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ARTICLE

Teachers' Ways of Talking About Nature of Science and Its Teaching

Lotta Leden[1] · Lena Hansson[1] · Andreas Redfors[1] · Malin Ideland[2]

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Abstract Nature of science (NOS) has for a long time been regarded as a key component in science teaching. Much research has focused on students' and teachers' views of NOS, while less attention has been paid to teachers' perspectives on NOS teaching. This article focuses on in-service science teachers' ways of talking about NOS and NOS teaching, e.g. what they talk about as possible and valuable to address in the science classroom, in Swedish compulsory school. These teachers ($N = 12$) are, according to the national curriculum, expected to teach NOS, but have no specific NOS training. The analytical framework described in this article consists of five themes that include multiple perspectives on NOS. The results show that teachers have less to say when they talk about NOS teaching than when they talk about NOS in general. This difference is most obvious for issues related to different sociocultural aspects of science. Difficulties in—and advantages of—NOS teaching, as put forth by the teachers, are discussed in relation to traditional science teaching, and in relation to teachers' perspectives on for which students science teaching will be perceived as meaningful and comprehensible. The results add to understanding teachers' reasoning when confronted with the idea that NOS should be part of science teaching. This in turn provides useful information that can support the development of NOS courses for teachers.

1 Introduction and Background

1.1 Nature of Science

National curricula and standards, as well as science education researchers, argue for the inclusion of nature of science (NOS) in science teaching (Hodson 2009; Lederman 2007;

✉ Lotta Leden
lotta.leden@hkr.se

1 LISMA, Kristianstad University, 291 88 Kristianstad, Sweden

2 Malmö University, 205 06 Malmö, Sweden

Matthews 2012; McComas et al. 1998; Osborne et al. 2003). The presence of NOS in science curricula in the Western world has been explored by Jenkins (2013), who claims that some aspects of NOS have been part of the agenda for more than a century. Much has been written about teachers' views of NOS, and about why NOS does not easily become part of science teaching. Much less is known about teachers' views regarding NOS teaching in response to respective national curriculum requirements. Research focusing on science teachers' concerns and issues in light of such requirements is needed in order to prepare them to meaningfully teach NOS. The study reported here is part of such a line of research.

Arguments raised for including NOS in science education are, for example, NOS as a crucial component of scientific literacy (Driver et al. 1996; Hodson 2009), as a facilitator of a deeper understanding of science content (McComas et al. 1998), and as a motivator and contributor to students' interest in science (McComas et al. 1998; Sjøberg 2010). In addition to this, several researchers (see for example Aikenhead 2006; Clough 2006; Duschl et al. 2006; Ryder 2002) argue that science teaching continues to have a narrow focus on logical and conceptual elements, and on cookbook lab-work—in other words, that science education has been (and still is) blind to broader perspectives on NOS.

Science teaching, traditionally, communicates a number of myths about science such as the existence of a single scientific method that produces indisputable knowledge (McComas 1998). Other such myths, concerning historical narratives, are examined in Allchin (2003), where examples are given of monumentality (scientists are presented as heroic and virtuous) and of the image of science as: "black and white, true and false, without any 'shades of grey', partial conclusions or residual uncertainties" (p. 333). This constitutes certain patterns, which are part of taken-for-granted practices in science teaching, where science is presented as an objective, and privileged way of knowing (Aikenhead 2006; Brickhouse 2001; Carlone 2003). These notions of science, which Carlone (2003) describes as "prototypical science", are obstacles to accomplishing the aim of "science for all" (Barton and Yang 2000; Brickhouse 2001; Carlone 2003). Different images of science communicated in the classroom could thus be understood in relation to the possibilities for different students to engage in science/science education in a meaningful way (i.e. the exclusion/inclusion of students, see e.g. Barton and Yang 2000).

Among scientists, as well as among philosophers and sociologists of science, there is a long-term debate and diverging opinions on what should count as important characteristics of NOS. While Alters (1997) argues that there is no such thing as one NOS, a number of other researchers (e.g. Eflin et al. 1999; Hodson 2009; Lederman 2007; McComas et al. 1998) argue that although there is disagreement on a couple of aspects (e.g. the extent to which social and cultural factors influence scientific knowledge), there still is great agreement on a number of other aspects (e.g. that there is no single scientific method).

Science education researchers have dealt with NOS in different ways. As most agree that there are many reasons *why* NOS should be taught, the main focus of the debate has been about *what* and *how* NOS content should be taught in school. Specific NOS tenets, relevant for K-12 students, have been suggested (see for example Lederman 2007; McComas 1998; Osborne et al. 2003). Such tenets/consensus lists have had a great impact on science documents such as *Benchmarks for Science Literacy* by the AAAS (1993/2009) (van Dijk 2011). Another perspective on NOS teaching is inspired by the family resemblance concept by Ludwig Wittgenstein. A "family resemblance concept entails that science can only be described by means of a loose cluster of features that many sciences share, whereas none of these features is present within all scientific disciplines and a particular scientific discipline may lack any of them" (van Dijk 2011, p. 1093). An explicit use of a family resemblance approach is advocated by scholars such as Eflin et al. (1999), Erduran and Dagher (2014), Irzik and Nola (2011, 2014), and Van Dijk (2011). Irzik and Nola (2011, 2014) used this approach to put forward categories providing "a structural description of NOS" (p. 596), which emphasise both heterogeneity and resemblances between scientific disciplines. Matthews (2012) advocates change from the term 'nature of science' to "a more relaxed, contextual and heterogeneous 'features of science'" (p. 4). He argues that focusing on features of science would open up elaboration, inquiry and discussion instead of risking that science teaching focuses on the memorisation of a couple of well-chosen NOS tenets. Such critique has also been put forth by many other scholars, e.g. Allchin (2011), Clough (2007), van Dijk (2011), and Irzik and Nola (2011). Abd-El-Khalick (2012) argues for the use of NOS tenets but emphasises the need for elaboration. He suggests that, especially when teaching students in higher grades, the complexity and intertwining nature of the NOS tenets should be reflected upon.

Studying science from a range of different disciplinary bases such as philosophy, sociology, psychology and cultural studies of science can contribute to the characterisation of science and help to elaborate on the perspectives on NOS (Duschl et al. 2006). Another perspective that could contribute to this elaboration is the scientists' perspective, or rather perspective*s*. Scientists' perspectives have been shown to be bound to context rather than discipline and have great potential in promoting discussions about contemporary science or "science in the making" (Latour 1987) among students and student teachers (Wong and Hodson 2010; Hodson and Wong 2014; Niaz 2010, 2012; Tala and Vesterinen 2015).

In this study we have been inspired by the above-mentioned debates and have taken the position that it can be valuable to use some kind of NOS themes as a point of reference, and that these themes should be broad, comprehensive, and possible to connect to different contexts. Thus we have developed NOS themes, adapted and broadened, from the tenets described by Lederman (2007). These themes allow for the inclusion of multiple perspectives (e.g. sociological, historical, and philosophical perspectives as well as those from contemporary scientists). As such, they establish a framework within which the NOS content of science teaching can be analysed.

1.2 Research on NOS Teaching

There are a variety of different lines of research on NOS in science education focusing on teachers, students, textbooks, curricula, classroom material, etc. In this article we focus on teachers' perspectives on NOS teaching. Even if teachers (often) do not intend to teach about NOS, messages about NOS are an inevitable part of science teaching, mediated through textbooks, teacher language, lab manuals, etc. (Abd-El-Khalick 2012; Clough 2006; Ryder et al. 1999). Previous research shows that these messages often provide the narrow and stereotypical image of science described above (e.g. Campanile et al. 2015; Vesterinen et al. 2013). Research has shown that logical positivism has had (and still has) a strong influence on science education (Aikenhead 2006; Carlone 2003; Duschl et al. 2006). Teachers and students often talk about science as a body of knowledge, "facts or truths" (Abd-El-Khalick 2001, p. 221), gained through one single structured method (Abd-El-Khalick 2001; Lederman 1992, 2007; McComas 1998), and there is a lack of reflection on cultural, moral and philosophical aspects (Lakin and Wellington 1994). A review of research projects aiming to change teachers' views of NOS is provided in Abd-El-Khalick and Lederman (2000). Matthews (2012), however, argues for modesty in terms of the expectations placed on students and teachers—that it is unrealistic to expect them to be experts in history, philosophy or sociology of science. The aim should be to make multiple perspectives visible in the science classroom.

Different opinions on how to teach NOS have been presented by several researchers. According to a review by Lederman (2007), NOS is "best learned through explicit, reflective instructions" (p. 869), but whether these explicit instructions should be embedded within the traditional subject matter or taught as a separate 'pull-out' topic is still up for debate. While some researchers emphasise the importance of NOS being taught *within* the context of a topic (e.g. Allchin 2011, 2014), others (e.g. Clough 2006) argue that there is an important place for both decontextualised (pull-out) and contextualised approaches to NOS teaching, since these different approaches meet different needs. Further recommendations are that teaching *about* science (explicitly) should be strongly focused while *doing* science (Abd-El-Khalick 2013; Allchin 2011, 2012b; Clough 2006; Duschl and Grandy 2013). Other research studies indicate that involving students in argumentation can be one way to enhance their understanding of various NOS aspects (e.g. Khishfe 2012, 2014; McDonald 2010). Explicit messages often compete with implicit ones, e.g. in textbooks, and therefore it is important to consider *both* these ways of communicating science to the students (Ryder et al. 1999).

In classroom studies the connections between teachers' views of NOS and their classroom instruction have been investigated (see for example Bartholomew et al. 2004; Brickhouse 1990; Clough and Olson 2012; Lederman 1992, 1999; Bartos and Lederman 2014). These studies indicate that even teachers with informed views of NOS often do not make it an explicit part of their classroom practice (e.g. Bartholomew et al. 2004; Lederman 2007; Lederman and Lederman 2012; Bartos and Lederman 2014).

A few long-term studies have focused on developing teachers' knowledge of both NOS and strategies for explicit NOS teaching (e.g. Akerson and Hanuscin 2007; Clough and Olson 2012; Lederman and Lederman 2012). This can be seen as part of teachers' pedagogical content knowledge (PCK) (Shulman 1986), which has been investigated by, for example, Hanuscin et al. (2011). However, research specifically focusing on teachers' reflections by directly giving a voice to teachers and their perspectives on NOS as a learning object is scarce (although there are examples of studies including such perspectives, e.g. Abd-El-Khalick et al. 1998; Clough and Olson 2012; Henke and Höttecke 2015; Schwartz and Lederman 2002).

Studies focusing on NOS teaching and teachers' translations of NOS knowledge into classroom practice show that: (1) teachers focus on "the scientific method" rather than on scientific theories (Duschl and Wright 1989); (2) teachers often think they are teaching about NOS when their students "do science" (Abd-El-Khalick et al. 1998; Bell et al. 2003; Schwartz and Lederman 2002); (3) teachers need, and ask for, teaching resources (Abd-El-Khalick et al. 1998; Akerson and Hanuscin 2007; Hanuscin et al. 2011; Lakin and Wellington 1994); (4) teachers, although considering NOS as important, believe it to be an add-on that is difficult to make room for (Abd-El-Khalick et al. 1998; Clough and Olson 2012); (5) strategies for NOS teaching often clash with traditional science teaching (Bell et al. 2000; Herman et al. 2013; Lakin and Wellington 1994); (6) teachers lack intention or motivation to teach NOS (Aikenhead 2006; Bartos and Lederman 2014; Schwartz and Lederman 2002); (7) beginning teachers' inexperience sets limits to NOS teaching (Aikenhead 2006; Brickhouse and Bodner 1992; Gess-Newsome and Lederman 1993); (8) teachers have concerns for students' motivation and abilities to deal with abstract or controversial issues (Abd-El-Khalick et al. 1998; Aikenhead 2006; Brickhouse and Bodner 1992; Hodson 1993; Lederman 1995); and (9) teachers have concerns about the "good students" who are accustomed to memorise facts for the test (Aikenhead 2006; Carlone 2004).

In order to be able to challenge and change the way teachers address NOS and view it as a learning object, and in order to help them develop explicit practices, professional development programs and teacher education need to scaffold teachers while they are reflecting on their teaching. This scaffolding should take place over a long period of time and provide both material for NOS activities and assessment, as well as strategies for how to develop these (and new) activities further (Akerson and Hanuscin 2007; Bartos and Lederman 2014; Bell et al. 2000; Hanuscin et al. 2011; Lederman and Lederman 2012). A lot of instructional material has been developed (e.g. Allchin 2012a; Clough 2011b; Höttecke et al. 2012; Lederman and Abd-El-Khalick 1998). Another important part of teacher education, highlighted by Herman et al. (2013), is to help teachers connect NOS to other science content so that it can become part of science teaching not only when carefully planned for, but also on the spur of the moment.

This article takes as a point of departure that science teaching would benefit from a more elaborate inclusion of NOS. Since we believe that it is important to broaden, question and challenge the traditional views of science often presented in the science classroom we have to focus on the teachers, as they play a key role in every educational change (Wallace and Loughran 2012).

This study seeks to add to previous research not only by focusing on teachers' knowledge about specific NOS aspects, but also by analysing what they say about NOS teaching per se. This knowledge is important since "If one [the teacher] does not feel NOS is important, relevant, or attainable by students, one is not likely to teach NOS" (Schwartz and Lederman 2002, p. 231). In Sweden, teachers have to implement curricula that explicitly and implicitly refer to NOS aspects. Teachers (many of them with no specific NOS training) are often left to make their own interpretations and decisions on what specific NOS content to include in their teaching and how to do this. What in-service science teachers say about NOS and NOS teaching is an important starting point when developing courses to meet pre-service and in-service teachers' needs. Furthermore, knowledge about, for example, teachers' anticipated difficulties has the potential to add to our understanding of why NOS teaching often does not become part of science teaching, as well as add to our understanding of what measures should be taken to change this.

1.3 Aim and Research Questions

In this study we aim to shed light on how teachers talk about NOS and about specific NOS-aspects in relation to teaching, e.g. whether these are regarded as appropriate, desirable or even possible to include in the teaching of science.

The research questions guiding this study are:

- How do compulsory-school teachers talk about different aspects of NOS?
- How do compulsory-school teachers talk about the teaching of different aspects of NOS?

This study will contribute to the development of strategies for deciding about what to focus on in pre- and in-service teacher education, regarding the teaching of NOS. The need for this is to increase future teachers' competence to include NOS in science teaching and thereby challenge the traditional images of science usually communicated in science class. Suggestions and implications for teacher education are included in the concluding remarks of this article.

2 Method

2.1 Study Context and Participants

In Sweden, all students study the same science curriculum throughout compulsory school.[1] NOS has been a part of the Swedish national curricula for the last couple of decades (Johansson and Wickman 2012), as is also the case in most other Western countries. However, the phrase 'nature of science' (in Swedish 'naturvetenskapens karaktär') is not mentioned in the current curriculum (Skolverket 2011a). References to NOS are made both implicitly and explicitly and all of the tenets described by Lederman (2007) are incorporated, at least if you study the curricular intentions described in an additional official commentary to the curriculum (Skolverket 2011b). With passages like: "Through teaching, pupils should be given the opportunity to develop perspectives on changes in the world view of the sciences and obtain an insight into how the sciences and culture influence each other" (Skolverket 2011a, p. 120), or "Usefulness of the theories and models of physics, their limitations, validity and variability" (Skolverket 2011a, p. 124), the intentions of the curriculum to include NOS is rather explicit. The intention to make NOS important is also strengthened by the official commentary to the curriculum (Skolverket 2011b). In this text the term 'nature of science' is also specifically mentioned:

> Knowledge about the nature of science is central in order to be able to distinguish between scientific information and other ways of depicting the world. That kind of knowledge makes it possible for students to see how facts are connected to values, and to examine the interests and values behind certain positions. (Skolverket 2011b, authors' translation, p. 31)

> …one reason to emphasise students' own questions is to avoid the notion of a subject that is mainly built on ready-made facts. The intention of the curriculum is instead to emphasise physics as a dynamic, creative and up-to-date subject in constant development. (Skolverket 2011b, authors' translation, p. 7)

> This means that physics, like all sciences, is an open and creative activity. (Skolverket 2011b, authors' translation, p. 10)

However, it is crucial to know that there are no specific, official teaching materials developed to help teachers transform these passages into classroom instruction and there are rarely any teacher education courses with a specific emphasis on NOS. Research by Högström et al. (2006) and Gyllenpalm et al. (2010) have shown that teaching about NOS is seldom mentioned by Swedish science teachers when they talk about science teaching.

The participants of this study were 12 in-service science teachers, teaching different grades in compulsory school (years 3–9). The teachers came from five different schools and most of them had long teaching experience (see Table 1 for details). There were large differences in their educational background. All participants had received teacher education, but the amount of science courses within the teacher education programs differed. Two of the older teachers (Bob and Carolyn) had received general teacher's education for all subjects taught in years 4–6. The younger teachers had received teacher's education with mathematics and science profiles aimed at years 1–7 or years 4–9. There were also two participants (Midge and William) with no science courses in their teacher education, but who taught science anyway.

[1] Compulsory school comprises years 1–9 (ages 7–16) and is divided into three stages (i) years 1–3, (ii) years 4–6, and (iii) years 7–9, with students mostly changing teachers at each consecutive stage.

Table 1 Teachers participating in the project (teachers' names are not their real names)

Name	Years in teaching	School year	Educational background	Name	Years in teaching	School year	Educational background
Ella	17	5–6	Years 1–7 Science, math	Tom	8	7–9	Year 4–9 Science, math
Mary	8	7–9	Years 1–7 Science, math	Bob	37	4–6	General middle school
Nina	10	7–9	Years 4–9 Science math	Mike	4	6–9	Year 7–12 General science
John	15	7–9	Years 4–9 Science, math	Lynn	11	5–6	Year 1–7 Science, math
Agnes	16	3–6	Years 1–7 Science, math	Midge	16	5–6	Year 1–7 Swedish, social sciences
Carolyn	32	4–6	General middle school	William	2	7–9	Year 7–12 History, environmental knowledge

2.2 Data Collection

NOS, as mentioned above, is an integral part of the Swedish curriculum even if it is most often not a familiar concept among Swedish science teachers. Thus, teachers could very well have things to say related to different NOS content and the possibility for NOS teaching even though they are not familiar with the concept. Therefore, in order to be able to study teachers' ways of talking about NOS, we started by using the open-ended VNOS-C (views of nature of science) questionnaire (Lederman et al. 2002). The questionnaire was complemented by follow-up interviews as recommended by Lederman et al. (2002), which asked questions on teachers' views of nature of science. In addition to this, questions about NOS teaching were asked (see below). The interviews were semi-structured and took place up to 4 months after the questionnaire was answered. All participants had access to their formerly written answers. The first author (who also was the interviewer) prepared every interview protocol by carefully reading teachers' responses to the written questionnaire and then preparing follow-up questions that were specific to each participant. In the first part of the interview, teachers were asked to elaborate on their answers in the questionnaire, in new contexts and with more examples (e.g. if the answer in the questionnaire described a school context, the follow-up question could be to elaborate in a scientific context and if the answer was from a global context the follow-up question could be to elaborate in a Swedish context). In the second part of the interview, where questions about NOS teaching were asked, the interviewer started by making a summary of the topics/themes discussed in the first part. These themes were written on a sheet of paper and the teachers were asked to relate to them all (tentative, empirical, subjective, creative, sociocultural aspects, and theories/laws/models) while answering questions about NOS teaching, e.g. what, why, when, how and for whom certain NOS aspects should be taught (or not taught). All interviews were digitally recorded and transcribed. We note that our data consists only of what the participants were willing to share with the interviewer during interviews (and questionnaires).

The questionnaire (which was translated into Swedish) and the first part of the interview were used with twofold purposes. First, as mentioned above, to be able to analyse how

Swedish teachers talk about NOS. Second, to give teachers an idea about what kind of issues NOS could be about. We wanted to ask teachers about their reflections on teaching about NOS, but since the term NOS is not often used by teachers in Sweden, and not mentioned in the curriculum even though NOS content is included (see above), questions about NOS teaching would have been pointless to ask without making sure that the teachers had a frame of reference.

During the interviews several of the participants claimed that they had never thought about these kinds of questions before [the same notion was expressed by scientists in Wong and Hodson (2010) and by teachers in Lakin and Wellington (1994)]. One of the teachers in this study articulated this by saying: "I have been thinking [since answering the questionnaire], my brain has been put to work. To discuss these kinds of thing makes me feel good" (Lynn).

2.3 Framework and Analysis

The analytical framework used in this study consists of five NOS themes (described below) inspired by debates about NOS as well as the NOS tenets described by Lederman (2007). In order to capture all possible aspects of NOS discussed by the teachers, the framework consists of comprehensive and broad themes with the specific purpose of allowing multiple perspectives to be analysed. The themes are employed as thematic lenses in the analysis of teachers' ways of talking about aspects of NOS inherent to each theme. We take the position, suggested by Potter and Wetherell (2007), that it is not fruitful to try to access a person's inner views but instead listen to the way people express themselves. In addition to this, Nott and Wellington (1998) argue that describing teachers' views of NOS as naïve or informed (following Lederman et al. 2002) can be problematic as NOS itself is a construct open to revision and "different professional groups have different perceptions of the nature of science" (p. 580). For instance, some STS (science, technology and society) scholars might take a deeply relativistic stance that would, by other scholars, be judged just as naïve as a radical positivistic one. That is, being naïve about NOS could mean very different things to different people.

Therefore, it is more interesting to study the range of teachers' answers and their different levels of elaboration, resembling the way Ryder et al. (1999) studied how the range of each person's different images of science constitutes a profile to draw on when talking about science. However, this is not to say that the authors of this article have no preferences concerning NOS teaching. We take the position that it is desirable that prototypical science and myths about science are challenged and that different aspects of NOS are addressed at different levels of depth at different educational levels (as discussed, from different points of view; by Abd-El-Khalick 2012; Allchin 2011, 2012b; Erduran and Dagher 2014). Therefore we use these NOS-lenses as a way to identify how teachers use different ways of talking about NOS, both in ways closely related to what Carlone (2003) calls "prototypical science," what McComas (1998) refers to as "the myths of science", and in ways of talking that opposes this portrayal of science. The themes are open to including a broad span of possible ways of talking coupled to different topics both related to science in general and to specific scientific disciplines and contexts (as suggested, for example, in Matthews 2012). Each theme represents a dimension extended between two extreme positions. Even though the themes are broad, they are still often intertwined and not easy to separate from one another. One example is argumentation and peer review as an important part of science, which could be an aspect that is in line both with ways of talking about empirical science (if we focus on scientists' working methods), with ways of talking about subjective/objective science, and with sociocultural aspects of science. As a consequence a specific statement can be (and often is) sorted into more than one theme. The theme descriptions (below) are based on science studies literature as well as science education literature.

- *Theme 1: Absolute and/or tentative NOS*
  A variety of topics, such as continuity/change and certainty/uncertainty, are relevant in relation to this theme and ways of talking can be coupled to historical and contemporary examples, as well as to different scientific disciplines (Eflin et al. 1999; Hodson 2009; Hodson and Wong 2014). The theme ranges from one extreme representing scientific knowledge as consisting of absolute and static facts (the mythical pictures described above) to the other extreme representing scientific knowledge as very uncertain or relativistic. The theme comprises Latour's (1987) discussion about "ready-made science" (science presented as facts in textbooks where the production of scientific knowledge is black-boxed) and "science in the making" (the construction of scientific knowledge in a social context where "uncertainty, people at work, decisions, competition, controversies" (p. 4) are in focus).

- *Theme 2: Empirical and/or rational (theoretical) NOS*
  This theme deals with ways of talking about the role of empirical as well as theoretical contributions to science. Emphasis may be on either empiricism or rationalism (Eflin et al. 1999). In science teaching the empirical base of science is often emphasised, e.g. through "the scientific method" (McComas 1998). Science studies literature shows that there are different ways to view the scientific endeavour and the way results are produced and criticised by the scientific community. Thus, this theme comprises ideas ranging from observations automatically providing truth (through one specific, well-structured method) to the notion of great diversity, e.g. in methods and between disciplines (see for example, Knorr-Cetina 1999; Pickering 1995). Examples of topics relevant for the theme are: the role of observations and experiments, trustworthiness, methods, and limits of science (see for example, Allchin 2011, 2012b; Hodson 2014; Hodson and Wong 2014; Wong and Hodson 2010). These topics could be connected both to general and discipline-specific features of science.

- *Theme 3: Objective and/or subjective NOS*
  This theme deals with ways of talking ranging from realism to radical constructivism, linked to a wide variety of areas such as ontology and epistemology of science, and to disciplines such as sociology and psychology. A number of topics, such as discussions of subjectivity/objectivity connected to different stages of the research process (Stenmark 2004), theory-laden/neutral observations, background factors, and biases are included in this theme. Feminist theorists have, for example, shown great interest in the debate of objectivity and scientific knowledge (see Freedman 2009; Longino 1990; Ramazanoglu and Holland 2002).

- *Theme 4: Rational and/or creative NOS*
  This theme deals with ways of talking that range from ideas that scientists use a well-structured, rational and predesigned approach, never deviating from *the* (objective) scientific method, to ideas about the necessity to use creativity and imagination throughout the entire research process (from problem stating to interpreting observations and inventing explanations) (Lederman 2007; Hodson 2009).

- *Theme 5: Universal and/or socio-culturally embedded science*
  This theme comprises ways of talking about the controversial and much debated continuum extending from ‘everything is science’ to ‘everything is culture’, a debate that has been labelled *science wars* (see Dadachanji 1998; Mosco 2012). Issues within this theme could be about the extent to which science is influenced by society/culture, and the extent to which it is universal. It could also deal with perspectives ranging from realism to relativism. As in the other themes, both historical and contemporary contexts are important to these issues. Furthermore, a number of perspectives could be relevant, such as: economy (Erduran and Mugaloglu 2013; Irzik 2010), cultural and social practices of different sciences—e.g. epistemic cultures (Knorr-Cetina 1999), and feminist theory (Longino 1990).

In a first phase of the analysis, teachers' ways of talking about NOS and its teaching were analysed with the different themes described above as a framework. Teachers' ways of talking concerning each of the themes were extracted through repeated reading of the transcripts. The unit of analysis was a teacher's statement. It should be noted that, for all of the themes, the same teacher can use different ways of talking about the same theme. The coding was done using NVivo™.

In a second step, teachers' statements within each NOS theme were analysed and coded, looking for different ways of talking about NOS and its teaching. The analysis was carried out through repeated reading, tentative coding and re-coding of the answers to the questionnaires and of the interview transcripts. In this second step pre-developed categories were not imposed on the data, but instead an empirically grounded analysis that can be described as a constant comparative approach was performed (Glaser and Strauss 1967). Through a constant comparison the properties of each category (i.e. way of talking) were developed and reorganised, finally resulting in the different ways of talking presented below. In the presentation of the results, teachers' different ways of talking are exemplified by (translated) transcript excerpts. Each theme is also summarised in a table which provides an overview of the number of participants using each way of talking as well as an overview of the number of statements made within each way of talking—both when talking about NOS and about its teaching. Thus, from the tables we are able to see which way of talking was most commonly used by the teachers, as well as the sometimes reverse relationship between the number of statements made within different ways of talking about NOS and its teaching.[2] We are also able to see that the same participant often uses more than one way of talking about the same theme.

3 Results: Teachers' Ways of Talking About NOS and NOS Teaching

In this section we present the results, based on the analysis described above, of different ways of talking about NOS aspects and its teaching related to each theme.

3.1 Theme 1: Absolute and/or Tentative NOS

Four different ways of talking were identified for this theme (see Table 2). The table shows that, in this study, the most frequent way of talking about NOS was as "scientific

[2] Note, however, that this refers to the frequencies of the different "ways of talking", not to how common different "views" are.

Table 2 Summary of teachers' ways of talking about theme 1—absolute and/or tentative NOS

Way of talking	Talking about NOS		Talking about NOS teaching	
	# Participants	# Statements	# Participants	# Statements
(1) Scientific knowledge as facts	9	29	11	41
(2) Scientific knowledge as progressive	11	30	9	24
(3) Scientific knowledge as subject to various degrees of tentativeness	10	23	1	1
(4) Scientific knowledge as changing or uncertain	12	118	9	29

knowledge as changing or uncertain". This differs from previous research, which has shown that it is common for teachers with no specific NOS training to talk about scientific knowledge as facts and objective truth (e.g. Abd-El-Khalick 2001; Lederman 1992, 2007; McComas 1998). Yet, concerning NOS teaching, teachers more commonly talked about "scientific knowledge as facts". Nevertheless, for this theme, most teachers used many different ways of talking about NOS in relation to teaching.

3.1.1 Scientific Knowledge as Facts

When talking about scientific knowledge as facts teachers emphasised its absolute status by making statements about proof and facts. Science was described as "ready-made"; the final products of science were emphasised, and orderliness, the scientific method, and rationality were highlighted (in line with previous research, e.g. Aikenhead 2006; McComas 1998). Even when claiming that science is subject to change most of the teachers still described it as less changeable than other kinds of knowledge.

> Religion and philosophy are constructed by humans. You deal with opinions and beliefs that can be changed. In natural sciences you deal with proven causal relationships. (Bob)

When talking about teaching, teachers often described their classroom instruction as based on the teaching of facts that are not up for discussion.

> I have to confess/…/I'm no good at this: knowledge as changing, and discussing that maybe it's not static./…/It's experiments and facts. And drawing conclusions. I know I focus too much on facts and that's not fun the long run. (Nina)

Some of the teachers criticised their own (and each other's) teaching due to the emphasis on facts and explanations (especially in years 7–9). They argued that students should not get the impression that science only consists of facts to memorise, but instead is something to reflect upon and could yield unexpected results. At the same time as it was considered to be "no fun, just learning facts" (Midge), it was also considered hard for many children to accept that there is not always an evident right or wrong and that some students, especially the younger ones, "get sad" because of uncertainties. Some teachers also talked about the necessity to teach science as black and white (see Allchin 2003) to facilitate students' learning:

> In school, to make things graspable, we talk about black or white, but in reality there are infinite shades of grey. But still, if we had talked about all that, the students wouldn't even get a clue, so we just provide really simplified models to give them a first hint. (Mary)

This means that even if teachers refer to scientific knowledge as, to some extent, changing or uncertain they still can, for different reasons, choose to teach science as facts (see also Sect. 3.1.2). Another reason, in addition to the above-mentioned concerns for students, is that the teachers themselves feel that they are not up-to-date on details about how scientific knowledge has changed. As Bob puts it: “I have to know it myself [laughter]. You are seldom one hundred percent up-to-date.”

3.1.2 Scientific Knowledge as Progressive

Teachers often strongly emphasised science as progressive, and as providing us with better and truer knowledge finally resulting in absolute truth. This progression was described as enforced by two different reasons: (1) researchers gaining/discovering *more* pieces of the scientific puzzle thus leading to increased knowledge, and (2) due to (sometimes drastic) *changes* in interpretation, thus leading to a more correct picture of science. Historical cases were the most common examples and the bottom line was that knowledge is going to get more and more certain until, somewhere in the future, we have reached the truth.

> As we get access to new findings, we are advancing the frontiers of our knowledge; alternatively, we get a more accurate picture of how reality works. (William)

When connecting progression to science teaching teachers talked about the importance of presenting scientific knowledge and research as being in constant progression. They argued that students should know that science means constant progress and material gains for humankind. The most common example brought up in science class (addressed by all teachers) was the heliocentric worldview versus the geocentric worldview, often described as science’s triumph over the church. Another example often mentioned was that at one time people believed the atom to be indivisible. One of the teachers mentioned using a parcel as a metaphor when teaching about how we gain scientific knowledge.

> I can shake and wobble [the parcel]/…/but there are still limits [to the knowledge we are able to gain] but one day we might be able to open [the parcel] and look, and then we will know/…/thus, in a way you [i.e. the scientists] sometimes fumble in the dark. We have not [actually] seen it but evidence suggests that this is, approximately, what it’s like. (John)

3.1.3 Scientific Knowledge as Subject to Various Degrees of Tentativeness

Teachers talked about a various amount of absoluteness/tentativeness in science depending on topic and context. School science is one example that was considered well established and fixed (“ready-made”) as compared to contemporary science, which was considered more uncertain and controversial (“science in the making”). Things that can easily be observed were also considered easier to confirm than small things (such as the atom) or events far back in history like the Big Bang.

> Some theories are subject to less change and are more secure than others. Some theories will never be proven. (Mike)

Only one of the teachers talked about varying degrees of tentativeness in relation to teaching (see Table 2) and in this case the teacher talked about it as something not really necessary to teach about:

> Well, of course you should address it [changes in knowledge] but I don’t think it should be done very often because what I do [at this level] is quite basic. Snow melts and clouds are formed and such. There’s not much change in that. You can watch it with your eyes. (Bob)

This teacher obviously expressed a belief that science can change but that this is not relevant to the students he is teaching, since this science is simple and well established ("ready-made science").

3.1.4 Scientific Knowledge as Changing or Uncertain

In contrast to many other studies (e.g. Abd-El-Khalick 2001; Lederman 1992, 2007; McComas 1998), in this study the most common way to talk about scientific knowledge was as changing or uncertain (see Table 2). Through this way of talking, the changes in scientific knowledge were not explicitly related to progress but rather to uncertainty and to different kinds of knowledge being regarded as true at different times and places. Teachers argued that the knowledge we possess here and now is not actually truer than the truth people knew 500 years ago, it is only different. Uncertainty was described either as inherent to the scientific problem being addressed (e.g. the origin of the universe), or as science as always being subject to change, up for discussion and revision. Reasons given to explain tentativeness or change varied from statements about changes due to new instruments and experiments to more general statements like: "there are no absolute answers" (John). Other less commonly provided reasons were, for example, changes in society or "new scientists who simply have other ways of viewing things" (Midge).

When relating uncertainty to teaching, some teachers pointed out that they tell their students that school only provides a simplified picture of science and that there is a possibility that contemporary knowledge might change (see also Mary in Sect. 3.1.1):

> I tell them [the students] that it is a simplified [picture]/…/but that if they perhaps study further, they shall not come back to hang me for the things I have said. (John)

That scientific knowledge is subject to change in a *historical* context was not considered as difficult or abstract and was therefore considered easy to teach in all grades. There was, however, more ambivalence concerning the teaching of uncertainty in relation to contemporary science. Most teachers talked about it as something the students should be aware of, just because it is a part of reality.

> It is important to tell the students that no one really knows for sure and that this is just a model of reality. (Mike)

Knowing that scientific knowledge is not complete and can be open to change was also regarded as motivating for students to engage in science and pose questions that could be investigated. Teachers argued that if they know that scientists can come to wrong or diverging conclusions the students themselves will not be afraid to try to answer questions, and that will increase their curiosity. A teaching focused on different ways of thinking, on argumentation, and on interpretations, was considered a possible way to maintain (or increase) students' interest and curiosity in science.

> There are different ways of understanding how science works and/…/that it [science] is actually not static/…/It can always be changed and I think that's what makes it challenging and exciting for the kids. That could make them gain an interest in science because they feel that "this is not just something I have to memorise, but instead I actually can think for myself a bit too". (Carolyn)

Still, teachers mentioned different groups of students reacting differently when leaving the focus on facts in the science classroom. There is the 'good student', defined by teachers as a student who studies hard to produce correct answers to a test, who will not benefit from a teaching where a correct answer is not easily found. Some of the teachers argue that the low achieving science students are the ones who will gain most. In addition, these students are considered to contribute most to classroom discussions if there is a shift from a black and white teaching approach to engaging students in discussions about non-consensus science-topics:

> They [the struggling students] are often the ones who are most philosophical. I get the feeling that, in many cases when you are supposed to be creative and imaginative, it's much easier for them because they are not so trapped in their minds by what's right and wrong/…/I think I feel they would contribute/…/the most in that kind of discussions [about science and uncertainty]. That's why it's important to make these students participate. (Ella)

3.2 Theme 2: Empirical and/or Rational (Theoretical) NOS?

Two different ways of talking were identified for this theme (see Table 3). The table shows that, within this theme, all teachers used both ways of talking about NOS. However, in relation to teaching 'the scientific method' was much more commonly mentioned than the idea that both empirical and theoretical practices play roles and interact with each other (i.e. "combining the empirical and theoretical"). Thus, in line with previous research (e.g. Duschl and Wright 1989), according to the teachers, highlighting the role of theories is not common in science teaching.

3.2.1 The Scientific Method

As in many previous studies teachers frequently talked about scientific knowledge as being gained through the well-structured *scientific method*. That everyone knows what the scientific method is, was taken for granted and therefore not elaborated on or specified: "The scientific method? Well, we all know what that is" (Mike).

Some features were, however, mentioned by most teachers: the importance of repeating experiments, and that experiments are driven by questions or curiosity about nature. The scientific method is considered to provide direct access to nature (see Aikenhead 2006; McComas 1998):

> The experiments make it concrete so that you, so to speak, can touch it. This is what it is like. You just have to look. Open your eyes and look. (John)

Scientists are described as following the same scientific method, working in the same kinds of places (labs), and using the same kinds of materials in a way that pretty much resembles lab-work in school:

> It is at a higher level than in school science, of course, since it is research, but I still think it's the same basic idea. (Ella)

However, when asked in more detail about the work of scientists, most teachers said that they were unsure of what scientists really do when they work. This shows that the teachers have no in-depth knowledge about the work of scientists, but instead take a starting point in the traditional way of working in science class. Rudolph (2005) has described how what

Table 3 Summary of teachers' ways of talking about theme 2—empirical and/or rational (theoretical) NOS

Way of talking	Talking about NOS		Talking about NOS teaching	
	# Participants	# Statements	# Participants	# Statements
(1) The scientific method	12	102	11	56
(2) Combining the empirical and theoretical	12	59	5	8

has become 'the scientific method' was constructed by Dewey as a "generalized abstraction of the scientific process" (p. 368). In the descriptions of science given by teachers in this study we can see how this abstraction, commonly used in school science, also serves as a model for the practices of scientific research.

When talking about teaching, teachers emphasised the scientific method and connected it to lab-work. However, teachers were ambivalent and concerned about why and how lab-work should be done. A common description was that lab-work is a way to clarify the scientific content. In line with previous research (e.g. Abd-El-Khalick et al. 1998; Clough and Olson 2012) teachers often find themselves under the pressure of time and content to cover. Therefore, students are supposed to follow a manual and get the right result otherwise there is the risk of losing time, spoiling the material, or not learning the intended content (c.f. Hodson 1993). Still, teachers worried that there is too little room for students' own reflections, questions and creativity:

> I'll try to get better at giving them lab-work [assignments] that is more open, where they themselves are supposed to find out what to do. And then, hopefully, there will be discussions about what to do, and then later on this can lead to discussions about plausibility in results and sources of errors and so on. But, usually, they get a manual to follow and they are supposed to come up with an answer. (Nina)

One teacher stated that: "[we don't discuss lab-work] we just do it" (Agnes). Still, for most teachers, lab-work is described as an approach to NOS through discussions of what scientists really do, and through connections to student-generated discussions about how we can know that things are 'true' (see also Sect. 3.1).

3.2.2 Combining the Empirical and the Theoretical

All of the teachers also talked about the importance of theoretical reasoning in the process of producing scientific knowledge. None of the teachers, however, discussed the possibility of a purely theoretical science.

> I do not believe that it is possible to develop scientific knowledge by relying only on theoretical reasoning. (Midge)

Instead, theoretical reasoning in combination with experiments and/or observations was emphasised. Teachers described scientific theories as sometimes created only in the mind of the scientist. However, they added that at some point these theories are always checked empirically through experiments or observations, which can either challenge or support them. A few exceptions, where the theoretical reasoning was awarded a more prominent role were when teachers talked about the theories concerning the origin of the universe or evolution. However, in these cases teachers sometimes regarded the theories as less confirmed and more due to scientists' own philosophising.

This way of talking about science as a partly rational endeavour was connected to science teaching through teachers' emphasis on student-generated hypotheses (which are tested during lab-work). Teachers also stressed the importance of students realising that theories are grounded in empirical work:

> …you want to connect experiments to theory/…/to make it credible. If you just assume that theories and hypotheses [are correct] without any justification – well, you cannot prove everything – especially not in school – but you can somehow show/…/that there is a foundation in practical work. (Tom)

Apart from this (in line with Duschl and Wright 1989), the role of theories in science was not discussed by the teachers in relation to teaching.

3.3 Theme 3: Objective and/or Subjective NOS?

Two main ways of talking were identified for this theme, of which the second is divided into three sublevels (see Table 4). The table shows that although the most common way for teachers to talk about science was "…as unavoidably influenced by subjective factors" and the most common way to talk about science in relation to teaching was "…as (objective) facts". Still many of the teachers also talked about, "(2b) science as unavoidably influenced by subjective factors" when talking about teaching, which differs from previous research (e.g. Aikenhead 2006; Brickhouse 2001; Carlone 2003; Lakin and Wellington 1994; McComas 1998).

3.3.1 Science as (Objective) Facts

This category is strongly linked to Sect. 3.1.1. Teachers described nature as something that cannot be controlled or influenced by humans (in contrast to economy, for instance), which meant that nature sooner or later will reveal the truth to us—a realist way of talking. Thus, science is almost relieved of opinions, and is not up to each and every one to believe something about—it is about truth and "hard facts" (John). Even when teachers described scientists as creators of explanations, these were, according to them, based on truth derived from working with structured methods and objective observations.

Teaching connected to this way of talking about science was characterised by focusing on facts, concepts and lab-work leading to the right conclusions (described above for themes 1 and 2). The existence of different interpretations was seldom mentioned. One reason for this was the view that different perspectives are too abstract and hard for many students to grasp (see also Abd-el-Khalick et al. 1998; Aikenhead 2006; Brickhouse and Bodner 1992; Lederman 1995).

3.3.2 Science as (Negatively, Unavoidably or Positively) Influenced by Subjective Factors

Even though most teachers talked about scientific knowledge as equal to objective facts (in line with previous research, e.g. Abd-El-Khalick 2001; Lederman 1992, 2007; McComas

Table 4 Summary of teachers' ways of talking about theme 3—objective and/or subjective science

Way of talking	Talking about NOS		Talking about NOS teaching	
	# Participants	# Statements	# Participants	# Statements
(1) Science as (objective) facts	9	29	12	31
(2) Science as subjective				
(2a) Science as negatively influenced by subjective factors	12	27	3	4
(2b) Science as unavoidably influenced by subjective factors	12	44	9	20
(2c) Science as positively influenced by subjective factors	3	4	–	–

1998), all of them also used ways of talking where scientific knowledge was more or less influenced by subjectivity. This influence was described as being due to the researchers' educational background, experiences, values, previous knowledge, prestige, funding, and personal gains and interests.

Subjective influences were often described as something negative, an impediment to the development of knowledge that should be avoided. Negative influences were discussed in relation to the influence of existing theories, personal subjectivity and bias.

> I believe there are research groups who stand above and do serious research without bonds, but if Astra offers some money it's easy to…, but I don't know… (Bob)

> …you have decided what you believe in most. For different reasons. And then I think you just see what you want to see. (Ella).

However, even more common was the fact that teachers described subjective factors as something natural or unavoidable. This way of talking can be related both to personal subjectivity and scientific activities as being theory-laden. Here being theory-laden was, in contrast to Ella above, described as the natural starting point of investigations giving a certain focus to research questions and hypotheses. New theories are, thus, developed from already existing theories.

> Well, just by looking to yourself you know what it's like/…/It's human [to be influenced]/…/There are probably very few researchers who get to work totally blank without an idea. (Midge)

> …you see [the world] trough the glasses you are wearing. (Agnes)

In some exceptional cases, personal influence was described as *favourable* in relation to scientific knowledge production:

> …new knowledge maybe, kind of, arrives with new scientists who simply have other ways of viewing things/…/it's a little bit more global nowadays too. I think that can have an influence on [new ideas]. (Midge)

Although teachers used many ways of talking about the subjective aspects of science, subjectivity is seldom, according to the teachers, explicitly addressed or made a topic in the science classroom. Sometimes teachers said that they make statements about biased research like: "everything can be bought by money". These kinds of statements were put forth as some kind of general truth, but teachers gave no examples of how this can be elaborated in the classroom.

That different interpretations could be made in the research society is not discussed. However, some of the teachers argued that if there are different interpretations on a topic (for instance global warming or the extinction of dinosaurs) there is good reason to mention or discuss this with their students.

> Of course you should present both [interpretations] and you should talk about why and such, but the question is if I [actually] do it. I don't know. (Agnes)

One of the reasons teachers provided for *not* mentioning differences in interpretations was that they avoid the topic if they themselves feel insecure about the interpretations. Another reason was, as mentioned before (see Sect. 3.3.1), the concern for students' abilities to think abstractly.

> I think many [students] have a hard time understanding that things can be viewed differently and explained in different ways, although you have access to the same facts. (Nina)

One of the few examples mentioned where different interpretations are brought up was in connection with watching a science movie in class, in which different theories about the same topic are presented (e.g. the origin of the universe). Another example given by one of the teachers was a discussion in class about how a researcher's background and interests can influence research projects:

> …and we actually talked about that/…/What is it that drives someone to begin their research? Could it be that I want to help someone who suffers from something, or that I think something is wrong/…/ or that this is interesting? What if I could come up with something new? (Carolyn)

In addition to this, teachers expressed an aspiration to give their students opportunities to discuss, debate and evaluate knowledge. They also mentioned that students themselves are supposed to be able to take sides and respectfully listen to their peers' arguments, especially in environmental discussions but also in connection to results from lab-work (although this is a wish that clashes with the aforementioned need for students to get the right result). Nevertheless, teachers had worries concerning classroom discussions: that students who have language problems or are having a hard time making their voice heard in group discussions will be losers in this kind of approach to science teaching. However, the 'good students' were also counted as losers in a discussion approach, not only because of the lack of right answers, as mentioned before, but also due to the risk that they will not get enough credit for their part of the job (c.f. Ideland and Malmberg 2012). A teaching where students are encouraged to take positions was however not explicitly associated with similar events taking place in research or society:

> I have had kind of discussion-cafés with pros and cons concerning different power plants and such. Then, in a way, camps [groups of students with different positions] have kind of developed in class, and then they [the students] just have to accept that this is what it's like in reality too. But, well, I haven't made it more explicit than that. (Lynn)

Some teachers argued that it makes sense to discuss these kinds of questions only with those students who are specifically interested in science (often outside the science class).

3.4 Theme 4: Rational and/or Creative NOS?

Three different ways of talking were identified for this theme (see Table 5). The table shows that many teachers described scientists as both "creative" and "well-structured". Also, when talking about teaching many of the teachers described scientists as

Table 5 Summary of teachers' ways of talking about theme 4—rational and/or creative NOS

Way of talking	Talking about NOS		Talking about NOS teaching	
	# Participants	# Statements	# Participants	# Statements
Scientists follow a well-structured method	8	15	7	14
Scientists are creative while planning investigations	10	27	9	19
Scientists are creative all the time	9	25	3	8

creative, at least in some way even if the "well-structured method" is also a common way of talking.

3.4.1 Scientists Follow a Well-Structured Method

When asked about creativity, there were teachers who emphasised the scientific method (see Aikenhead 2006; Duschl and Wright 1989; McComas 1998) and who described science as an entirely rational process. These teachers also stressed the importance of avoiding creativity, especially in specific phases of the knowledge generation process, such as collecting and/or processing data:

> …well, then [after the data collection] you are only supposed to look at the facts. Then you should preferably not be creative, just be kind of objective. (Agnes)

As mentioned in Sects. 3.1.1 and 3.2.1 teachers pointed to an emphasis on facts and lab-work (e.g. through emphasising the scientific method) in school science. Through this way of talking about teaching, science is portrayed as a strictly structured activity with no need for human fantasy or creativity.

> And when it comes to creativity and fantasy, I'm afraid that many times it [the teaching] is a bit narrow because you really want them to/…/learn the scientific method. (Ella)

3.4.2 Scientists are Creative While Planning Investigations

When explicitly asked about the role of creativity in science, all teachers (with one exception) talked about creativity and imagination as an important part of the development of scientific knowledge. Teachers commonly described creativity as, first and foremost, essential in planning investigations. A good scientist has to be able to come up with solutions to find the best way to elicit the truth—a kind of 'objective creativity'. A scientist is supposed to have an open mind to avoid being biased or stuck in old patterns.

> Yes [researchers need creativity]. During planning and designing [researchers have] to get as many different perspectives as possible. However, during data collection and afterwards the researcher has to stick to what the experiments really show, otherwise I wouldn't say it is a scientific experiment. (Mary)

When teachers talked about NOS teaching and creativity this was almost exclusively discussed in relation to the students themselves being creative (through planning investigations) during the science lessons. This is seldom, according to the teachers, explicitly connected to research processes outside school. This way of talking about creativity resembles the way teachers talked about theme 2 (empirical and/or theoretical science) and how it connected to students doing lab-work—which was easy, practical, concrete and possible to teach throughout the entire compulsory school. However, creativity coupled to lab-work is a delicate question of finding the balance between lack of time, the finding of the right answers, and the desire to let students think for themselves.

3.4.3 Scientists are Creative All the Time

Teachers also used ways of talking that emphasised the role, and need, of creativity in most (or all) parts of a scientific investigation (e.g. creating research questions, planning, creating new equipment, interpreting, creating new theories, applying results):

> In my point of view, if you are not creative you cannot build a theory that you will test with an experiment/…/I'm having a hard time imagining that it would work at all if you totally lacked

> fantasy./…/like, what's their name Curie or Becquerel or Röntgen or something/…/who of course discovered X-ray by chance, but without fantasy he would perhaps not have been able to think further. What could this be? And how do we create an experiment to check it?/…/Without fantasy you would probably just drop it in the wastebasket. And then just, well, that's a pity on those photographic plates/…/So, fantasy I would think is fairly central [in science] so to speak. (John)

Some teachers emphasised the necessity of scientists being creative in their interpretations and conclusions, as observations do not speak for themselves. In some statements the importance of creativity in different phases of the investigation vary:

> It is probably easier to be creative while planning and designing than it is while collecting data. And then when they have to interpret the collected data they probably have to be pretty creative to see various interpretations and explanations. (Carolyn)

In Table 5 we can see that 9 out of 12 teachers described creativity as something that is very important in all stages of the research process. Even so, only three teachers mentioned this kind of overarching creativity in relation to teaching. Again, creativity was coupled to students' investigations, in which they can be creative in both planning and interpreting, thus leading to discussions of results. Ella provided one of the few examples where teaching was discussed in relation to researchers' creativity, instead of students' creativity:

> …you bring that up for discussion automatically: but how did they arrive at these conclusions? How were they able to conclude about electrons for example? How do you know? And then you talk about how they did experiments with frogs' legs and loads of other stuff. But how did they get that idea? How can you just do something like that? Then these thoughts [about creativity] might get started/…/ I think that you have to turn to the history to realise that it [creativity] can be good. (Ella)

3.5 Theme 5: Universal and/or Socio-culturally Embedded NOS?

Three different ways of talking were identified for this theme (see Table 6). The table shows that teachers most commonly described "science as hampered by the surrounding society" even if the other ways of talking were also commonly used. Similarly, when it came to talking about teaching, this idea dominated, even if the total amount of statements was very low. It should be noted that even if statements like the one made by Nina below (in Sect. 3.5.1) implicitly pointed to the teaching of "science as independent of the surrounding society", there were no explicit statements about this. In comparison to previous research (e.g. Lakin and Wellington 1994), the results in this study differ in that the teachers have many ways of talking and reflecting about the socio-cultural aspects of

Table 6 Summary of teachers' ways of talking about theme 5—universal and/or socio-culturally embedded NOS

Way of talking	Talking about NOS		Talking about NOS teaching	
	# Participants	# Statements	# Participants	# Statements
Science as independent of the surrounding society	11	27	–	–
Science as hampered by the surrounding society	12	73	7	12
Science as by necessity influenced by the surrounding society	8	24	3	3

science. The results are however similar to Lakin and Wellington (1994) in that there are few statements about this in relation to science teaching.

3.5.1 Science as Independent of the Surrounding Society

With this way of talking, science was described as (at least basically) universal. The truth is waiting out there to be discovered and the truth will be the same no matter where you are. Research was also described as performed in the same way wherever you find yourself in the world.

> Science is not influenced by social, political or philosophical values. (Lynn)

> …when he or she [the scientist] is alone in his chamber then I don't think it matters if you are in Sweden or in France or in South Africa. It's somehow the same [results] (Mary)

As is evident in Table 6, no teachers in this study explicitly talked about teaching universal science. However, looking back to the other themes we see that many teachers sometimes emphasised facts and lab-work (as mentioned earlier in Sects. 3.1.1, 3.2.1, 3.3.1). One teacher described it like this:

> I have to admit that/…/I'm not good at/…/[teaching about] social aspects/…/I can only guess/…/but I think that goes for all of us. (Nina)

Thus, in a way, this became an implicit way of talking about a science teaching in which no socio-cultural aspects are mentioned.

3.5.2 Science as Hampered by the Surrounding Society

For teachers the most common starting point when talking about NOS was that "science is universal but…". Science is supposed to be universal, but never really lives up to that in reality. There is a mist of social, political and cultural influences that slow down or disguise the development of correct knowledge. Teachers provided multiple examples of how culture or society can influence science (mostly) by impeding the truth. One of the most common examples, put forth by all of the teachers, was the influence of economic factors.

> … Then there are economic interests that can control research. Like oil companies who can somehow prove that there is nothing dangerous about a load of emissions and you can have researchers saying that too/…/and cell phone manufacturers, they can prove that there is no danger having them [the phones] close to your ear because nothing else is demonstrated. (Bob)

Teachers also provided a great variety of other examples where they claimed that science is hindered by societal factors such as trends, religion, power, politics, prestige, and social pressure.

When using this way of talking about teaching, historical examples (i.e. one example—the geocentric worldview) are almost the only ones mentioned. Students of all ages are supposed to, in one way or another, encounter the story about how religion tried to stop scientific knowledge (see also Sect. 3.1.2). Apart from this teachers gave a few other examples (mostly concerning economic aspects) that they could bring up for discussion in science class:

> I'm sure I could convince them [the students] about it. That's the way it is [that money and funding from companies influence research], but I haven't exactly brought it up. Or, well, it hasn't really been an issue. (Bob)

> I have no evidence. I can't stand there and say that this is what it's like: Exxon has paid this much [for the results]/…/But, on the other hand, I could talk about how darn strange it is that every second/

…/report reached this and every second that conclusion. That must either have to do with who has ordered it [the research], or that it is hard to reach a conclusion. (John)

What Bob said can be compared to the results in Sect. 3.1.4, where teachers described science as tentative, but still, for different reasons, chose not to teach about it. In line with the results presented in theme 3 (*objective and/or subjective science*), teachers talked about socio-cultural influences on science as being abstract and difficult for students to understand. Again, the ‘good students’ as well as students with weak language or social skills were described as ‘losers’ when abandoning facts for discussions where diverse perspectives play a role.

…socio-cultural aspects/…/are suitable in higher grades/…/because you have to be able to use broader perspectives when you think/…/and I think it requires more advanced thinking abilities. (Nina)

3.5.3 Science as by Necessity Influenced by the Surrounding Society

There were also less common ways of talking about science where the socio-cultural influences were discussed in a more neutral, or even positive, way. Economy was still a frequent factor, but in this way of talking the economic influence was not necessarily considered as bad—it was just the way it is.

I believe that money as well as cultural and political values influence what kind of research is done and what kind of results the researchers get, but that’s part of the development. (Mike)

It was also considered to be normal that research questions are influenced by which part of the world you come from and that all questions are not equally interesting all across the world.

Science surely has to mirror the society in which it is produced—what is prioritised and what is considered valuable economically and politically. What possibilities the scientists have to engage in their research in different areas. The culture you grow up in. (Carolyn)

In our data, this way of talking was not commonly related to science teaching. In the few existing examples teachers mentioned tasks where students take position in issues concerning, for example, power plants. Here it was assumed that there are implicit messages about values and interests (see Lynn’s quote above in Sect. 3.3.2). Similar to the subjective aspects of science (see Sect. 3.3), science as influenced by the surrounding society is not, according to the teachers, explicitly addressed in the science classroom.

4 Discussion

Much has been written about students’ and teachers’ views about NOS, and the lack of explicit NOS perspectives in most science teaching (for an overview see, for example, Lederman 1992, 2007). This article focuses on Swedish science teachers, who rarely have a specific NOS educational background, but who still have to deal with NOS as presented in the curriculum and make educational choices about it in their own way. The study presented in this article shows how teachers use different ways of talking about NOS and its teaching. The results could add to our understanding of why explicit NOS teaching does not easily become part of school science. In this section, the results will be discussed in relation to previous research on NOS, and in relation to NOS and its part in science teaching.

4.1 Available Ways of Talking About NOS

For all five themes analysed in this study, all teachers talked about science as following a structured, objective scientific method leading to absolute truth. This way of talking about science is in line with previous studies (e.g. Abd-El-Khalick 2001; Lederman 1992; McComas 1998). However, for all themes, with one exception (i.e. theme 2: empirical and/or rational (theoretical) science), there was also a broad variety of other ways of talking when teachers discussed science. One and the same teacher might very well use different ways of talking, in line with both what earlier studies would refer to as "naïve views", and as more "informed views" (Lederman et al. 2002) for the same theme. That teachers use different ways of talking connected to a specific theme could be a sign of inconsistencies in their ways of reasoning, but it could also be an example that different contexts/questions could raise different kinds of reflections about science. One example of this is John, who described observations as talking for themselves: "You just have to look. Open your eyes and look", and as something that has to be interpreted by using creativity and imagination: "Without fantasy he [the scientist] would not be able to think further—what could this be and how can we check this?" (see Sects. 3.2, 3.4). This result is in line with the results in Ryder et al. (1999), in which students were found to have a broad range of images of science that were used in different contexts.

However, even if teachers had multiple examples concerning, for instance, the socio-cultural aspects of NOS (e.g. economic and gender aspects), they might still not feel that their knowledge is robust enough to bring these examples up for discussion in the classroom. As John put it: "Since I have no evidence I can't just tell them…" (see also Bob in Sect. 3.1.1). This insecurity could both have to do with handling questions with no straight answers, but we might also have to consider Matthews' argument (1994, 1998, 2012) that teachers should not be expected to have elaborate knowledge on these topics since they cannot be expected to be experts in philosophy, history or the sociology of science. Still, science teachers teach other science content every day without being expected to be science experts. Nonetheless, having access to multiple ways of talking (which we can see from the tables that most teachers have) could be a starting point for being able to handle the desired authentic, complex and controversial topics described in the science education literature (Allchin 2011, 2012b; Abd-El-Khalick 2012; Matthews 2012). This in turn could lead teachers to critically reflect on and challenge teaching traditions and images of science communicated in the science classroom (e.g. prototypical science, as described by Carlone 2003).

4.2 Why Does NOS Teaching not Become Part of Science Teaching?

Previous studies have shown that, for a number of reasons, teachers' knowledge about NOS does not necessarily affect their classroom practice (e.g. Aikenhead 2006; Bartos and Lederman 2014; Lederman 1999, 2007). In this study we have, through questionnaires and interviews, investigated how teachers make sense of the NOS content that they, according to the curriculum, should be teaching, although they do not have a great deal of experience of how this should be done. The results, based on these teachers' responses, deepen our understanding of the different reasons why NOS teaching is often not part of science teaching.

Based on the results, we will discuss some possible reasons for why some NOS aspects are regarded as appropriate to teach whereas others are not, and also why explicit NOS teaching seldom takes place in science classrooms. We start by discussing available ways of talking about NOS teaching. We then continue with a discussion about science teaching traditions and about how teachers suggest how NOS could possibly fit with other content and activities that are, more or less, well established in the science classroom. Furthermore, we discuss the results concerning who among the students, according to the teachers, will be winners or losers if explicit teaching of NOS is given more room in the science classroom (which ultimately becomes a question of students' inclusion/exclusion from science teaching).

4.2.1 Available Ways of Talking About NOS Teaching

The results show that although there are multiple ways of talking about most of the NOS themes, teachers talk about the *teaching* of NOS in less elaborated ways. Teachers give fewer examples, and fewer teachers use *multiple* ways of talking about the teaching of NOS (e.g. Tables 4, 6). Taking theme 1 *absolute and/or tentative* as an example, the results show that it is very common for teachers to talk about uncertainty in science and they use numerous examples (see Table 2). However, when talking about teaching, the greatest emphasis is on absolute science. Thus, prototypical or narrow images of science are not challenged to the same degree in the ways of talking about NOS teaching as when talking about NOS. That teachers with elaborate knowledge of NOS still do not teach NOS in their classrooms is not novel (Abd-El-Khalick et al. 1998; Aikenhead 2006; Lederman 1999, 2007). However, in this study it becomes evident that teachers with multiple and elaborate ways of talking about NOS do not exhibit the same complexity or elaboration while talking about NOS teaching. In addition, some of the teachers do seem to have strategies but still choose not to teach it (see, for example, Sects. 3.1.4, 3.5.2). Lacking access to complex and multiple ways of talking about NOS teaching could be one reason why NOS is seldom a part of science teaching. Limitations in the ways of talking about NOS teaching manifest themselves as teachers talk about NOS aspects as being important but difficult to teach (see also Aikenhead 2006). Throughout the interviews we identified these difficulties through teachers' insecurity in what to teach and also as a lack of teaching examples and approaches. Nina, as one example, obviously knew that there are social aspects to science, but she had no teaching strategies: "I have to admit that I'm not good at teaching social aspects". Still, it is important to note that there *are* also broader perspectives available to the teachers, which are actually used by most of the teachers to some degree—that is, there are possibilities to build on. The insecurity that these teachers express, highlights the importance of including NOS issues coupled to teaching strategies in teacher education (Bartos and Lederman 2014; Gess-Newsome and Lederman 1993; Hanuscin et al. 2011).

4.2.2 Lab-Work and Facts: Where Does NOS Fit in According to the Teachers?

In this study, by asking teachers about their views of the teaching of NOS, we have also been able to see other obstacles to broader NOS perspectives becoming a part of science teaching. One of these was found to be the science teaching tradition (Aikenhead 2006; Brickhouse 2001; Carlone 2003; Clough 2006; Duschl et al. 2006; Ryder 2002), which was explicitly and implicitly addressed by the teachers during the interviews. Teachers talked about science teaching as consisting of science concepts (emphasis on ready-made science—'facts') in combination with lab-work, which was described by teachers as primarily performed so that students could learn important facts (Högström et al. 2006) or use 'the scientific method'. In contrast to this, when teachers talked about NOS teaching in general, it was often with a notion that NOS teaching is something that is different from normal teaching practices, (e.g. "I only do experiments and facts", Sect. 3.1.1). In line with Aikenhead (2006) and Ryder (2002), NOS teaching was instead described as being linked to many different competences, which were considered important but unusual to address in science class (e.g. discussing, reasoning, interpreting and evaluating). Such deviation from traditional teaching was considered as time-consuming and a distraction to the main purpose—learning 'the scientific method' and introducing scientific facts to the students (see also Abd-El-Khalick et al. 1998; Aikenhead 2006). These are the few structural problems that the teachers mentioned in relation to NOS teaching. That teachers did not mention other structural problems concerning, for instance, the assessment of students' knowledge (as seen in other studies, e.g. Akerson and Hanuscin 2007) might be due to the fact that the teachers, at the time of the interview, were still concerned about how, why, and if NOS teaching should even be part of science teaching.

When teachers in this study gave examples of how NOS teaching is, or can become, part of science teaching they often seemed to try to avoid profound changes and make it fit within their traditional teaching. This was seen in how they talked about general approaches to NOS teaching, like lab-work (implicitly addressing NOS) (cf. Bell et al. 2003; Lederman and Lederman 2012) or discussions (which can refer to NOS both implicitly and explicitly). However, most teachers expressed a need to change cookbook lab-work to more authentic experimenting, if lab-work were to be considered as the solution to NOS teaching. On the other hand, this change is something that teachers blamed themselves for not accomplishing. They argued that if lab-work was done in a more authentic way, students would become aware of, for example, 'the scientific method' and scientists' creativity, and thus learn NOS while 'doing science'. However, such a way to teach NOS has been considered problematic in previous research (Bell et al. 2003; Clough 2006; Lederman and Lederman 2012) since students often do not seem to note the implicit messages about NOS. Another problem is that learning about NOS also involves aspects, such as sociocultural factors, which cannot easily fit into the lab format (Hodson 2014). For these aspects of NOS the 'discussion approach' is the only remaining strategy. Such an approach could, through for example engaging students in argumentation, be one fruitful way to enhance students' knowledge about different NOS aspects (see Khishfe 2012, 2014; McDonald 2010). Still, teachers' ways of emphasising lab-work could also, if it were more inquiry-oriented, become the starting point for them to include explicit reflections of NOS in science teaching (e.g. Hanuscin 2013; Bartos and Lederman 2014).

One great difference between lab-work, or the hands-on-approach, and the discussion approach, as described by the teachers, was the level of difficulty. While teachers argued that lab-work is concrete and hands-on, something that the students themselves can experience and gain knowledge from throughout compulsory school, the discussion approach was regarded as more difficult for a number of reasons (see below). In addition to this, the discussion approach was also often described as clashing with the traditional teaching approach (cf. Bell et al. 2000; Herman et al. 2013; Ryder 2002).

In summary we have seen that teachers talked about NOS aspects as something they already included in their science teaching. However, teaching about these NOS aspects was more often perceived as something new, which means that a change in their teaching approaches was viewed as necessary if NOS aspects were to be taught (a change that many of the teachers considered as being positive):

> But if it is [presented as] a more human subject from the beginning and more based on discussions then that will be what characterises science. And I think that is a change that should permeate all school years. (John)

It is important to note that these ‘changes’ are already part of the curriculum which, for example, emphasises the importance to avoid “the notion of a subject that is mainly built on ready-made facts” (Skolverket 2011b, p. 7, authors’ translation).

4.2.3 Who is Included and Who is Excluded According to the Teachers?

Whereas previous research (e.g. Aikenhead 2006; Brickhouse 2001; Carlone 2003; Hansson and Lindahl 2010) has regarded traditional science teaching and prototypical images of science as excluding a large number of students, the science teachers of this study talked about the risk of excluding students as a consequence of changing their teaching approaches and broadening the perspectives of NOS. Teachers argued that students with weak language skills, students who lack abstract thinking abilities or students who have limited social skills will experience difficulties during group discussions or reflections on abstract topics such as some NOS issues. Concerns due to weak language skills were also discussed in studies reviewed by Aikenhead (2006), where teachers considered NOS topics as requiring a lot of reading and writing, which they considered limiting for certain students. Concerns for students’ abilities to deal with abstract topics are also discussed in Abd-el-Khalick et al. (1998), Brickhouse and Bodner (1992) and Lederman (1995). Teachers in the study presented here typically gave examples of abstract topics as questions related to theme 3 *objective and/or subjective* and theme 5 *universal and/or socio-culturally embedded science*. These themes were also described as ‘discussion themes’ (not possible to address through lab-work; see also Hodson 2014) and were thus the NOS themes that, according to the teachers, would cause the greatest departure from the science teaching tradition. In addition, the ‘good student’ was also considered at a disadvantage since they, according to the teachers, are looking for correct answers on written tests. That the ‘good student’ shows resistance when teaching is less focused on route memorisation is well documented in Aikenhead (2006) and Carlone (2004). However, teachers also mentioned the possible benefits for some students, especially the ones who are having a hard time coping with just learning facts from a book. These students were considered to become more motivated by getting the opportunity to be creative and philosophical in classroom discussions with no right answers. To depart from route memorisation was thought to be “challenging and exciting” and attractive to the “more philosophical students”, who lose interest when they are only reading facts from a book. These kinds of reasons, which are concerned with student motivation, are also discussed by Aikenhead (2006). Similar to other studies (Abd-el-Khalick et al. 1998; Aikenhead 2006; Brickhouse and Bodner 1992; Lederman 1995), some of the teachers in this study have concerns about students’ abilities for abstract thinking, but there were also a number of teachers who presumed that the low achieving students would be the ones who benefit most.

Teachers perceived the teaching of NOS as a change. This change was, as shown above, considered beneficial for some students but caused trouble to others, some of whom would be ‘good students’. Teachers might consider such change problematic. If teachers believe that students who normally get high grades will disapprove the changed teaching approach, and in addition to that get lower grades, this would probably mean that teachers will have to be much more convinced about the benefits of teaching NOS explicitly (through discussion, for example) before trying to change their teaching practices (Aikenhead 2006). As Schwartz and Lederman (2002) argue, if NOS is going to be taught at all, teachers themselves must be motivated and find NOS worthwhile to teach as well as graspable for their students. Once again we return to John and his reflections on change:

> There will always be great resistance at first. Especially if you have had this focus on facts and then you change it, of course there will be a resistance from those who like facts and who have been good students because they will not be as good any more. But then again it could mean something positive for the student who would like a softer subject, as all of a sudden it might be graspable for them and they will get more motivated.

Although teachers talk about a number of difficulties related to explicit NOS teaching and the inclusion of broader perspectives on NOS the results show that they also highlight some gains that they regard as important. Some of these gains are related to scientific literacy, for example, critical thinking (through e.g. engaging in discussions and taking positions), evaluation and interpretation (through e.g. discussions of interpretations and results), and learning that the world is not 'black and white' (through discussions about e.g. how scientists can interpret data differently and scientific knowledge as changing). Other gains, as seen above, are related to student motivation, where the students who are excluded in traditional science teaching are especially considered to benefit from a more reflective approach where NOS is discussed explicitly in the classroom.

4.3 Implications and Concluding Remarks

The results reported here indicate that teachers' perspectives on NOS teaching sometimes need to be challenged in order to help them communicate science in a non-stereotypical way. However, it is also indicated that teachers themselves have identified this need, but without knowing how to put their thoughts into practice. Knowing more about teachers' presumed hindrances for, and benefits of, NOS teaching contributes to the knowledge of how teachers understand NOS in relation to their current science teaching. Further, it contributes to our knowledge of potential starting points when developing NOS courses for teachers (with no NOS teaching experience).

Changing the current science teaching tradition (in which explicit NOS teaching is usually not included) and turning the classroom into a place where different aspects of NOS are discussed is not something that can be easily achieved by offering teachers a couple of NOS courses. This is due to overarching structural issues (see areas of conflicts in Lakin and Wellington 1994) at different levels, such as, policy documents, textbooks and teaching materials, national tests, colleagues' and parents' views on science teaching, etc. Yet, courses developed for pre- and in-service teachers could constitute a starting point for change. In addition to what we know from previous research on what should be included in such courses (e.g. NOS activities and assessment of NOS, c.f. Akerson and Hanuscin 2007; Clough 2011a), the results from this study highlight some other issues that are important to include in courses aimed at broadening the perspectives on NOS and its teaching.

First, teachers need concrete (yet complex) examples to which they can relate their understanding of different NOS aspects. This concerns both basic knowledge about history, philosophy and the sociology of science (Matthews 1994, 1998), as well as knowledge about complex and controversial cases (Abd-El-Khalick 2012; Wong and Hodson 2010). The most apparent need for this is within theme 2 *empirical and/or rational (theoretical) science* (even if it is by no means exclusively related to theme 2), for which teachers exhibit fewer ways of talking about NOS than for the other themes. In contrast to other studies (e.g. Aikenhead 2006; Brickhouse 2001; Carlone 2003; McComas 1998), teachers in this study often challenged stereotypical images of science by using other ways of talking about it. For example, concerning theme 3, teachers did not only describe science as objective (which would be the prototypical way), but also as subjective (referring to, for example, scientists' backgrounds and values). These other ways provide a basis to further build on.

Second, in line with previous studies (e.g. Akerson and Hanuscin 2007; Hanuscin et al. 2011; Lederman 2007; Lederman and Lederman 2012), we found that knowledge about teaching approaches and topics that are relevant to K-12 students is most needed. This is specifically (but not exclusively) related to theme 3 *objective and/or subjective science* and theme 5 *universal and/or socio-culturally embedded science*, where there are very few statements related to NOS teaching. The results from this study show that teachers try to fit NOS into their traditional teaching of facts and lab-work. Drawing on what teachers say, one possibility is to search for ways to match NOS with traditional science teaching. Lab-work could provide one pathway to successful NOS teaching (see Hanuscin 2013; Bartos and Lederman 2014) if teachers can get equipped with tools that help them to find ways to explicitly connect to different NOS aspects. Concepts and models (which teachers talk about as 'facts') also need to be critically examined in teacher education. This could be done, for instance, by highlighting the processes that lead to the 'facts', or by discussing related, current research. This, together with discussions about how this can become part of science teaching, is important since the results in this study show that teaching about scientific uncertainties is sometimes deliberately avoided because it is considered too hard for students to grasp. Helping teachers find ways to connect NOS aspects to other science content ('facts') could also be a way for teachers to more easily see possibilities to fit NOS teaching with science teaching, even when NOS teaching has not been planned for (Bartos and Lederman 2014; Herman et al. 2013). Another feasible way (advocated in Herman et al. 2013), connected to less traditional teaching, is to build on teachers' suggestions for linking NOS to classroom discussions. Teacher education needs to address how a 'discussion approach' through, for example, argumentation (as suggested in Khishfe 2012, 2014; McDonald 2010) or taking a position (as mentioned by the teachers in this study) can help in making NOS an explicit part of science teaching.

A third important issue for teacher education courses is to broaden the perspectives on how science education can become meaningful to different students. This includes discussions on the kinds of knowledge or competencies that are valued, as well as discussions about how different students are included or excluded through the pictures of science that are communicated and the choice of teaching approaches. Teachers in this study have many, sometimes contradicting, things to say about different student groups and the possibility for these groups to gain (e.g. previously uninvolved students gaining interest) or lose (e.g. the 'good student' would feel insecure if facts were no longer in focus) from including broader perspectives on NOS in science teaching. Ways of talking of inclusion and exclusion also need to be critically examined in relation to, for example, the goals of science education.

These three issues (discussed above), based on teachers' voices, add to previous research in the area with respect to what should be taken into consideration when developing NOS courses for pre- and in-service teachers. Furthermore, to gain more knowledge about teachers' perceived difficulties and benefits in relation to NOS teaching we will continue to study these teachers for 3 years by using repeated small group discussions (containing reflections about NOS issues, appropriate activities for different school years, development of material, and implementation of NOS teaching). This will be reported on in future articles.

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