Exploring the negotiation of the meaning of laboratory work in a continuous professional development program for lower secondary teachers

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Abstract

This study aimed to explore lower secondary teachers' negotiation of the meaning of laboratory work in a professional development program. A total of 15 in-service teachers participated in the program. In the program, tensions between key ideas concerning traditional way of addressing laboratory work – with emphasis on subject content and skills – versus key ideas concerning laboratory work as a way of imitating aspects of real-world scientific practices – with emphasis on nature of science as process – was highlighted. The tensions between these key ideas were used in the program as a starting point to frame group discussions and negotiations among the teachers about purposes of laboratory activities. The participants were grouped into three and audio recordings of group reflections and group interviews were used as sources of data for analysis. The results also showed that there were differences between the groups in how they addressed the processes of meaning making of laboratory work. There were two groups of teachers challenged themselves and each other and developed an explicit awareness of tensions between different objectives of laboratory activities. However, a third group of teachers never did the same way of challenging and there is no indication of explicit awareness of different purposes of laboratory work in the data material from the group.

Keywords: laboratory work, inquiry-based science teaching, negotiation, continuous professional development

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Introduction

In line with an international trend that emphasizes scientific literacy for citizenship (Roberts & Bybee, 2014), both the current Swedish curriculum, launched in 2011, and its predecessor, launched in 2000, established that compulsory school science should prepare all students to deal with science as a part of society (National Agency of Education, 2000; 2011). The development of students' critical attitudes towards different kind of knowledge claims during their education is considered to be essential to achieve this goal because it will develop their competences on assessing knowledge claims and to use knowledge claims in various situations outside of school. Learning about science and its nature is considered to be central to developing such citizen competences (Jiménez-Aleixandre & Puig, 2012). Therefore, knowledge about scientific methods and the factors that characterize the production of reliable scientific information are important. The current Swedish curriculum (National Agency of Education, 2011) highlights the acquisition of such knowledge as one of the most important objectives of laboratory work in school science lessons. However, in the last fifty years, there have been several changes in our understanding of how scientific knowledge is produced and the characteristics of the processes that produce it (Latour, 1987; Kuhn, 1962; Ziman, 1968). Together with the growing emphasis on scientific literacy for citizenship, these new perspectives on the production of scientific knowledge mean that we must ask whether there is a need to rethink aspects of laboratory work in school science. If so, there is a need to investigate teachers' awareness of these aspects and to articulate their potential impact on the aims and content of laboratory work in schools, as well as the teaching methods used within them.

Laboratory work has a long history in science education and is commonly regarded as a way of communicating science content while also introducing general skills associated with laboratory work (Lunetta, Hofstein & Clough, 2007). This is consistent with the results of several Swedish studies, which found that laboratory work was primarily emphasized as a method for teaching science content and the related skills rather than a way of modelling scientific practices (Högström, Ottander, & Benckert, 2006; Andrée, 2007). Various researchers have criticized such 'traditional' approaches to laboratory work, arguing that they are based on naïve views of science (Windschitl, 2004). A picture of scientific methods as inductive processes that use observations to draw general conclusions has been and still is dominant in school science (DeBoer, 1991; Windschitl, Thompson, & Braaten, 2008). This picture of science is also ubiquitous elsewhere in the educational system, notably in science textbooks (Windschitl, 2004). However, as described above, there have been dramatic changes in our understanding of how scientific knowledge is developed and the characteristics of the processes that drive its development. In addition, there have been significant changes in the role of scientific research and its interactions with society. These changes have affected both society and science itself (Latour, 1998). Accordingly, most school science students acquire unrealistic views of the process of science in general, and science-in-the-making in particular. Kolstø (2010), Hudson (1996), Millar (2004), and Windschitl, Thompson, & Braaten (2008) among others, argue that practical work in general and laboratory activities in particular could be used to model certain aspects of scientific practices. If it is accepted that laboratory activities have a crucial role in developing students' understanding of science-in-the-making, there is a need to discuss the role of laboratory activities in school science. In particular, it is necessary to determine how laboratory activities can be framed to fulfill these new requirements and ensure that they produce outcomes that are consistent with the specified objectives of science teaching and learning.

However, changes in the purpose, content and teaching methods of a curriculum are never implemented in a vacuum. Rather, they are implemented within a compact body of existing practices into which science teachers are cultivated via their exposure to long-established teaching traditions and school cultures. Existing practices are also reinforced by well-established artefacts such as science textbooks, pieces of laboratory equipment, and laboratory instructions. This long tradition of laboratory work in school science influences teachers' responses to changes in the purposes and content of the curriculum (Gyllenpalm, Wickman, & Holmgren, 2010a). Therefore, to enhance teachers' professional development, it is important to give in-service teachers time and space to reflect on teaching practices and the ideas embedded within new curricula (Bryan & Abell, 1999; Parke & Coble, 1997). Accordingly, we have established a continuous professional development (CPD) program for in-service teachers that explores the purpose of laboratory work in school science as well as its contents and associated teaching methods. The study presented herein aimed to determine if and to what extent it is fruitful to let teachers participate in group reflections on explicit tensions between the purposes of laboratory activities in the teaching tradition and their use to model 'real world' scientific practices in inquiry-based science teaching to teach about nature of science as process. To facilitate such reflection, the key features of the traditional and inquiry-based approaches were stated explicitly and used as starting points from which the teachers could negotiate meaning within their own laboratory practices. This was done because we anticipated a need to take teaching traditions into account and to challenge them when introducing inquiry-based laboratory work as a mean to teach about nature of science as science-in-process.

Inquiry-based science teaching to enhance students' scientific literacy for citizenship

Kolstø (2001) argues that a huge part of the science knowledge encountered in everyday life is related to research frontiers. This knowledge, which is generally not supported by a consensus among scientists, can be referred to as tentative science-in-the-making and stands in contrast to traditional textbook science, which can be described as established consensual scientific knowledge (Bingle & Gaskell, 1994; Latour, 1987). If knowledge from research frontiers is commonly encountered in everyday life, it becomes relevant and important for students to distinguish between reliable 'established science' knowledge and tentative knowledge claims from research frontiers, and to understand their differences. This implies that it is essential to ensure that school science students acquire some knowledge about the process of science, whereby claims from research frontiers either disappear from the scientific field or become established as reliable knowledge (Bingle & Gaskell, 1994; Kolstø, 2001). It is also important for students to develop knowledge about the characteristics of the consensus-building processes that lead to the establishment of consensual knowledge in the long run (Bauer, 1994; Driver, Leach, Millar & Scott, 1996; Ziman, 1968).

These processes can be described in terms of the way researchers at the research frontier must develop multiple hypotheses to explain a given set of observations and then assess their durability. The establishment of a consensus concerning new scientific knowledge requires agreement among researchers regarding the validity of the relevant experiments and data, as well as their relevance to the hypotheses in question (Ziman, 1968). An underlying premise here is that there is no single scientific method, but rather several approaches that are practiced within boundaries defined by certain frames and rules (Kuhn, 1962). The purpose of these endeavors is to make theoretical claims about reality general and reliable. When a new hypothesis is proposed, researchers try to assess its credibility by discussing the new theory in light of accessible empirical evidence and the massive network of existing established knowledge. Experiments are performed and reported to support and defend specific interpretations or theoretical positions (Jiménez-Aleixandre & Erduran, 2007). From the perspective of Toulmin's model of arguments, experiments and observations can be seen as data that are used to support claims (Toulmin, 1958). Experimental reports, published articles, and conference presentations thus constitute a kind of argumentation in which data are used to support a specific interpretation that is linked to theoretical claims in an on-going discussion within a scientific discipline (Kolstø, 2007; Ziman, 1968). The aim is to convince other researchers of the advantage of one theoretical interpretation over another. Consequently, the communication of interpretations always involves argumentation. The desired outcome of this process is the establishment of a discipline-spanning consensus regarding the hypotheses in question. This perspective makes argumentation a core feature of science that permeates both the construction and criticism of scientific knowledge (Ford, 2008). The frontier of research represents the starting point of a process that allows new knowledge to develop from tentative science-in-the-making into established consensual textbook science.

Highlighting the public dimensions of scientific knowledge in this way emphasizes the social character of science. Established knowledge is a result of acceptance in the broad research milieu, and can be characterized as knowledge that no one considers productive to question further (Bingle & Gaskell, 1994). Together with the overarching aim of reaching consensus, social activities such as discussions, debates and controversies among researchers have been described as key components of science (Driver et al., 1996). This way of describing science-in-the-making can contribute to a more nuanced picture of scientific knowledge and makes it possible to examine scientific knowledge on different epistemological levels (Kolstø, 2001). Instead of using rough categorizations such as truth and falsehood, one can discuss knowledge claims in terms of the quality of their supporting arguments. This description of the scientific process can fruitfully illuminate the ways in which different scientific knowledge claims can have different characters and epistemological statuses without undermining established scientific knowledge. We believe that if these ideas were conveyed during school science courses, students would be better able to critically assess information encountered during day-to-day life in terms of science-in-the-making and established science.

Using inquiry-based activities to model scientific practices

Following from the line of argument above, the ability to critically assess scientific knowledge claims encountered in daily life depends on an understanding of the processes by which claims from the research frontier become established (or fail to do so) and consensus-building creates established knowledge (Kolstø, 2001). Laboratory work, which reflects some crucial aspects of scientific practices, is commonly regarded as necessary but not sufficient for the development of knowledge concerning scientific practices and the underpinning epistemology, both of which are necessary for scientific literacy (Driver et al., 1996; Ryder, 2002). To make laboratory activities fruitful, students require explicit guidance and instruction along with opportunities to reflect on the crucial aspects of the nature of scientific practices as well as their underlying epistemological assumptions (Abd-El-Khalick et al., 2004). This includes not only *learning about* and *learning to conduct* scientific inquiries (Hodson, 1996; Windschitl et al., 2008), but also learning about broader perspectives such as science as a consensus building processes, an argumentative research community, and a part of society (Driver et al., 1996; Kolstø, 2010; Wong & Hodson, 2009). Based on the importance of the process of science and related scientific practices, we define inquiry-based science teaching (IBST) as any activity that models (and thus mirrors) the epistemic characteristics of *science as a collection of methods; science as a collection of argumentative research communities;* and *science as part of society* with the purpose to teach about nature of science as science-in-process.An understanding of these different aspects of science will give students the functional tools they require to critically assess information they encounter in their everyday lives (Kolstø, 2001).

In order to obtain an adequate epistemological picture of scientific practices through laboratory work, students must have the opportunity to conduct open-ended inquiries while still receiving guidance concerning what should be investigated and how to carry out the investigations (Duschl, 2008; Hodson, 1996). In addition, the inquiries should be integrated with the rest of their scientific education rather than being conducted in a vacuum, and should start with a question whose answer was not covered elsewhere in their studies or a hypothesis that is rooted in everyday knowledge (Hodson, 1996; Windschitl et al., 2008). In addition, the activities should reflect those aspects of scientific and epistemic practices that are important for assessing and understanding the status of different knowledge claims within different contexts (Kolstø, 2010). However, the implementation of IBST as described above is not straightforward. This is partly because laboratory work has a long tradition in science teaching, which will influence how teachers responds to changes in the purpose, content, or recommended teaching methods of existing curricula (Windschitl, 2004). These challenges are discussed further in the next section.

Inquiry-based activities in the Swedish teaching tradition and Swedish curricula

As mentioned above, the long tradition of laboratory work in science education may influence teachers' responses to and interpretations of externally recommended laboratory teaching practices based on existing curricula. The Swedish curricula introduced during the reforms of 2000 and 2011 presented inquiry-based science activities as means of developing students' critical thinking abilities, and national tests that incorporated investigative tasks were introduced in 2009. However, analyses of recent Swedish studies and the current state of the art in school laboratory work clearly show that there is a growing gap between the teaching tradition and IBST as described in the new curricula. Laboratory work in traditional Swedish school science lessons was dominated by cookbook style verification-based activities with an emphasis on conceptual learning (Andrée, 2007; Gunnarsson, 2008; Gyllenpalm, Wickman & Holmgren 2010a, Högström, Ottander& Benckert, 2006). In addition, Högström et al., (2006) demonstrated that science teachers did not regard the understanding of scientific methods and the nature of science as an important learning outcome. Despite this, Gyllenpalm et al. (2010a) identified several activities that resembled inquiry as conceptualized in the science education literature in some respects but which lacked some of its essential elements. For example, the concept of a research question was not used to structure the activities; "hypothesis" was primarily used as a synonym of "prediction" in the sense of "a guess about an outcome"; an explicit focus on teaching about the characteristics of scientific inquiry was uncommon; and finally, "inquiry", "hypothesis and "experiment" were primarily used as pedagogical tools. All of the above-mentioned studies also showed that there is a tendency to conflate inquiry's roles as *a learning outcome* and *a teaching method* (Gyllenpalm, Wickman, & Holmgren, 2010b). These tendencies were confirmed by a later study which identified tensions between inquiry as emphasized in the curriculum and traditional laboratory work (Lunde, Rundgren & Chang Rundgren, 2015). In this study teachers responded to the curriculum's emphasis on IBST by developing hybrid activities that included elements from both IBST and the traditional approach. These activities combined traditional laboratory work with systematic investigations inspired by the newly-introduced national tests in a somewhat haphazard way, without any clear distinction between the two (Lunde, Rundgren & Chang Rundgren, 2015). The teachers mainly described the inquiry-based activities as tools for teaching scientific subject matter and preparing students for national tests; teaching about the nature of inquiry in general or scientific inquiry in particular was not highlighted as an aim. This can be understood as a conflation of the traditional view of laboratory work as pedagogical strategy for teaching scientific subject matter and its use as a way of teaching students *to do* and *about* scientific inquiry as a learning outcome. Given that the Swedish curriculum introduced in 2000 highlighted an understanding of scientific methods as a key learning outcome, it is clear that IBST has had only a limited impact on teaching over the last few decades (National Agency of Education, 2000). To bridge this gap, it will be necessary to take tradition into account when developing CPD programs relating to IBST.

Traditions can be selective

All activities are embedded in a wider historical and cultural practice that influences how we act and think (Engeström, 1999). Additionally, since all practices are interrelated, they can never be studied without taking their context into account. It is therefore important to point out that this study is situated in a Swedish context. Further, according to Wenger (1998), practice can be seen as a process whereby people experience the world and their engagement with the world becomes meaningful. Participation in such practices provides an experience of involvement in social enterprises. These experiences are given form by a process of reification in which physical and mental objects are created and then congeal the experiences into “thingness”. This creates an understanding that becomes a focus for the negotiation of meaning, as people use their understanding to argue points, to decide what to do, and as a basis for action. Teaching practices are no exception from this. Because they are embedded in a wider historical and cultural practice, teaching practices are collective experiences. This is demonstrated by a well-established Swedish teaching tradition associated with laboratory work in science (Högström et al., 2006). Freshmen are usually absorbed into this tradition when they start participating in the teaching community even though teacher education courses often emphasize other perspectives. This is consistent with the findings of Lager-Nyqvist (2003) in a study on the development of student teachers into in-service teachers. Within communities of practitioners, traditions are typically unarticulated and taken for granted but can also be selective in that they determine when and how new ideas will be adopted (Williams, 1973). Selective traditions, like other established traditions, are often largely unexamined. Therefore, as suggested by Gyllenpalm et al. (2010a), in-service teacher training must take existing teaching traditions into account to ensure that the central imported ideas are not simply modified to conform with pre-existing concepts while being incorporated into the established tradition by participants who hold unarticulated and unchallenged assumptions about key issues that contradict those on which the new ideas are founded. Consequently, it is important to explore the processes by which imported meanings are re-negotiated within long-established traditions.

Inquiry-based activities and in-service teacher professional development programs

Various researchers have suggested that school culture and teachers’ voices must be taken into account when introducing educational reforms if they are to be effective (Keys & Bryan, 2001; Kirk & MacDonald, 2001). Hoban (2002) distinguishes between two different approaches to teacher professional development. On the one hand you have knowledge-focused approaches with low degree of context. On the other hand you have very context specific approaches which do not necessarily involve any input of external knowledge. He suggested a balance between these two extremes and his *communities of enquiry*-model accommodate aspects from both sides (Hoban 2002). A key assumption in this model is that ”approaches which are based on collaborative enquiry that support teachers in reconstructing their knowledge are most likely to lead to transformative changes” (Fraser, Kennedy, Reid, & Mckinney, 2007). One example of an approach with these characteristics is described by Harrison, Hofstein, Eylon, & Simon (2008). In their review they suggested some key component characterizing a successful CPD-program.

- Engage teachers in collaborative long-term inquiries into teaching practices and student learning;
- Situate these inquiries within problem-based contexts in which content is central and integrated with pedagogical issues;
- Enable teachers to see such issues as they are embedded in real classroom contexts by reflecting on and discussing one-another’s teaching and/or by examining students’ work;
- Focus on the specific content or curriculum that the teachers will be implementing so that they have time to work out what aspects of their current practice will need to be adapted and how this adaptation should be achieved.

(Harrison, Hofstein, Eylon, & Simon, 2008 p. 580)

These features allows teachers to participate in a process of co-construction and gives them opportunities to challenge and re-negotiate the meaning of existing practices while also challenging key ideas introduced during the CPD program. Wickman (2014) claims that even if teachers are granted significant freedom to decide content, strong teaching tradition nevertheless reduce the options available to them. Therefore, "an important aim for didactic research is to make teachers critically aware that there are other options than those suggested by the local tradition" (Wickman, 2014 p. 146). This can be facilitated by explicitly describing key concepts of the laboratory teaching tradition and of inquiry-based teaching, in as well as, promoting the negotiation of meaning through group reflection and within a co-construction process. To these ends, the CPD program developed in this work aimed to explicitly describe different aspects of the tradition associated with laboratory work and to problematize some of the tensions that arise between the tradition and IBST. In addition, efforts were made to demonstrate the scope for harmonizing these tensions within laboratory work by considering the coherence of the purpose, content, and activity as suggested by Gyllenpalm et al. (2010a). By distinguishing between the different purposes of laboratory work in IBST and the traditional approach, we wanted to create space for different kinds of activities with different purposes. The teachers retained the autonomy to decide if and when to use different kinds of laboratory activities according to their intentions and objectives. In this way, they could take responsibility for deciding how to accommodate new ideas within the existing practices, as discussed by Kirk & MacDonald (2001). A major strategy in the CPD program was to thoroughly address *why* and *what* questions regarding the purpose and content of IBST. The teachers' reflections on the answers to these questions enabled the co-construction of answers to *how* questions concerning the implementation of IBST as a teaching approach (Keys & Bryan, 2001). This strategy was meant to confirm the teachers' autonomy as professionals and let them retain responsibility for deciding how to frame their own teaching according to the desired learning outcomes in line with Wickman (2014).

Aim and research questions

An earlier study identified tensions between IBST and traditional laboratory work that arose during a CPD program (Lunde, Rundgren & Chang Rundgren, 2015). The aim of this study was to clarify these tensions by exploring teachers' responses to a CPD-program that emphasized the negotiation of meaning regarding purposes, content and teaching methods in their own teaching, the laboratory tradition, and IBST. The study examined teachers participating in a CPD program whose aim was to encourage the implementation of IBST in order to promote scientific literacy among students. We aimed to answer the following three research questions:

1. How do the teachers' existing approaches to laboratory work emerge through their reflections?

2. How do the teachers respond to the explicit tensions between the teaching tradition and IBST during the group reflection exercises?

3. Could the teachers develop an explicit awareness of the different possible purposes of laboratory work in school science?

Methods

With a total of 15 participating in-service teachers in a CPD program, this study was designed as a case study according to Yin (2009) Group interviews and reflection exercises were conducted to study the development of three groups of teachers during a CPD program. The program and study design are described below.

The design of the CPD program

The CPD program was based on the EU FP7 PROFILES project (http://www.profiles-project.eu/). One of the hallmarks of this project is a three-step teaching module that is designed to enhance inquiry-based science education. This module was developed within the PROFILES project and shared through CPD programs for in-service teachers in 21 European countries. The first step of this three-step module introduces a student-relevant scenario, i.e. a context (such as a socio-scientific issue) that must be addressed by conducting an inquiry-based activity. In the second step, the students are required to develop a method of inquiry and then execute it to obtain answers. This stage is de-contextualized and may involve some kind of laboratory-based scientific inquiry-like activity. The third step is a re-contextualization stage in which the acquired science knowledge, knowledge claims or evidence are used to answer the question introduced in the first step. In this work, the three step module was used as a framework for the construction of a teaching sequence in which students were allowed to (i) take on the role of citizens who needed scientific knowledge during the first stage, e.g. to make some kind of informed decisions; (ii) act as scientific researchers making knowledge claims relevant to the issue in question during the second stage; and (iii) return to the citizen's role in the third stage and use the acquired knowledge to make an informed decision. This allows students to experience situations in which they must critically assess knowledge claims from the perspectives of both researchers and citizens.

The CPD program developed during this study lasted for 40 hours in total and was distributed over four whole-day and two half-day activities during one school year. The workshop was arranged during regular school hours. All of the teachers within a single school district were invited to participate; 15 voluntarily joined the CPD program. The program was conducted in cooperation with a municipality that guaranteed that the participating teachers would be paid their normal wages while participating and also paid for substitute teachers to handle their teaching duties while they participated. During the program, the teachers were separated into five different groups of 2-4 teachers each. The teachers were allowed to organize the groups by themselves based on the subject areas they wished to work on and their desire (or lack thereof) to work in groups with colleagues from their own schools. Participants were not allowed to switch between groups during the program. Each group was expected to develop, implement and evaluate one PROFILES three-step module over the course of the CPD program. The modules were then expected to be shared with the other groups at the end of the program.

A key strategy of the CPD program was for the teachers to take part in a co-construction process to establish the meaning of IBST. It was hoped that this would clarify the impact of IBST on laboratory teaching and learning outcomes within the overall context of promoting scientific literacy for citizenship. Another aspect was to give the teachers an opportunity to frame IBST according to the specific context they worked on and their individual abilities while being challenged by the other members of their groups. Another key strategy adopted in the program was to make the tensions between traditional school laboratory work and IBST explicit. It was hoped that these tensions would be reflected on extensively during the group reflection exercises. Table 1 provides an overview of the program's progression.

TABLE 1. The CPD program developed in this work and the associated data resources.

Sessions (Total 40 hours)	Agenda	Group activity	Data collection
Session 1 (8 hours)	*Presentation on importance and framework:* Provided a historical overview of the growth of scientific literacy (SL) in science education and the importance of scientific literacy for citizenship. The teachers were introduced to socio-scientific issues (SSI), context-based teaching and IBST by a facilitator. These concepts were then linked to the aims of existing curricula. The PROFILES three-step module was introduced as a framework for designing context- and inquiry-based science teaching sequences. The teachers participated in a context- and inquiry-based PROFILES science teaching module. The aims, contents, and methods of the science teaching tradition and existing curricula were problematized in relation to the concepts presented in the module and the aims of new curricula.	• The teachers organized themselves into groups • Each group reflected on the presentation • Each group chose a theme for their module	Audiotaped group reflections
Session 2 (8 hours)	*Didactic knowledge*: One of the authors presented content- and pedagogical content knowledge associated with IBST. An external lecturer presented didactic knowledge associated with SSI and context-based teaching. The role and nature of laboratory work in traditional teaching was contrasted to that in IBST.	• Each group reflected on the presentations • The groups started planning their three-step modules	Audiotaped group reflections
Session 3 (8 hours)	*Didactic knowledge*: One of the authors presented didactic knowledge associated with assessment in IBST. The assessment of laboratory work in traditional teaching was contrasted to the things that must be addressed according to the current curriculum.	• The groups continued planning their three-step modules	
Session 4 (8 hours)	Group activities (no presentations)	• The groups completed the planning of their three-step modules	Focused group interviews

		and implemented them.
Session 5 (4 hours)	Group activities (no presentations)	• The groups reflected on the modules' implementation • The groups documented their modules
Session 6 (4 hours)	Presentation of modules	• The groups presented their modules, experiences and reflections on the implementation process • The documented modules were shared

Data collection

Only the responses of participants belonging to groups in which every member had participated fully in the first three workshops were selected as data resources for further analysis. This was done because key concepts (the teaching tradition, IBST, and the tensions between the two) were introduced during these workshops and because the audio recordings of the group reflection exercises that followed these presentations were important sources of data. All of the participating teachers had more than ten years' experience and held the qualifications required to teach science at the level of grades 7-9. The groups, referred as A, B and C, consisted of (A) three females with 10-25 years' teaching experience, (B) four males with 10-25 years' experience, and (C) two females and one male with 13-16 years' experience. The characteristics of the teachers whose responses were collected as data resources for further analysis are presented in Table 2.

TABLE 2. Characteristics of the three groups of teachers.

Group	Teacher	Years of experience	Teaching qualification
A	A1	17	general science
A	A2	10	general science
A	A3	28	physics, chemistry
B	B1	15	general science
B	B2	25	biology, chemistry

B	B3	14	general science
B	B4	13	general science
C	C1	13	general science
C	C2	23	general science
C	C3	16	general science

Note: general science includes biology, chemistry and physics.

Audio recordings of group reflections were collected on two separate occasions and semi-structured focus-group interviews were transcribed. The procedure is described in more detail below.

The group reflection exercises: The lectures and activities during the CPD program's first two workshops introduced the concepts of context- and inquiry-based teaching for scientific literacy that are embedded within the current Swedish curriculum and compared them to the teaching tradition (2011). These lectures and activities were followed by template-guided group reflection exercises, which were recorded for future analysis. The templates encouraged the teachers to consider and compare various aspects of the teaching tradition and IBST during their reflections. The three-step PROFILES module was used during the first reflection exercise as both a source of guiding questions and a template for reflecting on the points communicated during the preceding lectures. The main emphasis of the first reflection exercise was on the differences and similarities between IBST for scientific literacy and the traditional approach to laboratory-based teaching. In addition, the template contained explicit references to the similarities and differences between the laboratory tradition on the one side and the content and aims of the current curriculum on the other.

In the second group reflection exercise, the teachers were offered a template containing several authentic quotations from other teachers along with guiding questions. The quotations were from teachers who had participated in an earlier CPD program and illustrated cases in which teachers had (perhaps inadvertently) reproduced the traditional approach when trying to implement IBST or struggled with the tensions between IBST and their traditional laboratory activities. The reflection groups were encouraged to use these quotations to reflect on how the traditional laboratory activities discussed in the examples had been adapted and transformed to comply with the requirements of the current curriculum and national tests. It was hoped that this would encourage the teachers to reflect explicitly on the teaching tradition and its potential tensions with IBST and the current curriculum.

The focus-group interviews: Semi-structured focus-group interviews were conducted during the fourth workshop. All of these interviews were conducted by the first author, using a semi-structured interview guide (Kvale, 1996) to ensure that all aspects of the purposes, contents and teaching methods associated with the traditional approach, IBST, and the current curriculum were covered during the interview. A key goal in the interviews was to clarify the extent to which the preceding three workshops had influenced the teachers or given them new perspectives on laboratory work. The interview guide included the following questions:

In your opinion, what are the purposes of laboratory activities?
Have your opinions on this matter changed during the CPD program?

What do you consider to be the desired learning outcomes of laboratory activities?
Have your opinions on this matter changed during the CPD program?

How do you think laboratory activities should be organized and conducted?
Have your opinions on this matter changed during the CPD program?

Data analysis

The recordings of group interviews and reflections were transcribed and then proofread to ensure that the transcripts were of high quality (Bloor, Frankland, Thomas, & Robson, 2001). In a first step we read the whole data material to get an overall impression, and then went back to specific passages to re-read several times and make a deeper interpretations of specific statement. In this stage longer statement were compressed into brief statements in which the meaning of what was said was interpreted and rephrased in a few words (Kvale, 1996). The statements addressing themes about purpose, content or method of laboratory work were identified and sorted according to the degree of relevance for the three research questions: (1) implicit or explicit statements relating to the purposes, contents, or methods of current laboratory work; (2) statements indicating lack of conformity in the group concerning purpose, content or methods of laboratory work; and (3) implicit or explicit statements indicating new insights into or awareness relating to the purposes, content or methods of laboratory work. In a next stage the statement were categorised within respective research question domain. The statements were then characterized thematicallyThe categories are discussed more extensively in the results section.. The transcripts were translated from Swedish into English and were checked by a native speaker who is a Swedish to make sure that the translation stayed as close as the teachers' original wording.

Trustworthiness

The researchers were not present during any of the group reflection exercises in order to ensure that they could not bias or otherwise influence the reflection process. This was done because we wanted the teachers to express their personal opinions as truthfully and accurately as possible. The semi-structured interviews were conducted by the first author, who also served as an instructor during the CPD program. However, this should not have been a problem because the purpose of the interviews was not to evaluate the CPD program or the quality of the instructor's work but to determine the extent to which the teachers had acquired new personal insights or awareness. The trustworthiness of the data analysis was secured by member checking: the second and third authors, both of whom are senior science education researchers, re-read all of the transcripts to validate the first author's interpretations and ensure that the conclusions drawn were reasonable (Abell & Smith, 1994).

Results

In this section, quotations are used to illustrate and exemplify the issues discussed in the text. The quotations are referred to using a simple code: the first number (1, 2, 3) indicates whether the quotation came from the first or second reflection exercise (1 and 2, respectively) or the semi-structured group interviews (3). The second number represents the identity of the quoted teacher, as listed in Table 2. For example, 1B2 would refer to something said by teacher 2 from group B during the first group reflection exercise, and 3C2 would refer to something said by teacher 2 from group C during the semi-structured group interview.

Teachers' reflections on their existing approaches to laboratory work

Using laboratory work to teach science subject matter

The group reflection exercises revealed that the teachers primarily regarded laboratory activities as part of a strategy for teaching students about scientific concepts and theories. In addition, they were considered to be important for developing students' practical skills, stimulating their interest in science, and adding variety to teaching content. Several of the teachers said that in their own teaching, they typically started by presenting the scientific subject matter relevant to the laboratory exercise and then had the students undertake instructional laboratory work to enhance their understanding.

> 2C1: Well, if we think about ourselves [in the laboratory tradition] and we are going to reflect on the aim [of laboratory work]… as we discussed a moment ago [about the aim of laboratory work], what you are saying now is that you have talked about something, and we think that it [laboratory work] is done to provide an understanding of concept and theory.
>
> 2C3: Yes, you do it because you want to reinforce the students' understanding and teach them practical skills.

The teachers stressed the importance of letting students propose hypotheses concerning what they thought would happen and why, make observations, and finally draw conclusions about whether the hypotheses had been "proven" by using the presented theory to explain the observations. The main purpose of making these hypotheses was to confirm the theory that was being studied by demonstrating that the laboratory observations were consistent with the theory in question.

The influence of national tests on the adoption of inquiry-based activities

Several teachers stated that they had opened up some of their laboratory activities to involve their students in inquiry-based laboratory inquiry activities. However, the teachers still considered teaching about scientific concepts and theories to be the main purpose of the activity rather than teaching students about scientific inquiries or how to conduct them. Many teachers stated that they primarily opened up their lab-based activities to comply with the new curriculum and because the national tests introduced in 2009 require students to perform a systematic scientific investigation.

> 2B2: Well, there are plenty of laboratory activities that students ought to perform step-by-step without needing to think too much. But we are all influenced by the new curriculum – we have to do things in a different way. So we take some old stuff and try to adapt it. It is like he said [referring to the instructor] earlier – there are no books telling you how to do these things, how to actually conduct these kinds of activities. The national tests were actually really helpful in that respect – they force you to think.

These tests, which require students to plan, conduct, and assess a scientific investigation, seemed to be the main factors that prompted the teachers to consider the meaning of laboratory activities and their framing. Several of the teachers indicated that their approach was to first present the relevant subject matter to the students and then assign them a question to investigate. None of the teachers said that they allowed the students to frame research questions by themselves. After having been given the question, the students were supposed to construct hypotheses or a guess about the outcome and then figure out the "right" way to conduct the investigation. To get a high grade, the students were required to draw suitable conclusions, i.e. to show that they could explain their results using the theories that the teacher had presented to them before they began their lab work. None of teachers said that they had ever encouraged the students to present their work to one-another or to argue about how they had designed their investigations, the reliability of their results, or the validity of their conclusions. The primary purpose of these activities, as revealed by the reflections, was to teach traditional science content while letting the students practice for the national tests. None of the teachers mentioned learning about the nature of scientific inquiries as an important learning outcome in its own right within the existing practice.

Negotiating the meaning of laboratory work

Challenging traditional laboratory work and its tensions with IBST

The three groups adopted different approaches to the challenge presented by IBST and the tensions between IBST and the established teaching tradition during the co-construction process. During the two group reflection exercises, groups B and C more explicitly challenged different ideas about the purpose of laboratory work and consequently also more explicitly challenged their own ideas. Such explicit challenging was not found in group A's reflections. The exchange quoted below shows how the teachers in groups C used the tensions between their own teaching practices, the teaching tradition, and IBST to challenge and negotiate the meaning of doing laboratory work. The teachers were reflecting on the purpose of doing laboratory work in the traditional perspective and in IBST.

> 1C1: I think a big difference is that normally when you do this sort of work, you want the students to learn a particular concept. When you are doing these activities, you are thinking that the students will experience something that reinforces the theory they have learned.
>
> 1C2: I still think that concepts are an important part of it. Are we going to distinguish between them now? Do we only focus on the investigation?
>
> 1C3: Well, then we have to focus on just that part, not the problem-solving, but the systematic part. It is quite a big difference!
>
> 1C1: Absolutely! Because normally when you do laboratory work, the students are supposed to write a report. And when they do that, you want them to reflect on their work at the end: why did these things happen? What were the results? What were the sources of error? And why did these particular things happen rather than anything else?
>
> 1C3: And as you say, it is done to enforce the theories that the students are studying or will study soon.

The teachers then turned to the tensions between laboratory work and IBST. 1C2 expressed a particularly critical attitude towards the emphasis on inquiry as a major learning outcome of laboratory work. However, all of the teachers' responses indicated that this perspective was in some sense new to them. They struggled to distinguish between science as *a product* and *a process*, and therefore conflated laboratory work as a teaching method and as something that mirrors scientific practices and provides insight into their nature. Despite this, there was a turning point in the reflection, quoted above, at which the teachers came to accept IBST as something different to traditional laboratory work.

1C1: But actually I agree. That is not how the scientific method really works. There are no researchers who get ready made instructions like “place 30 ml of the solution into a beaker.”
1C3: No
1C2: No, researchers don’t work like that. They have something to investigate.
1C3: Yes, I agree. What we are discussing is students creating investigations and asking questions like “How am I going to do this?” by themselves. That is what researchers do. These kinds of problems have no ready-made template telling you how to proceed. So one difference is that the students are going to wonder how to proceed in order to conduct a reliable and valid investigation.
1C1: But then the starting point is very important. That allows the students to create an investigation on their own.

Making the tensions between the teaching tradition of laboratory work and IBST explicit allowed the teachers to reflect upon and move beyond them. The teachers in groups B and C challenged the tensions and negotiated a change in the meaning of laboratory work from a way of learning about scientific subject matter to a way of learning about inquiry in its own right. The exchange quoted below shows how teachers from group B distinguished between the different purposes of laboratory work after reflecting on examples of traditional laboratory work and inquiry activities intended to let students learn about scientific inquiry in its own right. By negotiating how to incorporate scientific inquiry as a learning outcome in its own right into their existing practices, they reached a consensus about separating different laboratory activities and framing them according to their purpose.

2B2: If you re-construct a closed activity into something that is still quite tightly constrained, it might be better to just leave it closed.
2B1: It’s better to follow the line and let the students discover and explain what happened.
(…)
2B3: Yes, and when trying to help students understand the scientific process, you use another kind of activity, and focus more on things like research questions, planning, and sources of error.
2B2: I agree, we need to be more aware of each activity’s purpose.

Again, the above-mentioned challenges, negotiations and consensus-building processes were evident during the reflection exercises involving groups B and C, but not in group A. Group A instead focused primarily on the *how* aspects of laboratory teaching. Consequently, during the reflections exercise they never really challenged each other’s ideas concerning the *why* and *what* aspects of laboratory activities. This is discussed more extensively in the discussion section.

The incorporation of new ideas and the development of awareness in different teacher groups

Distinguishing between inquiry as a teaching method and a learning outcome

Groups B and C developed an explicit awareness of the difference between inquiry as a teaching method and a learning outcome in its own right. The exchange quoted below comes from a semi-structured focus-group interview in which the teachers from group B described the development of their thinking during the co-construction process.

3B3: And what we have done now is to let the investigation and the things relating to it become the most important part, so we have made the discussions much longer than they used to be. Earlier in the planning process, we wanted to incorporate this activity into a considerably longer teaching sequence that would initially feature traditional laboratory work, investigating food and so on, activities that have a given result - an expected result, and this inquiry was going to be a part of that sequence. But then we recognized, during the discussion, that the direction we wanted to take was to highlight the scientific method. It needs more space. So, we trimmed the scope of the investigation overall but increased the duration of the project in order to better highlight the scientific process itself.

3B1: It is like doing the opposite of what we did before, I think, where you present the facts and then let the students do the laboratory work.

(…)

1B3: The big difference, I think, is the focus on scientific methods themselves, on seeing them as content that should be taught alongside the traditional subject matter. That science is not just concepts and theories.

In contrast, group A continued to focus on laboratory work/inquiry as mainly a method for teaching scientific subject matter and practical laboratory skills. This is discussed further below.

Emphasizing different purposes and desired learning outcomes

In the interviews, the members of each group were asked whether their perspectives on the purpose of laboratory work and inquiry had changed. Group A did not show any explicit awareness of learning about inquiry as a learning outcome in its own right during the interview.

3A2: I think the purpose of laboratory activities is to help students to learn because just reading facts, facts, and more facts doesn’t always work. But doing practical things can encourage them.

3A3: Yes, partly it creates interest, but it also prepares them for further study. They learn a method – to make observations and then use theory to draw conclusions. That is also important.

Interviewer: Do you feel that your thinking has developed or that you have gained a new perspective on the purpose of laboratory inquiry during this teacher training program?

3A2: Well, I think it is more like it [the workshop] confirmed what I already thought – there wasn’t anything new, but it did support what I already do.

In contrast, the members of groups of B and C showed an explicit awareness of different purposes of doing laboratory work, and different learning outcomes that laboratory work can produce. Quoted below, they noted that laboratory activities can enable students to engage in open-ended inquiry and argumentation that imitate important aspects of science as a processes.

3B1: Before I felt there was a conflict, but now I have become aware, or it has been made clearer for me that there are many different purposes for doing laboratory work. I had never thought about this researcher thing before. This has changed my view! Now I can see more dimensions of laboratory work.

3B2: It has expanded my understanding of scientific inquiry. Before, I only emphasized the formal parts – you have to make a hypothesis, get some results, and draw a conclusion. But I hadn't discussed the things surrounding scientific investigation (…) or the idea that scientific inquiries often imply different conclusions that aren't necessarily either right or wrong when they are put forward, and that these conclusions feed into arguments that may require further research to resolve.
3B1: Because I wasn't certain about these things before, I found it hard to explain things when students got unexpected results in laboratory work or drew unexpected conclusions – you want all the students to get the same results. (…)
3B2: I didn't previously realize that there was value in having a discussion after the lab work had been completed.

The comment above, made by teacher 3B2, indicates a new explicit awareness of science as a process and the nature of such processes as a learning outcome. Both group B and C managed to accommodate multiple different purposes in their reflections about laboratory activities.

Discussion

Teaching practices and the teaching tradition relating to laboratory work

The teachers' group reflections showed that the learning of science as a body of knowledge in its own right was the dominant objective in their teaching. This indicates that teaching science content based on "the right explanations" and fundamental science concepts were a key component of the existing teaching. Laboratory activities seemed to reflect this. Moreover, the way the teachers talked about their laboratory tasks revealed similarities with the results of previous studies. For example, teachers have been reported to rely heavily on recipe-like laboratory tasks as tools for increasing students' understanding of traditional science subject matter (Andrée, 2007; Gunnarsson, 2008; Högström et al., 2006). In addition, general skills associated with laboratory work were emphasized, including the ability to follow instructions, get the "right" results, be exact, and perform tasks independently. The teachers were unclear about how such laboratory activities were related to the purposes of learning concerning scientific methods and the nature of science (Gyllenpalm et al., 2010a).

However, as found by Gyllenpalm et al. (2010a), the teachers also described some laboratory work that resembled inquiry as conceptualized in the science education literature. In these cases, the teachers involved their students in inquiry-like laboratory tasks that were based on a ready-made investigative question that the teachers handed over to the students to investigate independently. Several teachers noted that the introduction of these activities was due to the introduction of national testing in 2009. However, a main purpose seemed to be to teach students traditional science content rather than to educate them about scientific methods or the nature of science. Learning about scientific processes seemed to be neglected or treated as a desirable by-product, not the main aim of the activities. The teachers thus failed to clearly distinguish between science as a process and a product in their previous laboratory teaching practices.

The teachers' reflections on their existing practices indicated that they had been selective in their handling of the new purposes introduced by the new curriculum. The growing emphasis on scientific literacy for citizenship as an overall aim was thus subordinated to the traditional aim of teaching science as knowledge in its own right. This of course affects what content is highlighted and what teachers see as the key aims and learning outcomes of laboratory work. When they incorporated new elements, the teachers adapted and transformed them to fit in with the existing practice, as previously described by Gyllenpalm et al. (2010a). If investigation is regarded as a tool for teaching subject matter, teachers will approach a new curriculum's requirement for open laboratory tasks in this light rather than as a means of teaching students about scientific methods *per se*. As a result, they may conflate the role of inquiry as a teaching method with its status as a learning outcome. This way of handling imported changes is consistent with Williams' (1973) arguments about the selectivity of traditions.

The teachers' development during the reflection exercises

Changes of meaning within a practice require negotiation (Wenger, 1998). To this end, the participating teachers were placed into situations that were designed to facilitate processes of meaning negotiation. The teachers stated that they considered the aims and content of their existing laboratory practices to be meaningful but also took them for granted. During the reflection exercises, several of the teachers indicated that they had some difficulties with the switch in perspective required to move from focusing on teaching traditional content knowledge to regarding knowledge of scientific processes as content in its own right. The reflection exercises revealed some pronounced differences in the way different groups of teachers understood IBST. The teachers from groups B and C explicitly challenged the tensions between IBST and the traditional approach, and further, engaged in negotiation to resolve these tensions. In addition, they explicitly expressed an awareness of the different possible meanings and purposes of laboratory work. Both groups' negotiation processes revolved around determining how the new ideas should be understood and integrated with existing practices, how they should be implemented, and how the new perspective could be harmonized with the traditional approach. This suggests that meaning had to be negotiated for the teachers to become aware of the fundamental differences between the new ideas and the tradition, and to avoid conflating the new concepts with their existing ideas. Introducing new meaning into existing practices is difficult: meaning cannot be simply transferred. Instead, it is necessary to engage teachers in a process of reflection during which they can renegotiate the meaning of their practices and the implications of new ideas for their future teaching, in keeping with the arguments of Wenger (1998).

In contrast, the members of group A showed no sign of explicitly challenging their own assumptions. Our results indicate that established traditions must be taken into account when implementing new ideas in order to minimize the risk of key ideas becoming conflated with unarticulated and unchallenged assumptions. However, they also show that it is not sufficient to merely explicitly state the conceptual underpinnings of traditional approaches and encourage teachers to reflect on them. This may be because some participants will selectively interpret what is communicated rather than challenging their own assumptions. This does not imply that the approach outlined herein lacks applicability. However, it does underline the importance of stressing the contrast between new and established concepts, and ensuring that these differences are negotiated by the participating teachers.

School cultures and teachers' personal backgrounds are embedded in teaching traditions, reinforcing existing practices and making it difficult to introduce long-lasting changes via external influences such as new curricula or reforms, as discussed previously (Banner, Donnelly, & Ryder, 2012). In addition, CPD participants often consider existing practices to be self-evident and meaningful, so they are commonly taken for granted (Gyllenpalm et al., 2012a). They are also often largely unexamined. To make long-lived changes within such practices, the changes must be made meaningful. As discussed above, this cannot be done by simply implementing external ready-made concepts or ideas within an existing practice.

Given that teachers have well-established working practices and operate in a rough-and-tumble school reality with limited resources where they have comparatively little time to reflect on and develop their approach to teaching, it is not surprising that they are often reluctant to explore or adopt new ideas. However, as indicated above, it is important for teachers to reflect on their own practices if changes are to be implemented effectively.

The new state of the art

Wickman (2014) suggests that an important aim for didactic research is to make teachers critically aware that there are other options than those suggested by the local tradition. The main goal of the CPD program presented in this article was to increase the teachers' awareness of the need to increase students' scientific literacy for citizenship and the implications of this aim for their course content and teaching approaches. Awareness of why students should be involved in IBST and what to teach will necessarily influence how teachers think about engaging students in open-ended inquiry activities. Teachers who are aware of such aspects and regard them as valuable learning outcomes in their own right will probably be more able to explicitly and harmoniously incorporate them by addressing the aims of the traditional and new approaches separately. Two of the teacher groups (B and C) achieved such awareness by recognizing the need to be more aware of each activity's purpose.The teachers came to see an understanding of scientific practices and their nature as an end in itself. Moreover, their new awareness of the different perspectives on laboratory work prompted the teachers to explore the potential for harmonizing these perspectives without creating conflicts between them. This should reduce the risk of teachers conflating the aims and learning outcomes of IBST with those of traditional laboratory activities, a common problem discussed by Gyllenpalm et al. (2010a). The establishment of such an awareness is is not given by itself in the existing teaching tradition (Gyllenpalm et al., 2010b). In the CPD-program the participating teachers were treated as professionals and given complete freedom to decide how specific activities should be designed in order to fulfill specific purposes and achieve desired outcomes. This allows them to judge if a traditional approach or if some other approach is most suitable when designing teaching activities according to different purposes as discussed by Kirk & MacDonald (2001).

In contrast, group A did not show any explicit awareness of the tensions between different meanings and aims of traditional practices and IBST. This is consistent with previous observations regarding the perception of established practices as self-evident, and their selective effect on the adoption of new influences (Williams, 1973). In group A, the teachers still considered the learning of scientific concepts and the "right" explanations to be the main purpose when doing laboratory IBST-activities, even though they wanted to involve their students in activities associated with science-in-the-making such as a "conference" where students could present arguments about the trustworthiness of their inquiries and findings. That is to say, their aims, contents, and teaching methods were not aligned. This exemplify the tendency to conflate inquiry's role as *a learning outcome* and *a teaching method* (Gyllenpalm et al.2010b, Autor 2015) and the challenges present in developing an explicit awareness of the tensions between different meanings and aims of traditional practices and IBST

To enhance teachers' professional development, it is important to give time and space to reflect on teaching practices and the ideas embedded within new curricula (Bryan & Abell, 1999; Parke & Coble, 1997). Our results indicate that allowing teachers to co-reflect on the explicit differences between their established laboratory tradition and newer ideas *can* change their perceptions or understanding of their work. However, such co-reflection alone is not automatically sufficient to induce change. Hoban (2002) suggested a *communities of enquiry*-model which are based on collaborative enquiry. According to Fraser et al. (2007) such models are most likely to lead to transformative changes. Harrison, Hofstein, Eylon, and Simon (2008) presents some core characteristic of such an approach. In line with this, the teachers in this study were encouraged to develop a new laboratory teaching sequence within their groups via a process of co-construction, during which they could think through and articulate the implications of the new ideas for their classroom practice. The involvement of teachers in co-construction processes that allow them to articulate new meanings which will subsequently be implemented in their classrooms is consistent with the demand for teachers' voices and school culture to be accounted for when implementing inquiry-based activities (Keys & Bryan, 2001). Ideas are implemented through the interplay between the different external, internal and personal domains that influence a teacher's practice within their school. All of these domains and the interplays between them must be taken into account if long-lived changes are to be made (Clarke & Hollingsworth, 2002; Ryder & Banner, 2012). Accordingly, if teachers manage to re-negotiate what could be the aims of using laboratory activities and then reflect on the implications, it is more likely that lasting change will be achieved.

It should be noted that this study has some important limitations. In particular, we did not examine how the teachers implemented their teaching sequences and we cannot make any claims about the CPD program's long-term effects on the teachers' development. Nevertheless, we hypothesize that the teachers' new awareness of the different purposes of laboratory work will have a lasting influence and be incorporated in different ways by different teachers. Those teachers that achieved a deep awareness of IBST and its aims will hopefully engage their students in activities that model crucial aspects of scientific practices more accurately, and link these activities to situations in which knowledge claims are used in the same way as they are in day to day life: to make decisions and as a basis for argument in public and private debate.

This study demonstrated how existing approaches can be renegotiated to incorporate new ideas. However, it also showed how traditions can be conserved, causing new inputs to be realigned with existing practices. This indicates that established teaching traditions must be considered when implementing IBST. Our results indicate that teacher educators must take care to explicitly articulate the assumptions and foundations of existing traditions and their potential influence on teachers' interpretations of new ideas. Having done this, the teachers must be allowed to negotiate among themselves to decide how to harmonize new ideas with the explicitly defined traditional practices.

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