Aiming for responsible and competent citizenship through teacher professional development on teaching socioscientific inquiry-based learning (SSIBL)

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Abstract

In order to achieve the goal of scientific literacy for responsible citizenship, the importance of developing students' socioscientific inquiry-based learning (SSIBL) has been recognised by an EU FP7 project, PARRISE, including the essential notions of responsible research and innovation (RRI), and citizenship education (CE). The study aims to investigate pre-service primary science teachers' confidence in and need for further education on teaching SSIBL as well as their reflections -in and -on a three-step model SSIBL activity. Both quantitative and qualitative methods were applied in the study. Quantitative methods were applied to collect data from the 76 participating pre-service primary science teachers in Sweden; participants' confidence and need for SSIBL teaching was investigated via a Likert scale questionnaire. The qualitative descriptive analysis method was used to explore participants' reflection-on-action regarding the three-step SSIBL activity and the SSIBL framework. Thematic analyses were applied to analyse the participants' reflection-in-action concerning the design of the three-step SSIBL activity with three aspects of PCK. The results showed that the pre-service teachers had confidence in SSIBL, but still needed further education on SSIBL teaching. The outcomes of the study suggest that developing teachers' SSIBL teaching competence is important and needed from both of the researchers' points of view and the participating teachers' feedback.

Keywords: Teacher professional development, scientific literacy for responsible citizenship, primary science teacher, socioscientific inquiry based learning

Introduction

Our planet faces major socioscientific challenges in the near future. Climate change, deforestation, depletion of resources, and humanitarian crises in the wake of these are some of the challenges that future generations will need to tackle. Research has identified nine planetary boundaries where human activities threaten our planet's capacity for self-regulation, with potentially unprecedented consequences (Rockström et al., 2009). How to educate tomorrow's citizens to meet such global challenges and make informed decisions is a critically important question for present-day education. Socioscientific issues (SSI) are recognized as good contexts to develop citizens' competence on meeting the challenges. SSI are issues linked to science and technology - authentic, ill-structured problems which are often controversial and involve many stakeholders with different perspectives (Sadler and Zeidler, 2005; Sadler, Barab, and Scott, 2007; Simonneaux, 2008; Chang Rundgren and Rundgren, 2010). In recent decades educational research on SSI has focussed international attention on how to teach and assess students' socioscientific argumentation (e.g. Sadler and Zeidler, 2005; Chang Rundgren and Rundgren 2010; Rundgren, Eriksson, and Chang Rundgren 2017). SSI-based education is also seen as closely related to citizenship education (e.g. European Commission, 2015; Kolstø, 2001). Accordingly, the focus of the article is to investigate pre-service primary teachers' confidence, needs and reflections in relation to socioscientific inquiry-based learning (SSIBL) in the context of the EU FP7 project, Promoting Attainment of Responsible Research and Innovation in Science Education (PARRISE) (www.parrise.com).

Based on the PARRISE project, the conceptual framework of SSIBL addresses central aspects of SSI, including the notions of responsible research and innovation (RRI), citizenship education (CE) and inquiry-based science education (IBSE) (e.g. Knippels, 2015). In the following section research questions are framed through describing the importance of SSIBL, the need for teacher professional development (TPD) and its relation to the European Didaktik tradition, and the role of teacher professional knowledge and reflection.

The importance of SSIBL

While we brace for the abovementioned challenges, science as a school subject is simultaneously experiencing decreased enrolment and a perceived lack of relevance and interest among young people in the industrialised world (e.g. Jidesjö et al., 2009). The irony of this situation is that knowledge of science is key to understanding and finding solutions to the challenges of creating a sustainable future. In response, there has been an increased focus on science education through different efforts to help

young people understand its relevance (e.g. see the review work done by Stuckey et al., 2013). The issue of how to create a science education that is perceived as meaningful, also for students who will not continue to study science, has become an urgent need among science educators. Roberts (2007) has identified two separate visions of science education: Vision One, in which the structure of academic science determines the structure of science as a school subject, and Vision Two, in which societal issues and the question of how science can help solve them influence the structure of science teaching in schools. Both visions are intended to foster scientific literacy among students, regardless of whether they continue to pursue a science career or not. Aligning with Roberts' Vision Two, SSI has been identified as an approach to achieve a science education that is perceived to be relevant by the students. The different roles played by SSI in international literature, including promoting interest in science, science communication, critical thinking, etc., are also supportive of Vision Two (Chang Rundgren and Rundgren, 2010). In other words, SSI-based teaching can be a way not only to achieve a method of science teaching that does not focus entirely on facts and correct answers (as perceived by many students) but also to provide students with a way of using their science knowledge to debate specific SSI. In addition to SSI, IBSE has been emphasised by a number of researchers in science education as a way to increase students' interest in science education and to improve their scientific literacy (e.g. Gyllenpalm, Wickman, and Holmgren, 2010). The notion of inquiry in science education is one of the few overarching themes that cut across school curricula all over the world (Abd-El-Khalick et al., 2004). The inquiry process, i.e., how to pose questions, formulate hypotheses, design experiments to test hypotheses, collect data, draw conclusions, etc., is an important part of science education (e.g., Gyllenpalm, Wickman, and Holmgren, 2010; Lunde, Rundgren, and Chang Rundgren, 2015). In recent years, several EU-projects focusing on IBSE have been funded following the release of the Rocard report (Rocard et al., 2007), which highlighted the usefulness of IBSE in making science education in Europe more motivating for students.

As the core of SSI argumentation, inquiry and the reasoning process play an essential role in making informed decisions (e.g. Chang and Chiu, 2008). However, school teachers find practising SSI teaching and assessment on SSI argumentation difficult (e.g. Christenson and Chang Rundgren, 2015; Pitiporntapin, Yutakom, and Sadler, 2016), while IBSE teaching practices present a similar challenge (e.g. Lunde, Rundgren and Chang Rundgren, 2015). Thus, the teaching and learning of the combination of SSI and IBSE as SSIBL in the PARRISE project is an even greater challenge. Accordingly, the PARRISE project (granted from 2014 to 2017) aims to develop TPD courses to promote pre- and in-service teachers' competence to teach SSIBL at formal and informal primary through upper secondary education levels. These TPD courses are termed SSIBL TPD courses below.

In the SSIBL TPD courses presented in the study, SSI are seen as contexts for inquiry (linking to IBSE), and a three-step model (Vaino, Holbrook, and Rannikmae, 2012; Walan and Chang Rundgren, 2015) was applied as a model SSIBL activity in the SSIBL TPD courses studied. The three-step SSIBL activity embracing: (1) a contextualised step (describing the issue at stake), (2) a decontextualised stage (the inquiry process, designing the method, and collecting data to solve the task), and finally (3) a recontextualised step (using the collected data in the second step to argue for a certain standpoint and make informed decisions). All three steps, or the whole three-step SSIBL activity, contribute to RRI and CE. SSI and IBSE have their visible and concrete roles as teaching approaches in the three-step SSIBL activity, while RRI and CE are invisible and abstract learning goals behind the scenes. By realising the complexity and the difficulty of teaching SSIBL, the need for introducing SSIBL in TPD is recognised by the PARRISE consortium, which comprises 18 partners from 11 European countries.

The need for teacher professional development

TPD programmes constitute the core, not only of the PARRISE project, but also of several of the EU FP7 projects, such as PROFILES (Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science) and ESTABLISH (European Science and Technology in Action: Building Links with Industry, Schools and Home). In the PROFILES project, the focus was on continuing professional development (CPD) programmes developed for in-service teachers, while the ESTABLISH project focused on TPD programmes for pre-service teachers. However, both pre- and in-service teacher groups are taken into account within the PARRISE project.

In recent decades, there has been a growing interest in the importance of teachers' role and their professional knowledge in influencing educational research and student achievement (see Hattie, 2008). However, successful reform of education can never be a question of simply implementing theories; it has been established that teachers must be part of negotiating and implementing the change (Harrison et al., 2008). TPD/CPD can be seen as the medium to facilitate time and space for pre- and in-service teachers' to tackle change or other challenges of education. Even though TPD/CPD has traditionally focused on how educational research can contribute to changes in classroom practice (Hamza et al., 2017), today it is important to give teachers the chance to participate in reforming education, rather than merely being subjected to reforms (Rundgren, 2017). Hamza et al. (2017) have suggested seeing TPD as a two-way encounter between school teaching practice and educational research, in which both practices are mutually influenced in the process, rather than a one-way flow of educational ideas from research to practice. In this vein, there are

different ways to approach TPD/CPD, such as design-based research, action research and learning study which are recognised for their different strengths for diverse groups of pre- and in-service teachers (e.g. Chang Rundgren, 2015).

In Europe, TPD is also related to the tradition of Didaktik, in which teachers' professional judgement and choices are regarded as key factors in implementing educational reforms (Westbury, Hopmann, and Riquarts, 2000). In the tradition of Didaktik, teacher professional knowledge and pedagogical content knowledge have been discussed for decades. Especially in German-speaking countries and Scandinavia, the Didaktik tradition is connected to the German concept of Bildung, for which there is no real equivalent in English. Education and Formation have been suggested as possible translations of Bildung, but neither can accurately express the meaning of the German term. Central to the meaning of Bildung is the notion that knowledge fundamentally changes and develops a human being (Sjöström et al. 2017). Schneider (2012) describes a contemporary understanding of Bildung as a reflexive event relating to the formation of the self. The terms self-determination, freedom, emancipation, autonomy, responsibility, reason, and independence are all suggested to be crucial notions of Bildung (Klafki 2000). Some scholars, especially in the field of environmental education, emphasise a political and even activist dimension of Bildung, suggesting not only education for empowerment and citizenship, but also for emancipation and action-competence (e.g. Mogensen and Schnack, 2010). Accordingly, the authors see a strong connection between the Bildung tradition and the central notions of CE and RRI in the SSIBL framework.

Teacher professional knowledge and the need of reflection

According to Fensham (2009), a teacher in the Anglo-American tradition is more of an 'agent of the system', and the content being taught is more regulated by the authorities than in the Didaktik tradition. Still, in the Anglo-American tradition, there are suggestions about how to highlight teachers' professional knowledge and judgement. In the American tradition, teachers' professional knowledge is considered to include pedagogical knowledge (PK), content knowledge (CK), and pedagogical content knowledge (PCK). Shulman proposed the concept of PCK to describe the unique knowledge of teachers who teach specific school subjects (Shulman, 1986; 1987). More recently, Shulman has further asserted that PCK (including learners' learning difficulties, curricula, assessments, etc.) is a dynamic construct that describes what teachers enact when they are confronted with "the challenge of teaching particular subjects to particular learners in specific settings" (Shulman, 2015, 9).

Besides PCK, Fuller and Bown (1975) have identified three stages of concerns characteristic of the teaching profession. The first stage involves concerns about one's adequacy and survival as a teacher, class control, being appreciated by pupils, and

being evaluated. The second stage includes concerns about teaching situations related to, for example, methods and materials. The third stage relates to reflections about pupils, their learning, and their social and emotional needs. The experience of becoming a teacher involves the management of all three stages. However, the applicability of such stage-based models has been questioned and discussed (Burn et al., 2000). Reality may be more complex than what can be captured by such a model, although models can be a simple roadmap for orienting oneself in the terrain of becoming a professional teacher.

In addition to teacher professional knowledge, pre-service teachers' teaching needs have been discussed in teacher education literature (e.g. Nilsson, 2009; Nilsson and Loughran, 2012). Identifying some of the major aspects of what teacher students need to acquire and learn in the process of becoming a teacher can be helpful in teacher education. For example, Nilsson (2009, 253) has identified four overarching teaching needs for pre-service teachers, which were all recognised in the SSIBL TPD course design in the study:

- The need for good content knowledge in order to explain phenomena to pupils and connect scientific concepts to everyday situations (using SSI as the context and the inquiry process in the SSIBL TPD courses).
- The need to have a large repertoire of experiments and activities (through the three-step SSIBL activity conducted in the SSIBL TPD courses).
- The need to know about pupils' earlier experiences, general classroom organisation, and learning needs (through PCK reflection in groups in the SSIBL TPD courses).
- The need to know how to be self-reflective (through PCK reflection and SSIBL classroom group design in the SSIBL TPD courses).

In recent years, the concept of reflection has been much addressed in TPD/CPD, but it is not a new idea. Schön (1983) pointed out two kinds of reflection - reflection-in-action (reflection during an event) and reflection-on-action (reflection on a past event) - and addressed their critical role for professionals. Thus, teachers' reflections in and on actions were emphasised in the study, not only for the groups of pre-service primary teachers, but also, for the teacher educators (the authors). Pre-service primary teachers, in one instance, reflected 'on-action' after experiencing a three-step SSIBL activity themselves. In another exercise they were supported with 'reflection-in-action' while designing their own SSIBL activities for 4-6 graders using a PCK reflection tool (including the three main aspects of curriculum, students' learning difficulties, and assessment). As teacher educators, we reflected on our implementation of the first SSIBL TPD course as a whole. We then considered the practical constraints of our teacher education programme (for the second cohort) while also taking into account

reflections on the pre-service teachers' performances in the course in order to redesign the next course in the third cohort. The detailed research contexts and the TPD courses with the three cohorts are presented in the methods section.

The aim and research questions

Based on the context of SSIBL TPD courses presented in this article, the study has a two-fold aim: (1) to investigate pre-service primary science teachers' confidence and needs concerning SSIBL, and (2) to explore the pre-service teachers' reflections after experiencing and while designing the three-step SSIBL activities.

The specific questions are:

1. What are the pre-service primary science teachers' confidence levels and needs before and after the three cohorts of SSIBL TPD courses? Is there any difference between the three cohorts?

2. How do the pre-service primary science teachers reflect on the SSIBL framework (after experiencing the three-step SSIBL activity) and the PCK aspects of SSIBL (while designing their own three-step SSIBL activities)?

Method

A mixed-methods approach was applied in the study to gather evidence on the pre-service primary teachers' confidence levels and SSIBL teaching practice needs, as well as their reflections in and on the three-step SSIBL activity (Appendix 1). In the following section, the context of the study, the participants, and the data collection and analyses are delineated.

The context of the study and the participants

The SSIBL TPD courses were embedded in a TPD programme run at one of the biggest and most well-regarded universities in Sweden which provides regular courses for pre-service primary teachers. In the research context, the pre-service teachers needed to study one semester of science and technology education courses for grades 4-6, and the SSIBL TPD courses were embedded into that semester as part of the programme.

In accordance with the PARRISE project, teacher educators' reflections influenced the design of two rounds of SSIBL TPD courses by PARRISE consortium members in their local TPD programmes. In the case presented in this article, the

two rounds of the SSIBL TPD courses were designed and implemented for the first time in autumn 2015, with the second round planned for autumn 2016 based on the authors' (also the teacher educators') reflections on the pre-service teachers' responses. However, due to the need to have this course every semester (two semesters per year in our university education context), and the fact that the authors could not join the course in person, a distance course was conducted in spring 2016. A third course took place in autumn 2016. Therefore, a total of three cohorts of SSIBL TPD courses through three different instructional designs in three cohorts were developed and implemented.

The three cohorts' instructional designs shared both differences and similarities. The content was the same, but the total time and the sequencing of content were different; the first cohort followed an onsite top-down (OSTD) approach, the third cohort an onsite bottom-up (OSBU) approach (Table 1), while the second cohort was conducted via videotaped lectures - distance top-down (DTD) approach,. But still, the pre-service teachers were asked to do PCK reflection while designing their SSIBL classroom activities. Distance education and its effects have been discussed since the 20th century (e.g. Sumner, 2000), and hence it is also of interest to know its effect with regard to the SSIBL TPD course in this study. Accordingly, this study aims to investigate three groups of pre-service science teachers' confidence levels and SSIBL teaching needs within three different cohorts (OSTD, OSBU and DTD) in the SSIBL TPD courses.

As previously mentioned, the three cohorts were organised between autumn 2015 and autumn 2016, over three semesters. The detailed timeline and the number of participants are shown in Table 1. The three groups of pre-service teachers (a total of 76 participants) were seen as three cases occurring in a TPD programme focusing on developing pre-service teachers' competence in teaching science and technology. As argued by Yin (2009), the boundary between the phenomenon and its context is blurred, so the loose definition of case study was adopted, which is to see the case in its context.

Table 1. The number of participants in each instructional group.

Instructional group/cohorts	Semester	Timeline	Participants	Validated samples
OSTD	Autumn 2015	10 hours face-to-face lectures/activities over three days	28	26
DTD	Spring 2016	10 hours distance lectures over three days	24	23
OSBU	Autumn 2016	6 hours face-to-face lectures/activities in one day	24	22
Total			76	71

The data collection, instruments and data analyses

In order to answer research question 1, quantitative pre- and post-cohort questionnaires relating to the pre-service teachers' perceived level of confidence and SSIBL teaching needs were conducted using the Likert scale, before and after each cohort. The validated data shown in this article were from the 71 participants (20 males and 51 females) who completed both the pre- and post-cohort questionnaires. The dropout rate was approximately 7%, which was judged acceptable. Concerning the bias that might have been generated through the Likert scale survey, it is worth noting that the authors were not involved in participants' final examination tasks. The limitations of the study were the small sample size and unequal distribution of the genders, but these factors were unavoidably dictated by the actual context (i.e., regular, mandatory courses).

The data included the pre- and post-cohort questionnaires, including the two main aspects of teachers' confidence in the teaching strategies and their need for further education (scored 1 to 7 from 'not so confident' to 'very confident'). There were 10 items in the pre-cohort questionnaire (Appendix 2) on SSI and IBSE teaching and an additional five items were added for SSIBL teaching (since the concept of SSIBL was new for the participants), to the post-cohort questionnaire (Appendix 3). Additionally, another five items (also Likert scale) were added to obtain the participants' general feedback on the courses (scored 1 [disagree strongly] to 6 [agree strongly], and 0 [I do not know]) (Appendix 3). The data analyses involved descriptive analysis and one-way ANOVA statistics (SPSS version 23). The

significance was examined using the Mann-Whitney U test as a nonparametric test to compare the outcomes of two independent groups.

In addition to the pre- and post-cohort questionnaires on teachers' confidence and needs, two kinds of PCK reflection sheet were developed for 'reflection-on-action' and 'reflection-in-action' to answer research question 2. The reflection sheets (relating to the SSIBL activities developed for primary education by the teacher students during three rounds of TPD courses) were completed in groups of 2 to 4. The 'reflection-on-action' sheet was used after the teacher students had experienced a three-step SSIBL activity (Appendix 4) and were reflecting as a group on the link between the three-step SSIBL activity and the SSIBL framework (including SSI, IBSE, CE, and RRI). The PCK reflection sheet was developed to support the pre-service teachers' reflection-in-action while designing a SSIBL activity for 4-6 graders (Appendix 5). The qualitative reflection data of nine groups from the three cohorts were collected. Descriptive analysis was used to investigate the participants' reflection-on-action regarding the three-step SSIBL activity and the SSIBL framework. Thematic analyses (Guest, MacQueen, and Namey, 2011) were applied to analyse the participants' reflection-in-action on the design of the three-step SSIBL activity with the three aspects of PCK.

The second group developed a lampshade. The students obtained a broken sphere, a light bulb and batteries from the storage room. They voiced their intent to build a lampshade using these materials. One of the students set an electric circuit using materials such as the cable, light bulb, and battery, and came up with a working lamp. To adorn the chandelier, the students used paper in various colors. The students installed their light bulbs in the chandelier they built, only to realize that it did not produce sufficient light. Through further deliberation, they decided that they needed to increase the number of batteries in order to increase the amount of light produced. The students in the group thought about how to increase the amount of illumination, and reached the conclusion that using a larger bulb would help. The students brought a larger light, but failed to find a socket to install the larger bulb. Realizing also that they would not be able to operate it with batteries only, they thought of using a cable and a plug. The teacher brought a broken floor lamp from home, after securing the potentially hazardous sections and the plug and the cable using a tape. After attaching this cable to the chandelier, they connected it to the mains, and came up with a working means of lighting in the end. Figure 2 presented below is a compilation of the photos of the activities of the group members.

Results

The pre-service primary science teachers' confidence and needs

The pre-cohort questionnaire results revealed that all participants had low confidence on SSI teaching (mean = 3.637) and IBSE teaching (mean=2.907), in addition to a strong need for further education, indicated for both SSI teaching (mean=4.935) and IBSE teaching (mean = 5.468). After the SSIBL courses (Table 2), confidence on SSI and IBSE teaching increased in all three cohorts, with the average scores being over five, and the same results for SSIBL teaching. Confidence outcomes on SSI, IBSE and SSIBL teaching differed significantly between the OSTD and DTD groups in all three aspects. The need for further education on SSI and IBSE teaching after the TPD courses decreased from mean scores of 2.670 to 3.225 across the three cohorts. Generally, the OSTD group showed less need after the course for all the three aspects of teaching, but the DTD group had a significantly higher need for further education in IBSE and SSIBL teaching. All participants were positive about the SSIBL TPD courses.

Table 2. The post-cohort survey.

Categories of the survey oups			Mean	Std. Deviation	Significance (*P < 0.05)
Confidence	SSI teaching	OSTD	6,315	0,6839	OSTD>DTD*
		DTD	5,339	1,3490	
		OSBU	5,864	0,9121	
		Total	5,859	1,0746	
	IBSE teaching	OSTD	5,923	1,0057	OSTD>DTD*
		DTD	4,713	1,8279	
		OSBU	5,209	1,2413	
		Total	5,310	1,4606	
	SSIBL teaching	OSTD	6,177	0,9214	OSTD>DTD*
		DTD	4,783	1,7683	
		OSBU	5,427	1,4079	
		Total	5,493	1,4905	
Need for further education	SSI teaching	OSTD	2,177	1,3557	No significant difference
		DTD	3,209	1,8901	

		OSBU	2,691	1,7617	
		Total	2,670	1,7018	
	IBSE teaching	OSTD	2,354	1,3895	OSBU > DTD >OSTD*
		DTD	3,470	1,9255	
		OSBU	4,000	0,0000	
		Total	3,225	1,5314	
	SSIBL teaching	OSTD	2,108	1,5422	DTD>OSTD*
		DTD	3,470	2,1085	
		OSBU	3,236	1,9100	
		Total	2,899	1,9278	
General feedback on the SSIBL course		OSTD	4,700	1,5139	No significant difference
		DTD	3,635	1,5417	
		OSBU	4,436	1,6197	
		Total	4,273	1,6008	

The pre-service primary science teachers' reflections on the SSIBL classroom activities

A reflection sheet similar to Table 3 was provided to all participants (nine groups) from three cohorts of the SSIBL TPD courses. Each group needed to reflect on each element of the SSIBL framework in the three-step SSIBL activity which they had experienced during the specific lesson, with an X in each element, if they found the link (Appendix 4). The results showed that only one out of the nine groups could reflect on all the elements of the SSIBL framework with all three steps of the three-step SSIBL model (see Table 3). CE was less reflected in Step 2, and RRI was less reflected in steps 1 and 2. All groups focused on IBSE in Step 2, while step 3 had the most focus on the context of SSI.

Table 3. Numbers of groups that made the link between the SSIBL framework and each step of the three-step SSIBL activity.

The three-step SSIBL model	SSIBL framework	The number of groups showing the link/total groups
Step 1 Contextualisation	**CE**	**6/9**
	RRI	**3/9**
	SSI	**8/9**

(SSI context)	**IBSE**	**2/9**
Step 2 **Decontextualisation** **(Inquiry process)**	**CE**	**4/9**
	RRI	**4/9**
	SSI	**1/9**
	IBSE	**9/9**
Step 3 **Recontextualisation** **(Decision-making/argumentation)**	**CE**	**8/9**
	RRI	**8/9**
	SSI	**5/9**
	IBSE	**1/9**

Concerning PCK reflection while designing the three-step SSIBL activity, and the first of the three main aspects of curriculum, students' learning difficulties, and assessment, the results showed that the curriculum goal of providing students with action competence (i.e., to have sufficient knowledge and confidence to act) was present in all the groups across the three cohorts of the SSIBL TPD courses:

We want our students to develop action competence concerning environmental issues and become aware of the consequences of their own behaviour.

(One of the groups in the first round of TPD)

There was no consensus about students' learning difficulties throughout the three rounds of TPD, other than that awareness of typical learning difficulties connected to certain concepts or aspects of the content was needed:

Knowing typical learning difficulties is important.

(One of the groups in the third round of TPD)

All groups during all the three rounds of TPD agreed on the use of formative assessment:

We will use this assessment method [students' written argumentation] formatively, using group and individual feedback. We want to show the group's progression during the teaching sequence – from emotional to fact-based…

(One of the groups in the third round of TPD)

Further, the pre-service teachers suggested different forms of formative assessment were found in the teachers' feedback:

We will use exit tickets for the students to show their thoughts about the issue.

(One of the groups in the second round of TPD)

Conclusion and discussion

The results of the study showed that the pre-service primary teachers for grade level 4-6 did not have high confidence and demonstrated a need for further education concerning SSI and IBSE teaching before the SSIBL TPD courses. However, after the TPD courses, the teachers were found to have increased their confidence on SSI, IBSE and SSIBL. There remained, however, a compelling need for further education. Based on the findings, in line with other scholars' discussions (Sadler, Barab, and Scott, 2007; Rundgren, Eriksson, and Chang Rundgren, 2017), the complexity of SSI and its teaching practice was recognised to some degree by the pre-service teachers. Additionally, the embedded concepts of RRI and CE, as well as the skills of inquiry and teaching about SSIBL, were perceived to be difficult. This is also supported by the participants' reflections on the SSIBL framework and the link to the SSIBL three-step activity. Only one of the nine groups saw the link between all the elements of the SSIBL framework and the three steps of the SSIBL activity. Besides, it was found that the pre-service teachers' reflections on RRI were mainly linked to the recontextualised (argumentation) step of the SSIBL three-step model (Step 3), and less so in steps one and two. This could strongly influence their SSIBL teaching practices to address less RRI in the context (Step 1) and inquiry process (Step 2). However, aiming for the promotion of scientific literacy for responsible citizenship (e.g. European Commission 2015), developing citizens in different professions to reflect upon RRI starting from the issue, its context, and the whole inquiry process is of importance. The question of how to make CE and RRI visible with concrete roles in SSIBL teaching practices still requires more research. In sum, the results highlight the need for more SSIBL TPD courses – not only in Europe, but also globally.

Regarding instructional design of the future SSIBL course, the findings suggest that distance education was not helpful in developing the teachers' confidence to teach SSI, IBSE and SSIBL. Whether approaches to SSIBL TPD designs were top-down or bottom-up there was no significant difference in participants' confidence or need for SSI, IBSE and SSIBL teaching after the courses. Since this study was time-constrained (6-10 hours in total for each cohort), further research on how to organise the SSIBL TPD courses is needed. Teachers' reflections in the SSIBL TPD courses

revealed awareness of 'using formative assessment as a tool to promote school students' learning'. Apart from the other goals stated in the curriculum, the pre-service teachers repeatedly stated the development of action-competence (Mogensen and Schnack, 2010) in their students as a goal, which may reflect a focus on the use of knowledge in everyday contexts in their teacher training as stated in their teaching needs (Nilsson 2009). Furthermore, the teachers highlighted the need to not only use summative assessment to grade students, but also formative assessment to enhance the development of students' SSIBL. This highlights a special concern that teaching and learning is related to assessment and should be embedded in TPD/CPD programmes.

This study demonstrates the importance of teachers and teacher educators reflecting 'in and on' teaching practices (Schön, 1983), and that providing more SSIBL TPD courses can be an important contribution to future education (Knippels, 2015). Our findings reflected on the importance of TPD (for both in- and pre-service teachers), especially teacher professional knowledge (including CK, PCK and PK) (Shulman, 1986; 1987), teaching needs (Nilsson, 2009) concerning SSIBL. The need for relating content knowledge to everyday situations, providing experiences, knowing students' needs, and reflection were all identified as important aspects in the study. However, one more need should be added, which is about 'learning to adapt'. In the study, the authors faced the challenge of not being able to be physically present, while time for the third cohort in the TPD programme was shortened. Consequently, the teaching content was adapted, and collaborative reflection was required to develop a new instructional design for another onsite teaching course. It turned out that the participants' similar learning outcome was found in the cohort one, on-site teaching. In addition, one aspect concerning teaching needs should be added, which is about 'stakeholders'. Teaching needs are also learning needs, and the needs for teaching SSIBL were, in this case, pre-service teacher and teacher educator needs, but they can also be in-service teacher needs. The same needs are relevant for SSIBL in school at all levels, in higher education, and for the public.

In sum, this study stresses the need for developing more SSIBL TPD courses internationally, which is one way to enhance teachers' competence to direct SSIBL. The ultimate goal, however, is to help tomorrow's citizens and school students develop their competence in making informed and responsible decisions about SSI, which are the issues currently challenging both our planet and individual lives.

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Appendix 1. 3-step SSIBL activity

How can we avoid energy losses in our school?

A 7th to 9th grades' students module for use in natural sciences and chemistry and physics sciences

Overall Competencies: With this task, students are supposed to investigate how school manages energy use, in order that the school remains warm during the winter and cold during summer time. For that, students are expected to:

- Develop a plan for resolving the initial problem (How can we avoid energy losses in school?).
- Identify places and "equipments" from where energy losses or gains might occur, during winter as during summer.
- Search for information and, based on that, suggest a number of actions for reducing energy transference.
- Develop a pamphlet or a model about ways to render school energetically efficient and present it to the school community.

Curriculum content: Energy and heat.

Kind of activity: Developing and carry out an investigation to find out the energy resources used in school and how to avoid energy losses in school; group work on making a justified decision after discussion on an efficient way to avoid energy losses.

Anticipated time: 4 lessons plus students' investigation in school

Prior knowledge: Type of energy resources.

The developer: Revised from PARSEL project

Appendix 1. 3-step SSIBL activity (contd.)

Steps	Time cost	Content of the activity	Classroom management	Learning objectives
1. SSI context	45 mins	***How can we avoid energy losses in our school?*** 1. Let students discuss what energy is and how to measure energy? 2. Let students discuss and what kinds of energy resources that our school use?	1. Small group discussion first 2. Whole classroom shareing	• Understand the definition of energy and how to measure energy • Understand how energy is needed and used in everyday life

		3. Let students discuss whether there is any possibility to waste energy in school?		
2. Inquiry process	45mins X 2	1. Let students discuss how to plan an investigation on evaluating energy losses in school. 2. Let students conduct the investigation in the school environment for real	Group work	• Apply the knowledge of energy obtained from the first lesson. • Experience an inquiry process.
3. Decision-making/ Argumentation	45mins	Let students present the results of their investigation in the classroom and provide the answer to '*How can we avoid energy losses in school?*'	Group oral presentation and possible a written report from each group	• Learning to make an argument based on the evidence or information collected in the inquiry process.

Appendix 2. Background and confidence/need survey (pre-cohort questionnaire)

Name:_____

Gender: □ Female □ Male

Teaching experiences:

- How many years have you taught in school? _____ Years _____

What do you expect from this course?

- _____

Aspects of your teaching practices	To what degree, am I confident on it? 1 (not so confident) → 7 (very confident)	To what degree, do I still need (help) to develop? 1 (not so need) → 7 (very need)
1. I understand **SSI**		
2. I understand **why** we need to **use SSI in teaching**		
3. I know **SSI** is part of **Swedish curriculum**		
4. I know **how to plan SSI teaching**		
5. I know **how to teach SSI**		
6. I understand **inquiry-based science education (IBSE)**		
7. I understand **why** we need to **use IBSE in teaching**		
8. I know **how to plan inquiry-based teaching**		
9. I know **how to teach inquiry-based science**		
10. I know **inquiry-based science education** is part of **Swedish curriculum**		

Appendix 3. Post-cohort questionnaire

Name:

(1) After the SSIBL course, how do you feel in the following aspects?

Aspects of your teaching practices	**To what degree, am I confident on it?** **1 (not so confident) → 7 (very confident)**	**To what degree, do I still need (help) to develop?** **1 (not so need) → 7 (very need)**
1. I understand **SSI**		
2. I understand **why** we need to **use SSI in teaching**		
3. I know **SSI** is part of **Swedish curriculum**		
4. I know **how to plan SSI teaching**		
5. I know **how to teach SSI**		
6. I understand **inquiry-based science education (IBSE)**		
7. I understand **why** we need to **use IBSE in teaching**		
8. I know **how to plan inquiry-based teaching**		
9. I know **how to teach inquiry-based science**		
10. I know **inquiry-based science education** is part of **Swedish curriculum**		
11. I understand **SSIBL**		
12. I understand **why** we need to **use SSIBL in teaching**		

13. I know **how to plan SSIBL teaching**		
14. I know **how to teach SSIBL**		
15. I know **SSIBL** could be a powerful approach to enhance students' competence in the modern society		

(2) Please present your feedback on the SSIBL course

Items	**Disagree strongly**	**Disagree**	**Disagree a little**	**Agree a little**	**Agree**	**Agree strongly**	**I do not know**
1-1 The SSIBL course added my knowledge to know how to combine SSI and inquiry-based teaching as SSIBL teaching	☐	☐	☐	☐	☐	☐	☐
1-2 The SSIBL course helped me to understand the complexity of SSI	☐	☐	☐	☐	☐	☐	☐
1-3 The SSIBL course promoted my learning interests and motivation to teach science	☐	☐	☐	☐	☐	☐	☐
1-4 I would like to participate the SSIBL related course again in the future	☐	☐	☐	☐	☐	☐	☐
1-5 I will like to explore SSIBL knowledge by myself in the future after the SSIBL course	☐	☐	☐	☐	☐	☐	☐

Appendix 4. Reflection-on-action sheet

The 3-step SSIBL model	RRI and the 3 pillars
Step 1 Contextualization (SSI context)	□ CE
	□ RRI
	□ SSI
	□ IBSE
Step 2 De-contextualization (Inquiry process)	□ CE
	□ RRI
	□ SSI
	□ IBSE
Step 3 Re-contextualization (Decision-making/argumentation)	□ CE
	□ RRI
	□ SSI
	□ IBSE

Appendix 5. The PCK reflection instrument for reflection-in-action.

PCK aspects	Aspects to reflect	Your reflection and plan
1. Curriculum	What do you intend your students to learn (learning objectives) through the SSIBL-module?	
	Why are the learning objectives important for your students to learn?	
2. Students' understanding and/or learning difficulties	What do you know about the learning difficulties/ alternative ideas the students might have regarding the SSIBL-module?	
3. Assessment	What assessment method(s) are you going to use to assess the students' development from this the SSIBL module?	
	Why do you choose the assessment method(s)?	
	How are you going to use the assessment method(s)?	