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FORUM

Developing teacher professionalism for teaching socio-scientific issues: What and how should teachers learn?

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Abstract
This commentary reinterprets the findings of Macalalag, Johnson, and Lai's study in terms of the substantive content of and ways of initiating professional development for teaching socio-scientific issues. First, regarding professional development content, we introduce the concept of SSI-PCK, which refers to pedagogical content knowledge for teaching socio-scientific issues. From the perspective of SSI-PCK, the teacher education program designed by Macalalag and his colleagues contributed to shaping the "orientation for teaching SSIs," which is an overarching component of SSI-PCK. Second, regarding how to implement teacher education, we examine the key features of strategies to enhance effective professional development. Among the various activities of Macalag et al.'s teacher education program, the cultural practices provided by the field study encouraged the participant teachers to understand the importance of SSIs as learners, thinkers, and reflective practitioners. Finally, educational implications are suggested for organizing further professional development for educators.

Keywords SSI · SSI-PCK · Teacher professional development

Teachers' learning experiences during teacher education play key roles in developing their professionalism, instructional practices, and opportunities for enhancing student learning. The meaningful activities provided in professional development can improve teachers' knowledge as well as beliefs, thereby changing the content of their instruction and their approaches to pedagogy, which ultimately will help to increase the quality of student learning (Desimone 2009). In this sense, providing high-quality teacher education programs can be regarded as a basis for improving teaching and learning in classrooms.

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This review essay addresses issues raised in Augusto Z. Macalalag, Joseph Johnson, and Michelle Lai's paper entitled: *How do we do this: learning how to teach socioscientifc issues* (https://doi.org/10.1007/s11422-019-09944-9).

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In this study, we noted that Macalalag, Johnson, and Lai attempted to develop a teacher education program for teaching socio-scientific issues (SSIs) and therein described the changes of teachers who participated in their program. In particular, their professional development consisted of various activities focusing on case-based cultural practices. These activities can be categorized into four parts: discussions on socio-scientific issues, hands-on activities, organizing lesson plans, and field studies. In this paper, we examined these activities in terms of what and how the participant teachers learned to apply what they learned to teaching socio-scientific issues. We reinterpreted the results of Macalalag and his colleagues' study based on the concept of pedagogical content knowledge and the features of effective professional development discussed in the previous research. Based on the discussions, we suggest educational implications for the continued enhancement of teachers' professional development for teaching SSIs.

Teachers' pedagogical content knowledge for teaching socio-scientific issues

What knowledge should teachers learn in order to be prepared for teaching SSIs? The most representative concept of teacher professionalism is pedagogical content knowledge (PCK). PCK is the knowledge used to transform knowledge of a subject such as science or mathematics into a form that students can understand (Magnusson, Krajcik and Borko 1999). This means that PCK is subject specific, depending on the content of each subject curriculum, to be applied to student learning in classroom environment. In this sense, PCK can be also domain or topic specific because it requires a variety of inquiry methods or instructional strategies depending on the subject (Magnusson et al. 1999). For instance, Van Dijk (2014) suggested the notion of PCK to enhance students' scientific literacy including the nature of science and inquiry. Niess (2005) argued that different forms of PCK are necessary to teach science with technology, which is referred to as technology-enhanced PCK. Therefore, the changes in teacher knowledge described by Macalalag and colleagues can be approached from topic-specific PCK, in this case related to teaching socio-scientific issues.

As has been seen, socio-scientific issues differ from other topics in science in that they are characteristically open-ended, ill-structured, disputable problems subject to multiple perspectives and solutions (Sadler and Zeidler 2005); this suggests that specific PCK can be applied in the classroom teaching socio-scientific issues. The need of specific PCK for teaching SSIs is also supported by the research of Forbes and Davis (2008), who reported difficulties in teaching SSIs because these issues are distinct from other science topics. Recently, Lee (2016) conceptualized the PCK specialized for teaching SSIs and renamed it SSI-PCK. SSI-PCK encompasses six components, which are detailed in Fig. 1.

As shown in Fig. 1, Lee (2016) presented orientation for teaching SSIs as the overarching support for the other five identified components. It is noted that the orientation for teaching SSIs can be divided into two broad categories (Lee 2016), the teaching orientation and the SSI orientation. Teaching-oriented teachers implement SSI education to provoke students' interest in teaching science by introducing SSIs rather than SSI itself; these teachers value SSI education as an effective tool for teaching science because it motivates students' interest. In contrast, SSI-oriented teachers implement SSI education not as a tool but as an intrinsic value. For instance, SSI-oriented teachers aim to help students be prepared to make decision-making in SSI. Orientation for teaching SSIs shapes the remaining five components: knowledge of instructional strategies for teaching SSIs, knowledge of

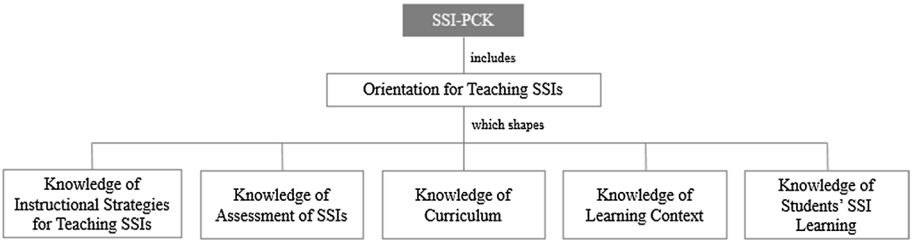

Fig. 1 SSI-PCK components and their relationships (Lee 2016)

assessment of SSI, knowledge of curriculum, knowledge of learning context, and knowledge of students' SSI.

Macalalag and his colleagues addressed teachers' notions of SSI and how to teach these issues after they completed a graduate course on helping teachers learn how to teach SSIs. Looking at their research from the perspective of Lee's (2016) SSI-PCK conceptualization would provide a more systematic review of how this research has changed teacher knowledge and suggest more specific implications for teacher education.

Macalalag and his colleagues conducted a graduate-level course with the aim of teaching educators how to teach SSI, with. Four major course activities noted were discussion on SSIs, hands-on activity, lesson planning, and field study. With this study, we matched each activity to Lee's (2016) SSI-PCK components, presented in Table 1.

As shown in Table 1, in the discussion on SSIs, teachers had several chances to learn various SSI topics and perspectives. As thinkers, they discussed SSIs and studied associated beliefs and attitudes. This procedure focused on SSIs itself and provided teachers with the chance to raise their awareness in this area. Therefore, this discussion activity can be effective in more effectively promoting orientations toward SSIs themselves rather than toward teaching.

The hands-on activity that Macalalag et al. used was the EiE (Engineering is Elementary) module that teachers can use in their classrooms. This hands-on activity can promote teacher knowledge of instructional strategies that teachers can then apply in their lesson planning. Similarly, the lesson planning activity promotes not only teacher knowledge of instructional strategy by designing units and lessons about SSIs but also knowledge of curriculum, students' understanding of science, and assessment. Macalalag et al. asked teachers to include national or local educational standards, anticipated students' prior knowledge, detailed instructional methods, and assessment in their lesson plans. Lastly, the field study activity was visiting a local arboretum, an urban farm, and a water treatment facility. This activity was reported to be effective in developing cultural practices about SSIs, and we could see that this activity developed teachers' orientations toward teaching SSIs.

We found that Macalalag et al.'s activities matched with each component of SSI-PCK except knowledge of learning context. In this context especially, we could see that the course was focused more on orientation for teaching SSIs and that it was effective. In this sense, the discussion on SSIs and the field study played a role in developing the teachers' orientation for teaching SSIs. It is very meaningful in that orientation for teaching SSIs is the first part of the SSI-PCK to be completed because it is the overarching concept of SSI-PCK.

Meanwhile, a review of the hands-on activity and lesson planning in Macalalag et al.'s study was related to developing the rest of the SSI-PCK components: knowledge of curriculum, instructional strategies, students' SSI learning, and assessment. However, Macalalag

Table 1 Matching the activities of Macalalag et al. to Lee's (2016) SSI-PCK components

Components of PCK for teaching science (Magnusson et al. 1999)	Components of SSI-PCK (Lee 2016)	Activities in the study of Macalalag et al.
Orientation to teaching science	Orientation for teaching SSIs	Discussion on SSIs Field study
Knowledge of science curricula	Knowledge of SSI curricula	Part of lesson planning (national or local educational standards)
Knowledge of students' understanding of science	Knowledge of students' SSI learning	Part of lesson planning (students' anticipated prior knowledge)
Knowledge of instructional strategies	Knowledge of instructional strategies for teaching SSIs	Hands-on activities Lesson planning
Knowledge of assessment of scientific literacy	Knowledge of assessment of SSI learning	Assessment as part of lesson planning
	Knowledge of learning contexts	No activity found

et al. showed only that teachers did consider students' prior knowledge in their lesson plans. Although we could not clearly see the effectiveness of these activities and how they developed the SSI-PCK components, we value that these activities included the components of SSI-PCK. Thus far, we have discussed what was covered in the graduate course for learning how to teach SSIs in the paper of Macalalag et al. In the next section, we examine how to improve teacher knowledge through teacher professional development.

The essential features of professional development for learning how to teach SSI

What kinds of learning experiences should be provided to teachers for learning to teach SSIs? Teachers' experiences in the pursuit of their professional development influence their knowledge, skills, and attitudes, and for the last decades, researchers have identified how to construct teacher professional development programs. Desimone (2009), based on the empirical results of existing studies, suggested five core features of effective professional development as follows: content focus, active learning, coherence, duration, and collective participation. Focusing on these five features, we examined the features of professional development designed by Macalalag et al. and discussed their meanings in terms of improving teachers' SSI-PCK.

First, professional development activities are effective when they focus on subject matter content and teachers' knowledge about teaching that content (Desimone 2009). In this vein, the professional development activities for teaching SSIs also need to focus on the contents of various subjects related to these issues. In particular, Macalalag et al. designed the program to teach teachers how to incorporate SSI instruction into STEM curriculum. Considering that most SSI contexts address interdisciplinary aspects such as science, economy, and psychology (Eastwood, Schlegel and Cook 2011), the teachers' experiences of incorporating SSIs in STEM curricula can provide opportunities to develop their knowledge of integrating interdisciplinary contents of SSIs.

Second, in effective professional development activities, teachers should be active learners and classroom participants, not passive listeners (Desimone 2009). For this, it is recommended that teachers engage in active learning such as practicing real lessons and having interactive discussions (Desimone 2009; Garet, Porter, Desimone, Birman and Yoon 2001). In Macalalag et al.'s program, the roles of teachers were emphasized as learners, thinkers, and reflective practitioners in hands-on activities, discussions, and field study. The participant teachers engaged in various activities as inquirers and designed their own lesson plans, although they did not have the chance to implement the lesson plans. In enacting SSIs in actual classrooms, it is essential for teachers to deeply review and restructure science lessons (Zeidler, Applebaum and Sadler 2011). For a deep restructuring of lessons, teachers need to embody pedagogical knowledge such as knowledge of instructional strategies, students' SSI learning, and learning contexts through more practical teaching experiences, together with content knowledge or orientations for teaching SSIs.

Third, the learning experiences provided in professional development are effective when the experiences are consistent with teachers' knowledge and beliefs (Desimone 2009; Lee and Witz 2009). In practicing SSI lessons in actual classrooms, it is important that teachers have their aspirations for teaching SSIs, because teaching SSIs has different features and difficulties from the teaching involved in managing traditional science lessons (Lee 2016; Lee and Witz 2009). Teachers' inspirations for teaching SSIs can be especially deepened

with their actual experiences related to practical aspects of science (Lee and Witz 2009). In this regard, in Macalalag et al.'s study, the real-world experiences in field studies in Philadelphia, Pennsylvania, and Sicily, Italy, could give teachers the chances to understand the importance of teaching SSIs and students' decision-making on these issues. In addition, the discussion activity can be a facilitator to change the teachers' beliefs and practices by reflecting their experiences in depth. Therefore, these continuous activities of field study and discussion in this program are deeply related to developing the orientation for teaching SSIs in the SSI-PCK model (Lee 2016).

Fourth, in order to make practical changes in teaching practices, it is important for teachers to participate in these kinds of activities for a sufficient duration of time (Desimone 2009); however, there is no absolute standard of "sufficient duration" to change teaching practices. Sometimes, more than a semester is needed for changing teaching practices, although only a day or even a few hours of experience can be a tipping point to lead to practical changes of teaching (Desimone 2009; Supovitz and Turner 2000). Given that teacher change is a gradual and difficult process, it is important to provide teachers with ongoing supports and feedback to show their progress, no matter how good activities are provided in teacher education program. In Macalalag et al.'s program, as mentioned above, teachers' continuous experiences with the field study and the discussion activity could develop the teachers' orientations for teaching SSIs. However, the development of orientations for teaching SSIs could not guarantee the teachers' practical changes to teaching SSIs in actual classrooms. Thus, continued supports need to be made to teachers' practical changes in teaching SSIs in their actual classroom.

Finally, teachers can extend their knowledge and practices through collective participation (Desimone 2009). For example, it has been reported that significant changes occur when teachers participate together in community activities to improve and sustain their professionalism (Arthur, Marland, Pill and Rea 2010; Desimone 2003). Teacher professional communities provide intellectual, social, and material resources that can open up opportunities for teachers to learn (Little 2003). In particular, effective professional communities enhance not only teachers' learning but also their shared values, visions, collective responsibility, autonomy, and voluntary participation in general (Arthur et al. 2010). This virtuous circle improves as well as sustains their continued professional development. In this context, the participant teachers' changes in their field study can be reconsidered in terms of the noted collective participation.

Implications for organizing professional development to improve SSI-PCK

In this paper, we have discussed the professionalism that teachers should have in order to teach SSI education and the necessary component features of professional development programs to promote it; as a professionalism requirement for teaching SSIs, we introduced the concept of SSI-PCK and its components (Lee 2016). We also considered the key features of professional development and reviewed how to promote professionalism for teaching SSIs based on the previous research regarding professional development. Our discussion can be presented as shown in Fig. 2, which describes the contents and methods of teacher professional development to improve SSI-PCK. In this model, the inner part represents the SSI-PCK components of teacher professional development that should be managed by the teacher educator. The five elements of the outer part of the model can be

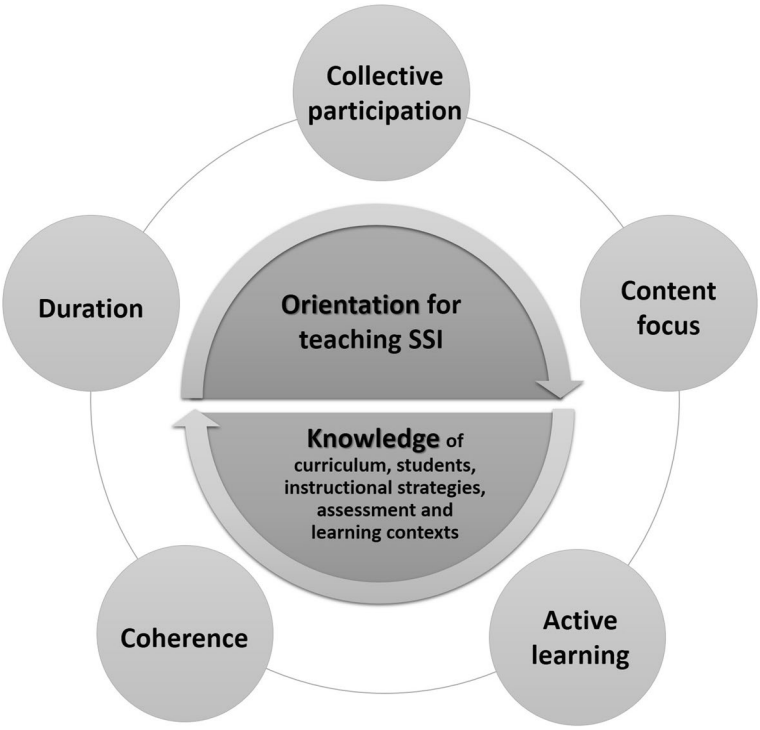

Fig. 2 Content and method of teacher professional development to improve SSI-PCK

the regarded as the desirable directions of this learning method for use in effective teacher professional development.

We can discuss the teacher education program designed by Macalalag et al. based on the model presented in Fig. 2. Macalalag et al.'s program has the advantage of being able to allow teachers to experience SSIs personally and also endeavor to embody the value of SSI education through cultural participation provided by field study. Considering that changes in values and beliefs are particularly difficult, the knowledge embodied in cultural participation can lead to more active changes than any indirect activities. This means that the identified cultural participation in SSI has allowed teachers to understand and experience the importance of SSI as learners, thinkers, and reflective practitioners. Therefore, we consider Macalalag et al.'s attempt to shape orientations toward teaching SSIs, which is an overarching concept of SSI-PCK, by providing active learning experiences such as field study to be significant.

In addition, in order to continuously develop SSI-PCK, it is important that "orientation for teaching" and "knowledge of curriculum, students, instructional strategies, assessment, and learning contexts" are interconnected as shown in Fig. 2 (Lee 2016). It is noted that teachers' orientations toward teaching SSIs developed through discussion and field study need to be aligned to actual teaching practices. Macalalag and his colleagues also provided hands-on activity as a form of instructional strategy and opportunity to consider their knowledge of students through lesson planning. However, providing additional opportunities to develop more practical knowledge about SSI learners and actual classrooms will

be more effective in changing teachers' practices. Also, learning more practical knowledge such as learning strategies can influence teachers' orientations toward teaching SSIs as an effective educational tool for science learning.

Finally, in terms of supporting teachers' continued growth in their teaching practices, they need to be encouraged to have collaborative participation with community members beyond participating individually (Lee and Yang 2017). The collective participation of teachers can increase spontaneity of professional development, as well as their commitment to participate in learning, and serve to promote continued practices in actual classrooms (Desimone 2009). The cultural practices provided in Macalalag et al.'s program are appropriate for developing into community participation by interpreting SSIs in the contexts of community rather than individual issues. Therefore, based on the results of Macalalag et al.'s study, which reported the changes in individual teachers' knowledge, we look forward to further studies that will expand these changes from the community perspective.

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