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Negotiating the relevance of laboratory work: Safety, procedures and accuracy brought to the fore in science education

Abstract

This text addresses the problem of the discrepancy between teachers' and students' positions in negotiations about the authenticity and legitimacy of school science activities. The study focuses on the apparent conflicts concerning legitimacy and authenticity when teachers and students bring attention to safety, authenticity and accuracy during issues laboratory activities. The analysed data are excerpts made from video observations in two science classes. Analysis was made using epistemological moves describing how teachers and students make their activities relevant. The result indicates that in the classroom conversation about laboratory practice, teachers sometimes draw the attention to safety, procedures and accuracy to legitimize the activity and how they try to control it. Negotiations concerning the legitimacy and authenticity of activities seem inevitable. Unless understandable agreements are reached, the negotiations jeopardize a successful understanding of the Nature of Science (NOS). Misunderstanding of the authenticity of activities contributes to a reduction of their legitimacy, and undermining teaching of context independent knowledge.

Introduction

The influences on students' motivation and their attitudes towards science and the learning of science have been given increasing attention in recent years (Nolen & Haladyna, 1990; Osborne, Simon & Collins, 2003; Ramsden, 1998; Schreiner & Sjoberg, 2004). Initiation of the Relevance of Science Education (ROSE) project was motivated by the lack of interest in science and technology identified among students in industrialized countries (Osborne et al., 2003; Schreiner & Sjoberg, 2004). This lack of interest was attributed to the students' perception that science education had little or no relevance to everyday life (Aikenhead, 2004; Osborne & Collins, 2001; Osborne et al., 2003; Ramsden, 1998). Students were found to view school science as science for its own sake, and completely separate from societal science, such as for practical use in medicine and technology, for example (Breakwell & Beardsell, 1992). Hence, the purpose of this study is to address how students, in collaboration with their teachers, turn their attention to and from activities related to laboratory work. By studying these moves, we interpret what students question and what they might find relevant.

Background

Relevance and authenticity in science education

Four well-known motives for science education were challenged by Sjoberg (1997). Two were cultural (science for citizenship and science as part of our culture), and two were utilitarian (economic and personally practical). One of his conclusions was that science is not easily understood as part of our culture. Still, curricula are collections of the above-mentioned motives and demands from educators and other stakeholders, which sometimes fail to include students' interests. Authenticity is one factor that might render relevance to science education, at least for those who wish to do 'real things'. Giving authenticity to a task, thus making it 'real', can, for example, be accomplished by doing a simulation of a non-school professional practice (Sharma & Andersson, 2009). Multiple stakeholders influence the changes and developments of curricula (Fensham, 2009), who generally represent views and practices of which students have little awareness. Hence, from the students' perspective, school science reconstructed from such practices can seldom be appraised as authentic, or relevant to their everyday lives. However, science education seeks to be legitimized by borrowing authenticity, and thus relevance, from both the professional practices of scientists and activities within society, which make use of scientific knowledge (Braund & Reiss, 2006; Brown, Collins & Duguid, 1989; Gaskell, 1992; Hogan, 2000).

One approach to lend authenticity to science education is through teaching the Nature of Science (NOS). The NOS has been advocated for more than a century (Lederman, 2008), and one of its roles has been to entice students to understand the scientific enterprise. The concept of the NOS refers to science as a professional activity belonging to a culture enacted by scientists. Bringing this concept into school requires special attention because school science does not usually involve professional science activities. In this context, science education comprises learning about another culture (Brown et al., 1989). Munby, Cunningham and Lock (2000) argue that 'when science is removed from contexts that match and support its goals of inquiry and experiment, its character can change' (p. 208). They conclude that the nature of school science is an inauthentic representation of experimental science. When the NOS emanates from the utilitarian perspective, as a means for societal development, science is usually based on indisputable facts giving the impression of a non-authentic science practice (Lederman, 2008). Fears have been advanced that the presentation of this image of science is likely to develop and sustain myths (Allchin, 2003; McComas, 1996). Such teaching practice is contested with the assertion that science education ought to be made more authentic by providing activities that more accurately represent how scientists deal with scientific problems (Bencze & Hodson, 1999; Roth, 1997). In this view, the NOS can provide authenticity to science education through scientific inquiry. To conduct science as a scientist, teachers need to develop a more scientific attitude in their practice for the purpose of presenting a more truthful view of scientific inquiry (Bencze & Hodson, 1999). By engaging in hands-on activities, educators hope to promote interest and lend authenticity from science to the teaching practice. However, there are many pitfalls to scientific inquiry, as practiced in science education. Chinn and Malhotra (2002) suggest that school inquiry tasks need to be trustworthy imitations of authentic scientific inquiry to promote students' scientific reasoning. Although teaching with trustworthy imitations is desirable and feasible, it should also be pointed out that science education practice is a recontextualized scientific practice that is presented as scientific in order to gain authenticity (Sharma & Anderson, 2009).

School knowledge and its relevance to students' lives

Although there are promising possibilities to engage students in science, teaching practices usually include a multitude of activities, some of which students may have difficulty finding interest in or consider unauthentic. For many students, at least initially, knowledge as presented in science class seems detached from their everyday experiences. The discrepancy between the knowledge prescribed by the curriculum (school knowledge), students' previous out-of-school experiences, and access to conceptual knowledge untied to specific contexts (context-independent knowledge) have been discussed for decades (Young, 2008). However, teachers still struggle to recontextualize the seemingly irreconcilable domains of knowledge in their practice (Sharma & Anderson, 2009). One obstacle appears to be how to recognize school knowledge. School knowledge is not necessarily what is taught, but rather where it is taught. It has an institutionally-legitimated character (Paechter, 1998), which contrasts with students' everyday knowledge. Students' questions pertaining to the legitimacy of learning activities and school knowledge (Firth, 2011; Young, 2008) have to be met by teachers. Although professional authority, i.e., authority based on school knowledge (Pace, 2003), typically legitimizes teachers' actions, it is not attainable for all teachers (Servage, 2009). Instead, teachers have been shown to depend on textbooks as the sole legitimate source for their teaching (Goldson & Kyzer, 2009; Matthews, 2008), thus neglecting cultural knowledge and students' personal experience as the starting point for teaching. Such disregard for students' previous out-of-school experiences tends to disengage students from school subjects such as science (Costa, 1995). The problem of making use of both subject knowledge and everyday knowledge has been addressed (Szybek, 2002), with the suggestion that successful teaching depends on a restructuring that combines both in such a way as to facilitate a smooth transition between world views (Aikenhead & Jegede, 1999), and allow students to attain some ownership of knowledge (Firth, 2011; Paechter, 1998; Young, 2008) . The difficulty for some students to find congruence between their daily life and what is taught in science education (Costa, 1995) indicates that the subject's relevance has been problematic for some time and that students have found ways to disengage from it (Aikenhead & Jegede, 1999).

Although classroom activities have to be justified in terms of relevance, by, for example, referring to authenticity, what is relevant to the teacher may not be to the students (Fensham, 2000; Mayoh & Knutton, 1997). Thus, students and teachers can have divergent views on the authenticity of an activity (Petraglia, 1998). Furthermore, the scientific content may not even be relevant to the teachers (Lawrenz & Grey, 1995), but rather promoted by them to reinforce science as 'ready-made science', proven to provide the indisputable right answer (Bingle & Gaskell, 1994; Duschl & Wright, 1989; Latour, 1987; Lederman, 1999). In addition, an activity's authenticity may not be clear to the students if its relevancy and to whom it is, in fact, relevant remains vague (Aikenhead, 2004). In our view, a student learning by means of an activity may understand its relevance in the contexts of concrete and/or abstract aspects of real life, further education, or insight into science as a culture. Hence, with the activity's potential applicability on one or more levels, students may question its relevancy. Subsequently, it is of interest to study how a teacher responds to questions concerning why a particular classroom activity should be done or why it should be done according to the given instruction, in order for activities to be understood in context. This arena is what we address in this article.

Scope of research and research question

Our research interest is how laboratory-learning activities are made relevant by students and teachers. The investigation focuses on how teachers and students negotiate the relevance of laboratory work by using the following research question:

> What rationalities are used to make laboratory activities and observations relevant in the science classroom?

The word 'laboratory activities' does not only refer to complete laboratory assignments but also to minor activities related to laboratory work. Accordingly, the word ‘observation’ refers to the students’ different experiences during laboratory work or lectures when the teacher is explaining the practical work. Students’ questions that cast doubt on how school science activities are made relevant will be addressed by relating to the concept the NOS. This approach implies looking at how authenticity and relevance can be borrowed from both professional practices and students’ out-of-school experiences.

Method

The two participating teachers were from two different schools. They were contacted upon recommendation from their principals, on the basis that they could accept participation. The classes were not chosen for any particular reason, except that both teachers and students were acceptable to being video recorded during their lessons. All participating groups of students are part of the Swedish lower secondary compulsory school. The studied schools and their participants were not part of any intervention or experiment. Prior to the observation period, written information was given to the students and their parents, who gave consent to participate. They were informed that personal names, as well as the name of the school, were to be omitted from all documents, in order to provide anonymity for the students.

During the observation of one group of students (13 years of age), the theme for the lessons was ‘Introduction of electricity’. The lessons focused on the function of a battery using zinc (Zn) and sal ammoniac (NH_4Cl). The theme for the lessons of the other group of students (15 years of age) was ‘The human body’. Both classes were observed during every lesson for each theme. The total time of the observed lessons was 30 hours, but the recordings used for this analysis are limited to those parts in which the participants address laboratory work of some kind in their speech or actions. During the observations, the video recording equipment received very little attention from the participants; perhaps the extensive number of lessons made the equipment more or less a natural feature in the classroom. The teachers and the groups carried out the science lessons without the researcher interfering with their planning.

The analysis was initiated by making a general, broad view of the content of the video recordings and identifying the rich parts of communication during lessons. In this initial analytic step, the sequences that comprised challenges to or arguments for the relevance of activities were extracted. This initial step implied a substantial reduction of the data material. As illustrative excerpts were found in the material, the sequences were divided into three qualitatively different themes, namely safety, procedures and accuracy. The chosen sequences should neither be regarded as rare or special in any way, nor as an exclusive selection of utterances showing a desirable scientific approach. Transcribing and translating colloquial Swedish while preserving the original meanings was a challenging task. Nevertheless, transcripts need to be readable and comprehensible after translation to English. Sentences were interpreted from the transcripts and capital letters and full stops were marked.

Analysis was made using defined ‘epistemological moves’ (Lidar, Lundqvist & Östman, 2006) to address how teachers made their issues relevant, that is, to show how they brought attention to certain activities and observations. By addressing these moves, we can see how attention is turned to and away from both classroom laboratory methods and various suggested topics and ideas. Lidar et al.’s (2006) epistemological approach, which describes teachers’ moves, is useful for analysing ‘the process of privileging in students’ meaning making and how individual and situational aspects of classroom discourse interact in this process’ (p. 148). In contrast to Lidar et al. (2006), this study makes use of both the teachers’ and students’ epistemological moves to analyse their participation in the classroom discussions and examine how observations and activities are made relevant. As shown in Table 1, we use a modification of Lidar et al.’s (2006) five definitions to show how attention is directed to relevant issues in the activity: confirming moves, re-constructing moves, instructional moves, generative moves, and re-orienting moves. This use of the epistemological moves acknowledges students’ moves in the classroom, thus implying that students as well as teachers can turn the group's attention to and from different topics. These epistemological moves describe how teachers focus student attention on important phenomena and issues. They show how teachers shift the focus from observations that might be relevant from an everyday point of view in order to elicit observations that are relevant from a scientific point of view, e.g., the NOS. The re-constructing move turns students' attention to facts that have already been noticed but regarded as less important; the re-orienting move implies pointing out what properties are worth investigating. In this paper, the five moves are used to analyse what attention is turned to and what attention is turned away from. We regard the moves as a way to address how science activities and scientific observations are made relevant in the classroom, as a part of learning about the NOS.

Table 1. Epistemological moves made by teachers and students.

Epistemological move	**Description of epistemological move** [1)]
Confirming	Confirms that the other participants are recognizing the addressed phenomenon and events or confirms what they say or do.
Re-constructing	Makes the other participants pay attention to 'facts' that they have already noticed, but have not perceived as valid, yet are important to recognize.
Instructional	Gives the other participants a direct and concrete instruction of how to act to be able to see what is perceived as worth noticing.
Generative	Enables the other participants to generate explanations.
Re-orienting	Points out that there can be other properties worth investigating. This demands that the participants take another direction than the one they are on.

1) Adapted from the description of teachers' epistemological moves, according to Lidar et al., 2006.

Subsequently, the original definitions are adjusted to enable an analysis, which does not separate the participants depending on their role (see Table 1). Furthermore, the epistemological moves, due to practical reasons, are only addressed here as oral communication, not as gestures.

Results

Both teachers and students make epistemological moves, bringing attention to different aspects and contexts for laboratory procedures and related knowledge. The results indicate that teachers direct learning attention towards three different areas. In our interpretation, the laboratory approach was questioned or made relevant while turning attention to safety, procedures and accuracy. Conversations concerning the authenticity of the activities are integrated in the results.

Safety as a rationale for relevant procedures

The first excerpt illustrates how a group of students discuss building a model of a battery. To make it work, they need a fluid, and when the excerpt begins, the teacher is showing the fluid (NH_4Cl in water) to the students. The different students' voices could not be distinguished and, therefore, all are denoted as 'student' in the excerpt. As a first step, the teacher shows the fluid to the students, and at the time of the conversation, the laboratory work has not yet started. It seems that at least one of the students has come across the substance before which, in this context, seems to jeopardize the safety regulations on the teacher's agenda:

Excerpt I

> Teacher: Okay, eh, this is called a tray, it is not very interesting but, eh, a small beaker that can contain fluid, for example water (shows a tray). We are going to put something else in it.
> Student: Soap?
> Teacher: Tada (shows a bottle with a fluid in it), it's called sal ammoniac (opens the bottle slowly).
> Student: It tastes good…
> Teacher: It is like this, one thing to keep in mind, if you get it on your clothes, it will cause stains and I believe it is not particularly corrosive, but try to avoid getting it on your fingers, and wash your hands after your laboratory work please (pours the fluid into the tray)
> Student: Is it dangerous?
> Teacher: No, not dangerous, but you should always be careful with these kind of things I believe.

Excerpt I shows how a student refers to sal ammoniac as something edible. The student's second utterance is a re-orienting move, turning the topic to something which is not part of the on-going science activity. The teacher also makes a re-orienting move, in which he avoids confirming and replies that there are reasons to be careful with the fluid. The teacher's concern about safety is a plausible explanation for not allowing the students to taste chemicals in the laboratory. The lack of information in the teacher's answer turns the students' attention from logical reasoning and explanations based on observations, to merely practical issues concerning safety. The subsequent response, where the student asks whether it is dangerous, is interpreted as a generative move to get information for the understanding of the apparent conflict. In the conversation, some noticeable properties of the fluid are addressed and made relevant both from an everyday setting, e.g., sweets with the same taste that contain the substance, and the laboratory setting where safety is the issue. The student's claim that 'It tastes good…' can be interpreted as a suggestion to address previous out-of-school experiences. The teacher's turning the attention to safety dismisses such knowledge and instead points out the significance of school knowledge, which is dependent on the school science context.

The student's last question can be understood as a rhetorical question: Is the fluid *really* dangerous? However, the teacher's denial of the possible hazard is not followed up with any reason, scientific or otherwise, for the suggested cautiousness. Here, the teacher is trying to use a re-constructing move to make the student's question irrelevant.

In the above example, the student seems to express something contradictory to what is implied by the teacher. This causes a problem concerning what is relevant in the situation. The more the teacher focuses on the students' safety, the more discordant the situation becomes; the question of safety, which is made relevant by the teacher, is jeopardized by the student's re-orienting move describing the chemical as edible. The question concerning why the students should be careful is not answered, and they are left in the dark about: 1) the chemical properties of the fluid (content knowledge); 2) the details on how to perform a scientific experiment; and 3) the value of using observations, inference and evidence when reasoning about science.

The generative move illustrated above, which introduces everyday experiences, is responded to as being irrelevant without argument. Instead, the teacher's move makes safety issues relevant while the focus on the properties of the substance brought about by the student is neglected. It could be interpreted that safety is the only focus of the activity since the possibilities for learning about chemicals actualized by the students' questions are overlooked. The teacher does not present any explanation as to why the everyday application of the substance becomes irrelevant. School knowledge is taken for granted since the teacher refers to procedures without engaging in logical reasoning and explanations as to why safety is relevant in this situation.

Authenticity as a rationale for relevance of procedures

The second excerpt shows how students and their teacher negotiate the authenticity of a blood testing activity (AB0-test). The group of students were told how to handle the reagent as well as the blood that they were supposed to extract from their own fingers. Before the excerpt begins, the teacher has just completed explaining to the students exactly how they were expected to perform the blood testing.

Excerpt II

> Mark: The hospital doesn't do it this way, with this kind of...
> Teacher: They can do so, but they have certainly automated it, though it's basically the same procedure.
> Mark: Wasn't it kind of, put the blood into computers?
> Teacher: I don't dare answer that. Nevertheless, it has formerly been done this way, but there certainly is some machine that manages all that (murmuring). How many of you want to check your blood group? (students raise their hands)
> Bryan: Yes, me too (show of hands).

Mark's first turn is a re-orienting move where the explained procedure is questioned and another procedure is made relevant. He refers to health care practices and brings the attention to a mismatch between how things are done professionally and in school science. The teacher responds that the seemingly different procedures are basically the same, possibly implying the existence of context-independent knowledge that could legitimize the suggested procedure. Apparently, the discussion does not actualize any context-independent knowledge that might be available to the student. The teacher makes a reconstructing move, bringing up the previously addressed information again and drawing a relationship between the present health care practice and former laboratory practice. However, the similarities are not made explicit, and Mark points out an apparent difference between the two procedures. This is Mark's generative move, which calls for an explanation of the differences. That is, based on Mark's questions, the suggested procedure is questioned due to the lack of correspondence with the procedure in hospital laboratories. This situation reveals that the procedure's relevance would have been more obvious if correspondence with the hospital procedures had been clarified. The teacher's response to Mark can be interpreted as an instructional move (cf. Lidar et al., 2006) as the teacher turns the attention to the procedure for their classroom work. One reason for this move is to promote the students' learning of a basic tenet, not to expect a correspondence between practices. Mark seems to expect a similarity between the two procedures on a practical, context-dependent level, which might be his view of school science – to imitate a professional procedure. However, the teacher maintains that there is a similarity. The teacher tried to strengthen the belief of a correspondence between the procedure in school science and that in health care practice in order to legitimize the activity, by implying the existence of context-independent knowledge. Our interpretation of the example is that the activity is best explained by pedagogical aims. That is, the objectives for the activity are to provide learning of the core ideas of blood groups, and not to bring attention to any similarities to practices outside of school.

Accuracy as a rationale for relevance of procedures

The next excerpt describes the teacher–student interaction just before the group of students is about to start their laboratory work. The teacher has described how the students should identify their own blood groups. We enter their conversation as the teacher finishes explaining how the procedure is intended to be carried out.

Excerpt III

> Teacher: …and then we take the blue anti-A. If you pipette a drop of anti-A on the blood that contains factor A, it will form clots. Then, it is really important again, when you pipette, you must not dip the pipette into the blood. You should pipette at least half a centimetre above. This tip absolutely cannot touch any blood.
> John: Then it becomes…
> Bryan: What happens if you put that in your hand then?
> Teacher: Well nothing special I guess…
> David: What happens if you take it in a vein? What is…?
> Fred: Does it attack [as an acid]?
> Teacher: **Absolutely** not.
> David: What **happens**, does it become some kind of blood clot?
> Teacher: No, I do not think that happens…
> Nick: Clot of blood.
> Teacher: There, it probably stays, but, you do as I have said.

In this third excerpt, the teacher describes a precise procedure. The teacher's description is an instruction to the students, an instructional move, relating to the predefined procedure. The teacher emphasizes the procedure by saying: 'This tip absolutely cannot touch any blood'. However, the students (John and Bryan) ask what would happen if the procedure is not followed properly. Their question relates to content knowledge, thus making basic scientific knowledge relevant, at the expense of the procedure. In response, the teacher makes a move, denying the student's suggestion that the antibody solution is corrosive (attacking as an acid). In the last line of the excerpt, the teacher eventually denies the relevance of their inquiries by renewing the instructional move, implying that what is relevant here is to follow an unquestionable step-by-step procedure. This could imply to the students that science as a practice can be described as following given predefined procedures.

When the teacher repeats the instructional moves, defending the step-by-step procedure by stressing accuracy, the intention is to legitimize the activity by ensuring that the accurate result will eventually be accomplished. Hence, to make a scientifically-based laboratory activity relevant in a school context, an accurate result is needed.

In summation, the sequences that have been exemplified involve challenges to activities or words specifically chosen to make the activities relevant, and these are sorted into the themes of safety, procedures and accuracy. It could be interpreted that *safety* is the crucial focus of the first exemplified theme, as the teacher did not present any explanation as to why everyday application of the substance becomes irrelevant, and subsequently safety became indisputable. This interpretation fits with the school setting where the students' well-being cannot be jeopardized. A lack of time could, of course, also explain the teacher's answer, especially as an additional explanation. However, the teacher's final comment before continuing the talk supports the interpretation that a safety concern is a crucial reason for how the student is responded to. Our interpretation of the second theme is that the procedures were best explained by pedagogical aims. The objectives for the activity were to provide learning of the central ideas of blood groups and not to bring attention to any similarities to practices outside school that could jeopardize the laboratory work. In this endeavour, the authenticity was questioned by one of the students. In the last theme, the teacher repeats the instructional moves and focuses on ensuring the accuracy of the results. That is, in order to make a scientifically-based laboratory activity relevant in a school context, *accuracy* has to be given significance.

Discussion

In school science, many factors have to be accounted for, some of which are not related to scientific practices. These factors may be related to learning about proper laboratory practices, basic scientific content knowledge, and the NOS. One way to describe scientific research as an authentic practice is that it is dedicated to learning and gaining deeper knowledge about phenomena. This is in contrast to school science which is a practice mainly dedicated to learning about scientific knowledge that, for instance, is presented in textbooks. Hence, the school science practice is mainly dedicated to teaching students about science and not to making discoveries of the unknown (Gunstone, 1988). The differences between the two practices seem to be either unrecognized or implicit in the science classroom (Abd-El-Khalick, Bell, & Lederman, 1998). The present study gives examples of how students, in situations when implicit learning goals are at hand, make reorienting moves that challenge the relevance and authenticity of school knowledge and school science laboratory activities.

Several important goals for laboratory work have been proposed, such as understanding scientific concepts and the NOS, and developing scientific practical skills and problem solving abilities, as well as methods of scientific inquiry and reasoning (Hofstein & Lunetta, 2004). To reach such goals, the setting and instructions have to be guided by a proper laboratory practice to enable students' construction of knowledge based upon reliable observations (Schwartz, Lederman & Crawford, 2004). Thus, it is usually important that the procedures used will result in data that is sufficiently clear and reliable to support students' attempts to build knowledge on both observation and theory. Another important issue for teachers is, of course, that the practical work be done in a safe way (Lundin & Lindahl, 2005).

Laboratory work gaining legitimacy

In our study, the laboratory activities seem to focus on the understanding of scientific concepts: electrochemical processes for the understanding of the zinc-carbon battery, and the specific antibody-antigen interaction. In their instructions, teachers seem to convey an image of laboratory procedures as indisputable. This is accomplished by drawing the attention to safety (Excerpt I) and accuracy (Excerpt III). Safety is used to defend the legitimacy of school knowledge when challenged. Accuracy is given significance for the purpose of achieving the right results to ensure the legitimacy of the activity. To enhance the credibility of basic principles of scientific knowledge, reproducible step-by-step procedures are pursued by the teacher.

Thus, understandable conflicts arise between safety and the NOS, as well as between accuracy and the NOS. If, for example, students are unable to learn from the results of an unsuccessful experiment, then both the credibility and understanding of scientific knowledge are at stake. The NOS may have been used as a motive for the activity, but this is only effective if there is no conflict between accurate laboratory work and the students' understanding of the NOS. The conflicts mentioned above could have been reduced if the learning goals for the laboratory work were made explicit to the students. Then, they would not have to be uninformed about the kind of practice they were expected to participate in.

Authenticity as a way to gain relevance

Teachers may want to present laboratory work as authentic scientific work in order to stimulate student interest, or to have a valid argument for initiating the activity. The negotiation concerning the authenticity of the blood group testing procedure (Excerpt II) also relates to legitimacy, and whether the activity is relevant to students. Explicit teaching of context-independent school knowledge could have made the class procedure relevant, not because of similarities with professional practices, but because of the learning possibilities, which possibly was the teacher's motive for choosing the activity. Implicit learning goals, afforded by means of an activity given relevance by borrowing authenticity from a scientific practice, is likely to promote the development of erroneous understandings of the

NOS. This approach renders scientific work as a reproduction of historic facts, instead of a search for the development of knowledge. Furthermore, the prescribed laboratory work was defended as being authentic when challenged, for the purpose of appearing credible and worthwhile instead of promoting the learning of context-independent knowledge. Hence, it was framed as being authentic for another, possibly scientific, practice. This is how school science has become a hybrid culture (Brown et al., 1989) in which students can hardly understand the difference between the NOS and laboratory work for learning goals. However, when learning goals about a science practice outside school are made explicit, such as distal knowledge (Hogan, 2000), then the NOS can be made relevant and understood as belonging to an authentic culture apart from the authentic school culture. This means that if the NOS is a learning goal, then teachers need to make both laboratory work and learning goals valuable without necessarily giving science education an air of authentic scientific practice or scientific research.

Possible implications for science education

Science teachers, just as teachers in other subjects, are challenged regarding the relevance and authenticity of what is taught in lectures and through laboratory activities. The relevance of school knowledge in the context of legitimate previous out-of school experiences is questioned by students. Hence, the science education practice is negotiated in the classroom. Teachers have the opportunity to help the students towards understanding by teaching context-independent knowledge, which can facilitate making sense of students' previous out-of-school experiences along with scientific learning. School knowledge comprises context-independent as well as context-dependent knowledge, but it is the former that has the potential to provide students' with an understanding of the real world; topics such as environmental education, socio-scientific issues, and the NOS, for example, offer excellent possibilities for this through scientific inquiry. Of course, the NOS is fundamental as a learning object, and should be taught explicitly. Unfortunately, the NOS is often taught implicitly (Abd-El-Khalick et al., 1998), and when similarities between scientific research and school science is used instead to depict authenticity, as seen in the present study, the result can be misunderstandings about the NOS as well as features of science laboratory activities.

However, scientific research is an authentic practice producing new knowledge, whereas school science has been described as an authentic practice for the purpose of learning about scientific endeavours and to impart knowledge from the results of scientific research (Munby et al., 2000). In the three excerpts presented, the conversations can be understood as concerning the relevance of actions or observations. Using our interpretation, the learning purposes (pedagogy) constitute a reason for the chosen explanation or the chosen approach in each case. However, the learning purpose is not very visible to the student. One approach that we would like to suggest emerging from the presented excerpts is to help students to discern the learning purposes from, for example, the purposes for illustrating a proper science method or an anticipated hospital method. Thus, the NOS should be extracted from school science practice as a more or less invisible integrated part, and instead be treated as an explicit learning object belonging to an external authentic culture distinguishable from the school culture. Therefore, we propose an additional concept, the *nature of school science* (NOSS). In contrast to Munby et al. (2000), who also use this combination of words, we do not argue that school is an inauthentic representation of experimental science. As school science comes with a learning purpose, it should be regarded as an authentic learning practice.

The NOSS is a concept that describes the basic elements of school science activities as part of an authentic practice. The NOS can be unambiguously studied as a practice separate from the pedagogical considerations within the school context. As a consequence, issues such as safety and laboratory accuracy can be presented as relevant for school science laboratory work without being disguised as scientific work. Instead of implicitly trying to portray the school science laboratory work as scientific work, activities can explicitly focus on relevant learning goals, thus facilitating students' learning of the NOS or other content knowledge. For example, the procedures mentioned above for determining blood groups in school are not fully understandable if related only to the context-dependent activities of hospital procedures and science practices. Instead, the attention could have been drawn to the learning of the particular basic principles for the procedure, in other words, the context-independent knowledge. It seems as though students have difficulties discerning between what Young (2008) describes as context-independent knowledge from the conceptual knowledge applicable in more than one specific context. By introducing this perspective on the NOSS, we want to provide a concept that could be developed to motivate and make learning activities relevant without the need of imitating other practices. Hence, the NOSS provides opportunities to focus on learning context-independent knowledge. Imitating scientific practice can still be an important activity for learning about the NOS, but the relevance of science learning activities should not only depend on this relationship.

Based on the analysis, we suggest the following distinctions for future practice. The NOS will refer to the classroom work that relates to professional practices outside school. Teachers and their students can address these practices and explicitly talk about their distinguishing features; in other words, teachers should teach NOS as content knowledge. Most laboratory activities in school are accomplished to elicit specific features of a natural phenomenon. They can occasionally be described with reference to the NOS; in other words, aspects of what students do in the laboratory can relate well to professional practices, and thereby be used for discussing scientifically authentic practices. Nevertheless, laboratory activities in school are usually done to reach expected learning goals and not for obtaining precise laboratory results. To some extent, the learning situations can be similar to the professional practices, but they are indeed intended for other purposes. We conclude that it is important for teachers to explicitly address the NOS concept in accordance with Schwartz et al. (2004), in order to point out similarities to the professional practices of science. In this endeavour, the term and the concept the NOS is important to teachers. This paper has indicated situations where distinguishing characteristics of laboratory activities are explained in view of the students' learning or safety. The results of this study indicate that teachers need to point out that such characteristics should not be understood as indicators of the NOS. Instead, the NOSS concept is used to explain the design and intent of these activities. In summation, we suggest that awareness of the NOSS provides teachers with opportunities to introduce activities in a way that allows presenting them as relevant for learning, without needing to claim that everything being done in the science classroom consists of a transformation of an authentic activity.

Conclusions

Procedures in school science experiments are not made relevant because of the need for exact results or by claims of authenticity in relation to professional science practices, but for educational purposes. We suggest that using the NOS and NOSS concepts can facilitate scholars and teacher educators to differentiate between the various rationales in science education. This contention is based on limited Swedish empirical material and more extensive data collection is needed to take the step beyond suggestions. Nevertheless, since other studies has shown that the NOS is often taught implicitly, it is likely that the implications suggested here could be useful for contexts other than Sweden. That is, future research could benefit from acknowledging the authenticity of school science practice using the NOSS concept. Similarly, the NOSS could be of help to teachers and teacher educators to discern science classroom features from science practices and the NOS. The NOSS here is intended for emphasising rationales that are suitable for learning purposes. By making use of the difference between the two concepts, teachers can inculcate credibility in classroom activities by referring to the purpose of the activity without confusing it with the NOS in an inappropriate way. Hence, students do not need to expect aspects of the NOS to bring about authenticity to activities relating to the NOSS. By these means, activities can be regarded as a legitimate part of a learning process without being classified as dealing with solely in-school knowledge (cf. Young, 2008). In addition, the differentiation between the two concepts in teaching practice can facilitate students perceiving aspects of the NOS as relevant when they explicitly correspond to the presented laboratory practice. To provide a deeper understanding of how educational aspects are explained to students, we suggest future research in order to avoid teaching strategies or other learning prerequisites being perceived as aspects of science.

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