and shampoos. The debate over whether the number of lung diseases was increasing due to the use of humidifier disinfectant had been going on for several years. Consequently, PST-G5 assumed that the humidifier disinfectant scandal would be a good topic to meet both students' interests and curriculum standards. However, the information on the scandal included complicated molecular formulas and chemical reactions that were far beyond school science. PST-G5 knew that they had a certain level of freedom to organize their lessons within the curriculum but were afraid of introducing scientific knowledge beyond the textbooks. As such, they focused on the social implications of the issue by leading a discussion on how citizens responded to the humidifier disinfectant scandal.

As shown in the examples above, some PSTs easily linked the curriculum to an SSI but struggled with how to present the social and ethical aspects of the technology. Other PSTs chose an SSI that had explicit social and ethical connotations, but in these cases it was difficult for them to present students with the relevant level of scientific knowledge. PST-G6 pointed out this dilemma: “It seems that there are cases in which the scientific content disappears because we focus too much on the SSI, or there are cases where the characteristics of the SSI class are not clearly revealed because we focus on the scientific content.”

4.2 Confusion About How to Incorporate the Nature of SSIs Into Lessons: SSI-CK – KIS

The PSTs struggled when constructing a specific SSI scenario and designing the activities (KIS) because they started to see the complex, uncertain, and contentious nature of SSIs (SSI-CK). It was challenging for them to represent this nature in the SSI scenarios. One of the common myths that the PSTs revealed was that they had to suggest debatable situations in SSI classes. The PSTs tended to focus on how to highlight conflicts between pros and cons by dividing students into two groups. However, when developing the scenarios in more detail, they began to understand that debate itself was not the goal of SSI lessons. While such debates can help to develop students’ ideas, it is ultimately more important to embrace multiple perspectives and negotiate them to find better directions, as demonstrated in the following excerpt.

We had thought that we had to separate the groups for discussion. We were stuck in that part, which was so difficult. We were obsessed with thoughts like, “We should implement one of the debate models, such as jigsaw type model ....” Our mindset was that “debate had to be executed.”
We thought, “Social issues create two different opinions, so there has to be a debate.” We were imbalanced by the thought that we had to debate and to make decisions on that matter. Being in that trap [hindered our ability to plan a lesson].... When we received the first feedback, at that moment, we were like, “oh, my!” No matter who you are – whether you are a doctor, a teacher, a parent, or a student – it is “I” myself who needs to make the decision. We thought, “Why did we separate their stands [on the SS1]?” We decided ..., “It is okay to take out the debate.” (PST-G6)

At first, PST-G6 planned a debate about taking diet supplements (i.e., Garcinia) to control weight by assigning students to “pros” and “cons” groups. However, as they explored the issues, they realized that such debates would reduce the complexity of the issues and hinder students’ personal engagement with deeper values during the discussion. Thus, they came to develop a very specific scenario on weight control to maximize the seriousness and reality of the issue by including the SNS context. They even thought about whether to make the person trying to lose weight a fictional character of a given weight and height, a friend suffering from obesity, or the students themselves. That is, they had a clear understanding that the way the SS1 scenario was constructed could affect how students accepted the issue and, accordingly, produce differences in their engagement. The following response of PST-G6 demonstrates the improvement of their understanding of the complexity of the issues.

Our scenario was “my friend lost weight during winter break, so I wanted to lose weight also.” [After reading some advertising posts on weight-control medicine provided on SNS.] We thought, “SNS should be added.” Even then, we thought a lot about the question, “Do they learn about the product through SNS accounts of other people, or do they decide whether to take it from an SNS ad?” The conflict situation should come up because they willingly take it after watching the advertisements on SNS. Then how could we construct it?... [Creating a fictional character] When we call the given weight and height an average, I might not fit into that average. That average can differ for each student, so we took it out after we thought about it. We just thought it was important that “I” had the willingness to take it. We spent a lot of time on this part. (PST-G6)

A similar situation occurred in PST-G5. While researching the humidifier disinfectant scandal, they recognized the complexity and ambiguity of the issue. The scandal was highly debated among various stakeholders, specifically on the question of whether a causal relationship between specific chemicals
and the occurrence of lung diseases could be proved. PST-G5 stated, “We don’t think it was possible to make a decision because the consumer’s position and the manufacturer’s position were so tightly opposed.” Consequently, they chose to be open and let students see the uncertainty of science. They expressed the aims of the lesson as follows:

When developing chemical products, manufacturers try to produce the best results with the least harmfulness through scientific experiments or processes, but science, by its nature, is uncertain, and the products can harm humans. We aim to provide an opportunity for students discuss in diverse ways what attitudes we as citizens should have when purchasing chemical products for daily use. (from PST-G5’s lesson plan)

It is notable that PST-G5 designed the discussion focusing on the uncertainty of science. To achieve this aim, they came up with three major questions in the lesson plan: “Why did the humidifier disinfectant crisis happen?” “Why did this product harm some people despite scientific experiments used to verify risk?” and “How should we as citizens view and deal with this situation?”

Other PSTs also tried to reveal the complexity of the issues. For example, PST-G2 planned a lesson by starting with the concepts of phase changes and heat flow and then making a transition to global warming by addressing the overuse of air conditioners. While constructing their example scenario, they noticed that their approach would oversimplify global warming because many factors are complexly involved in the issues. Eventually, they narrowed the lesson to calculating the amount of CO₂ created due to air conditioner overuse.

4.3 Teachers’ Role in Facilitating Students’ Reasoning and Participation: KIS – KSL

When designing SSI lessons (Step 2), the PSTs planned and constructed detailed lesson plans using their SSI scenarios. They specified lesson goals and selected instructional models (e.g., 5E model and STS instructional model) to achieve the goals if necessary. For the effective execution of the lessons, they chose class activities (e.g., discussion/debate and experiments) and instructional strategies (e.g., questioning and scaffolding) to facilitate students’ engagement, then developed assessment plans (KIS). The PSTs had a strong belief that SSI classes should enable students to actively lead and participate, and they constantly thought about how to encourage students to get more involved. However, with little experience in guiding discussions, the PSTs
struggled to create an environment in which students could more actively participate during their micro-teaching (KIS).

[During class,] the same story kept spinning around and around due to the limited materials and time ... I naturally expected them to bring up that healthy citizens would be responsible for that tax. It was not brought up at all, surprisingly. So I was trying to find a solution while going around the classroom.... Rather, the kids were talking from the perspective of sick patients. (PST-G1)

I looked around their group activities while implementing the latter part of the lesson. I remember a few students who stood out. And I might have missed them, but there could have been some who couldn't talk while others had the chance.... If I had used the discussion model with fixed roles for every single participant, there would have been none left out. (PST-G5)

PST-G1 explained how surprising it was to receive the unexpected reactions of the students. Before classes started, they had predicted that even if it necessitated a tax increase, students would suggest that society should support the artificial retinal transplantation operation for patients. However, in the actual discussion, students objected to financially supporting the artificial retinal transplantation operation, taking into account other patients struggling with more serious diseases. Moreover, the PSTs found that similar stories kept spinning around in the discussion, rather than the discussion gradually progressing (KSL). This caused PST-G1 to get lost in the question of how to support students in moving forward. Other PST groups also responded that the discussion did not proceed effectively because students debated with limited information in SSI classes. Through this process, the PSTs came to appreciate the importance of applying proper instructional strategies to facilitate student activities (e.g., providing information necessary for the discussion and giving opportunity for the students to search for the evidence) and preparing effective questions that stimulate students’ reasoning.

Another issue with classroom discussion was raised by PST-G5. They had expected that every student would be willing to engage and present their opinion in debates/discussions, but they observed that some students felt pressured to express their opinions (KSL). They had a hard time explaining why it was difficult for some students to participate in SSI discussions and discovering how to scaffold them to be engaged and to express their opinions. Other PSTs also
found that most of the questions used in the class were simple queries to check content rather than encourage discussion:

We struggled with the questioning before class. In order to lead the class smoothly, it was crucial to open the lesson with good questions. We continued to ask what would bring more from students. But in the actual lesson, no such questions were asked... We cared about [the question of] “what protocols would we take when we respond to earthquakes at the level of the central government or a citizen?” We first emphasized this question, then we asked what we could do to prevent damage. It might be in a similar context, but the goal was to draw out what students were thinking. The questioning was only about simple check-ups on what they “knew” from the cramming teaching method. (PST-G3)

Writing the lesson plan, I could see that my questions were very limited. I wanted to ask questions from various perspectives at different levels, but I tended to keep asking questions in a single direction: knowledge. And actually I considered the application aspect, but I couldn't come up with questions asking about their deeper thoughts.... I consider questioning a process where interactions occur in class. I would like to interact more with students, but I can't grasp the idea. What should I ask to get answers from students? You know, I had no general sense of what they knew. Answers depend on which questions the teacher asks, so it was more difficult. Questions actually decide the boundary and direction of their thoughts. (PST-G2)

The PSTs understood the importance and need for good questions to facilitate student reasoning, but they struggled to formulate such questions. PST-G6 said, “We also wanted questions that students could say, ‘Wow, we can think of this issue this way.’” In preparing for the SSI class, the PSTs spent a large amount of time preparing the key questions. However, during the actual class, the PSTs were puzzled by the unexpected reactions of students to their questions (KIS – KSL). PST-G5 said, “I didn’t know what to say and how to communicate because I couldn’t anticipate how students would react.” In other words, when asked questions prepared by the PSTs, students rarely gave the in-depth answers or thoughts that the PSTs had expected. By watching the recorded video clips of their lessons and tracing back what they had done, the PSTs recognized that most questions were only simple information checks and opinion confirmations. PST-G4 commented, “We only checked if they could remember what we taught in class. There was nothing else. Nothing deep.” One reason for
this might be that the PSTs had limited experience in micro-teaching and so could not deliver the planned questions effectively. This issue also indicates the importance of obtaining KSLS, which includes students’ reasoning patterns, difficulties that students might have during the SSI discussions, and the common reactions of students when they are overwhelmed by the complexity of the issues.

4.4 Utilizing Resources for More Effective SSI Lessons: KIS – KLC

Effective SSI lessons require an environment where students have access to a diverse range of resources, communicate with each other respectfully, and negotiate and build collaborative products with the guidance of teachers as facilitators (Lee & Chung, 2013). In Step 3, the PSTs tried to formulate a collaborative environment where students could explore and share various resources in and outside of the classroom. They utilized various technologies (e.g., tablet PCs and smart phones) and web platforms (e.g., discussion boards) to formulate this environment. After micro-teaching, they positively evaluated the experience of utilizing tablet and web platforms in SSI lessons because it expanded the learning context by bringing various information into the classroom and effectively sharing it in a timely manner. As shown in the following excerpt, the PSTs asked students to post relevant materials they found from diverse sources on web platforms such as Lino-it, Socrative, and Padlet and to develop, share, and present their sources and ideas.

It was my first use of Lino-it and Socrative. Definitely, it was a lot different from previous classes. Students could engage more, and we could communicate through the iPad, back and forth between teachers and students. If we hadn’t used it, students would have had a hard time figuring out how to respond to different earthquake situations; in that case, they would have used their limited knowledge. It would have been difficult to lead it [to a] more powerful [conversation]. We could have used paper-based materials or worksheets, but it was much more effective to use Lino-it. (PST-G3)

PST-G3 realized that using technology expanded the range of student learning spaces. In the technology-friendly environment, students could find a wider range of information not limited to science textbooks to understand the issues and experience their complexity in real-world situations. Technology was a window that both the PSTs and students could use to bring outside resources into the classroom. Additionally, it provided the PSTs with some degree of
freedom from the burden of needing to be knowledgeable on the issue. They could look up the information with their students using technology when they received unexpected questions. As they discovered the positive aspects of a technology-friendly environment, however, the PSTs also started to observe new issues (KLC).

I personally saw the need to educate [students on] how to evaluate the sources of the information. We didn’t have specific guidelines for the students, so some of the data sources were uncertain and some information was cited from less reliable sources. Some students couldn’t search for information [without my guidance]. They just copied and pasted from the websites I suggested. The sources were at the top of the search engine results. So I thought, “It is true that there are tons of information on the web, but there can be a limited amount of information students can use, so I should help them to go further in using them.” (PST-G6)

When we actually looked it up, there’s too much information and too many perspectives. So we thought, “Should we select the articles? What if the students read this article? It doesn’t seem right…” But students won’t be able to understand this. There’s too much information. Searching for information on their own to take a position on the issue, I guess, would not be easy for students. (PST-G5)

As demonstrated by these excerpts, the PSTs found that many students collected biased information from untrustworthy sources and only searched for a limited range of information because they did not use the right keywords. As such, the PSTs realized that they should scaffold their students both to search for the information on the web and to evaluate the quality of resources and information (KIS). Additionally, PSTs feel the necessity to teach how to construct their arguments on the basis of appropriate evidence.

4.5 Feeling of Tensions with Teaching Orientations: OTS – KLC – KAS
Teachers can hold different orientations when teaching SSIs. These orientations become a more concrete driving force as their teaching experiences accumulate throughout their career (Lee & Witz, 2009). The PSTs in this study did not have enough prior experience teaching SSIs to possess their own orientations. However, as shown in Table 3, they attempted to construct lesson goals that represented their orientations for teaching SSIs (OTS). The most common orientations they held were a focus on presenting the “application of science in everyday life” and the “nature of science and technology.” Some groups emphasized citizenship or activity-driven orientations. For instance, PST-G3 primarily
<table>
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<tr>
<th>PST</th>
<th>SS1 topic</th>
<th>OTS</th>
<th>Lesson goals from lesson plans</th>
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| G1  | Artificial retinal transplantation operation | Application of science in everyday life | – Students can explain the structure and function of eyes.  
– Students can listen to and share opinions on the artificial retinal transplantation operation. |
| G2  | Overuse of air conditioners     | Application of science in everyday life | – Students can explain how air conditioners work using the concept of phase changes.  
– Students can understand the seriousness of global warming and take action to protect the environment. |
| G3  | Earthquake                     | Activity driven teaching      | – Students can explain the severe impact of earthquakes on our lives.  
– Students can search and find out how to respond to earthquakes. |
| G4  | Designer babies                | Application of science in everyday life | – Students can search for media information and explain Down syndrome.  
– Students can actively participate in discussions on the issue of designer babies. |
| G5  | Hazards of humidifier sterilizer | Nature of science and technology | – Students can find examples of chemical reactions in daily life.  
– Students can search for hazardous chemical products and discuss what attitudes citizens should have toward such products. |
| G6  | Use of weight-control supplements | Nature of science and technology | – Students can search for the ingredients and side effects of diet supplements.  
– Students can share their thoughts on using diet supplements.  
– Students can question and explore the reliability of information on diet supplements. |
focused on activities that could stimulate students’ interest and engagement in learning. Consequently, they prepared group activities where students would search and present on the serious impacts that earthquakes have on society and how to appropriately behave when earthquakes occur. On the other hand, PST-G5 and PST-G6 emphasized examining, with skepticism, the nature of science and technology that the issues represented and guided students to join the discussion on how to react to these issues as citizens. PST-G1 and PST-G2 aimed to see how science could be applied in everyday life by examining a limited range of its societal impacts, while PST-G4 not only showed the application of scientific knowledge in genetic engineering but also examined the development of designer baby technology to be aware of its nature.

The PSTs recognized that students would have opportunities to see the interrelationship of science and society by engaging in various activities, to be aware of the contradictions of science and technology development, and to communicate with others or make arguments to reach a consensus. They knew that SSI lessons would be a more effective approach to provide such experiences. However, the following excerpts show that the PSTs questioned whether SSIs would meet the students’ demands within the test-oriented academic environment (OTS – KLC – KAS).

While preparing for the lesson, we watched some related videos. It was a lecture. The lecturer in that clip was so good. It was for middle school students. We were preparing for the SSI and handling the topic including social and ethical aspects. Then we thought, “Would I want such a lesson if I were a middle school student?” I actually thought about this question a lot. Because..., there’s a teacher who helped me to get better grades [the pressure motivated me.] But another thing I learned [from SSI-TEP] was that this might be much more important than such things [lectures]. But still, I was not sure ... (PST-G1)

Many PSTs decide to become science teachers because they were attracted to or interested in science during their own secondary school years (Witz & Lee, 2009). However, the nature of science that they admired may not be the “knowledge about science” emphasized in SSIs. Issues like how science can be applied into daily life, the connections between science and society, how technologies are related to one another, and what responsibilities citizens should carry out for science to advance equitably are often distant from what high school students are interested in. Therefore, the PSTs wondered, “Would students like SSI lessons?” even during SSI lessons. Moreover, while designing and
implementing SSI lessons, the PSTs questioned, “Would teachers be passionate enough to enact SSI lessons? If so, would they be able to?” Thus, the PSTs were compelled to consider the educational conditions of Korea.

Such conflicts and tensions also appeared when the PSTs were discussing their assessment plans. Because assessment is normally linked to entrance into better colleges in Korea, maintaining objectivity by quantifying students’ performance is considered a very important issue. The PSTs expressed their concerns about both what and how to evaluate.

Assessment, actually, was really hard for me. I watched every student engaging in discussions during class time, and they pitched in their thoughts. It was so difficult to evaluate such participation. So, I built up the assessment sheet. But still, I thought there might be some subjective components in assessing them. (PST-G3)

Implementing SSI classes seemed to be okay in middle school, but I wonder how it would be in high school. You know, in high school, even though we are evaluating their process of learning, the ultimate goal is to get them into better universities. Then, teachers would have to line up the students to send to better schools ... I don't know how to evaluate who performed better than others. (PST-G2)

These responses showed that the PSTs were bound by the idea that securing objectivity and credibility would be of the utmost importance to evaluation in science class. They agreed that process-oriented evaluation could be more suitable for SSI classes, but questions arose about whether subjective aspects, like personal opinions and participation, should be evaluated. The PSTs struggled to complete an evaluation on unquantifiable aspects of the lesson and to maintain objectivity. Indeed, PST-G4 said, “We are still used to ranking students in order, and it is difficult for us to abandon this frame.” Because SSI lessons were not aimed at learning specific scientific knowledge, the PSTs had to come up with ways to assess students' achievement in other areas.

5 Conclusion and Discussion

Teaching SSI requires a certain level of teachers’ knowledge and skills (Bayram-Jacobs et al., 2019; Sadler, 2011; Presley et al., 2013; Sadler, et al., 2017), referred to respectively as SSI-PCK and SSI-CK in this study. Because teachers often experience tensions when moving to SSI classrooms from traditional
science classrooms (Lee, et al., 2020), it is necessary to guide them with more systemic programs to teach SSIs. The SSI-TEP in this study was systematicaly designed on the basis of the SSI-PCK framework and empirical evidence. After participating in the SSI-TEP, most PSTs presented a better understanding of SSI teaching and felt more confident designing and implementing SSI lessons. They highly valued SSIs as a way to clearly demonstrate the connections between science and life while highlighting the complexity and uncertainty of cutting-edge science and technology. Ultimately, the PSTs recognized that their SSI-PCK had improved through the SSI-TEP. This finding aligned with other studies (e.g., Kinskey & Callahan, 2022; Kwon & Lee, 2018) that SSI-TEP provided the opportunity to better understand the nature of SSIs (SSI-CK) and observe the potentials of SSI teaching.

Despite these positive indications, I paid more attention to the challenges and concerns that the PSTs encountered because I believe that such challenges served as a trigger for them to develop their SSI-PCK. Some challenges were pedagogical ones directly related to the design and implementation of SSI lessons, while others were epistemological issues that led the PSTs to deeply consider the nature of science and technology in the context of SSIs. Below, I suggest more practical implications based on the observations of these challenges.

The results showed that PSTs’ challenges were often intertwined with specific SSI-PCK components. For example, KC and KSL were implicated in the process of choosing SSIs and constructing SSI scenarios. To effectively create SSI scenarios in connection with the curriculum, PSTs not only needed knowledge of the science curriculum but also had to obtain an understanding of students’ SSI learning. For instance, if the given scenario is too broad, students may feel that the issue is far from their actual lives. However, if the scenario is too specific, students may not have enough room to apply their own values and feelings. Likewise, if the scenario requires complex knowledge, students may try to avoid serious engagement with the issue. Consequently, understanding the overall patterns of students’ engagement in an SSI can aid PSTs in effectively designing SSI scenarios.

When designing lessons, PSTs encountered common myths about SSIs. This relates to SSI-CK and KIS. Limited understanding of the nature of science and technology led PSTs to simply focus on formulating opposing groups for debates. The PSTs needed an understanding of the complexity and uncertainty of science and technology developments (SSI-CK), such as how various stakeholders are involved and intertwined and which social and ethical implications are produced by the development of science and technology. As their
understanding of the nature of SSI deepened, the PSTs recognized how to reflect that nature in SSI scenarios and activities. Ultimately, learning to reveal the nature of science and technology through SSI was not a mere pedagogical question but also contained epistemological aspects. Since teachers’ epistemological beliefs about science influence their teaching practices (Witz & Lee, 2009), it is necessary to provide PSTs with opportunities to discuss the nature of science and technology for effective SSI teaching.

Another pedagogical challenge occurred when the PSTs facilitated students’ reasoning and participation. This issue originated partly because the PSTs did not have adequate knowledge of effective instructional strategies for teaching SSI (KIS) and partly because they were not fully aware of the patterns of students’ engagement in SSI (KSL). Many empirical studies have reported that students were afraid of engaging in SSI discussions because they found deficiencies in their science knowledge (Abi-El-Mona & Abd-El-Khalick, 2011). Additionally, some students tried to be detached from SSI reasoning because they were overwhelmed by the number of aspects to consider (Dreyfus & Roth, 1991; Sternäng & Lundholm, 2011). Other students emotively engaged in SSI with their personal values and feelings rather than applying scientific knowledge (Herman, et al., 2018). Understanding such patterns can scaffold teachers to generate appropriate questions and apply suitable strategies to guide their students.

KLC is also an important SSI-PCK component. Specifically, SSI teaching often requires various learning resources beyond science textbooks. Students can use the internet to search for information then share and distribute their ideas in diverse forms. They can also visit local libraries or similar organizations to collect diverse and practical perspectives on SSI. Effective utilization of resources can expand the scope of students’ learning (Kim & Lee, 2017, 2021), as confirmed by the PSTs in this study. KLC also includes knowledge of classroom and school cultures and of potential resources. For effective SSI instruction, teachers need to focus on formulating an atmosphere where students are able to lead their own learning by collaborating with others. Sometimes, this requires teachers to construct new rules for teachers and students to facilitate a more collaborative, mutually respectful atmosphere. The PSTs often expressed that they had challenges in creating such cultures within the traditional lecture-based classroom environment.

The PSTs also felt strong tensions when their SSI teaching orientations conflicted with school atmospheres, and they questioned whether they could find a niche to teach SSI within the test-oriented culture. This tension intensified when they were planning assessments. They struggled to decide what
to evaluate and how to evaluate the reliability of SSI material. Although they aimed to enhance students’ interest in the issues, understanding of the nature of science and technology, and citizenship, such aims could not be evaluated by traditional methods. As such, the PSTs were afraid that they might lose objectivity in their assessments.

One of the SSI-PCK components that needs more attention is OTS. Friedrichsen and Dana (2005) mentioned that instructors’ science teaching orientation is a crucial component that drives their teaching practices. They found that teaching orientation can be influenced by teachers’ beliefs about learners and learning, personal work experiences, and other contextual factors. However, the clearer the teacher’s orientation for science teaching is, the more the teacher can represent their pursuits through science teaching in any circumstance (Lee & Witz, 2009). The PSTs in this study disclosed their OTS in their lesson plans, but it seems that they felt pressured by the external forces and context (i.e., need for quantified tests and expectations of parents and students about college entrance) because they did not possess stable teaching orientations. Whenever they encountered obstacles, the PSTs tended to raise epistemological questions like, “Should I address the social and moral implications of science?” and “Am I teaching science?” It will take time for the PSTs to develop their own stable orientations. Accumulating successful experience teaching SSIS would help in this process. Bayram and Ates (2020) reported that argumentation-based SSI teaching let PSTs change their teaching orientations to be more compatible with their knowledge of SSI teaching. We expect that the SSI-TEP will contribute to this success as well.

**Abbreviations**

KAS Knowledge of assessment of socio-scientific issue learning
KC Knowledge of curriculum
KIS Knowledge of instructional strategies for teaching socio-scientific issues
KLC Knowledge of learning contexts
KSL Knowledge of students’ socio-scientific issue learning
OTS Orientation for teaching socio-scientific issues
SSI Socio-scientific issues
SSI-CK Content knowledge for socio-scientific issues
SSI-PCK Socio-scientific issues pedagogical content knowledge
SSI-TEP Socio-scientific issues teacher education program
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Ethical Considerations

Approval to conduct this study was granted by the Ewha Womans University Institutional Review Board (IRB). The data collected from this paper has obtained the necessary clearance from the students involved in the study and their guardians. Pseudonyms are used for names of all participants.

About the Author

Hyunju Lee is a professor at Ewha Womans University, Seoul, South Korea. Her research centers on science teaching and teacher professional development for socioscientific issues (SSIs). She has published papers that address patterns of decision making on SSIs, instructional approaches to SSIs, and the development of teachers’ practical knowledge about SSIs teaching.

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