LOTTA LEDEN

BLACK & WHITE OR SHADES OF GREY

Teachers' perspectives on the role of nature of science in compulsory school science teaching

MALMÖ UNIVERSITY

BLACK & WHITE OR SHADES OF GREY

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ABSTRACT

The thesis explores teachers' perspectives and negotiations on the role of "Nature of Science" (NOS) in compulsory school science teaching. Previous research has described school science teaching as having a strong focus on science concepts, and structured lab-work with an implicit focus on finding correct answers. In such teaching, there is little room for the individuals and contexts involved in the knowledge production. This description of science and science teaching is referred to as "black and white" in this thesis. Science Education research has proposed that by broadening the images of science, more students might identify with science and that desired scientific literacy outcomes could easier be achieved. One suggestion from Science Education research has been to include NOS in science teaching.

Including NOS in everyday science teaching means that tensions are created in relation to already existing traditions. Here, teachers become an important factor as they are deeply entangled in the middle of policies, traditions, and discourses that surround science and school science. Methods used for exploring the teachers' perspectives were: questionnaires, interviews, and focus group discussions. In particular, negotiations in the focus groups, over the three years, contributed to illuminating perspectives and tensions. A theoretical framework consisting of five comprehensive NOS themes was developed. This framework guided the contents of the focus groups as well as parts of the analyses.

The thesis includes four articles, each with its own specific aim and research questions. The main results from these articles are

summarized and discussed in relation to policies and traditions that surround science education. The results show that the NOS practice that the teachers constructed through their negotiations: a) aims for a broad rather than deep NOS understanding (i.e. including many NOS issues, but avoiding philosophical depth), b) is contextualized within lab-work practices or communicative activities, and c) aims to develop student engagement and reaching other curricular goals than learning science concepts. This construction of NOS practice results in strong tensions in relation to traditional science teaching, which means that teachers' and students' roles are challenged. However, NOS becomes a means in the work of expanding lab-work practice, as well as a catalyst in the formation of science teaching practice directed towards communication (e.g. reflections on science in relation to society, both from perspectives within and outside science). The resistance between NOS and the teaching of science concepts means that they become parts of different practices. As a consequence, students encounter different images of science that are seldom compared or negotiated. A suggestion for science education is to create structures for balancing or merging parallel practices as a way to ease tensions and expand the concepts-based practice.

SVENSK SAMMANFATTNING

Avhandlingen utforskar lärares perspektiv och förhandlingar gällande vilken roll "naturvetenskapens karaktär" (engelska "nature of science", NOS) kan spela i grundskolans NO-undervisning. Tidigare forskning har visat att NO-undervisning ofta har ett starkt fokus på naturvetenskapliga begrepp och strukturerade laborationer med ett implicit fokus på "korrekta svar". I den sortens undervisning ges sällan en bild av de människor och kontexter som är av betydelse för naturvetenskaplig kunskapsproduktion. I avhandlingen diskuteras den här beskrivningen av naturvetenskap och NO-undervisning som "svart-vit". Inom ramen för forskning om naturvetenskapernas didaktik har förslag lagts fram som handlar om att bredda bilden av naturvetenskap. En sådan breddning skulle kunna medföra att fler elever kan identifiera sig med naturvetenskap och att mål som handlar om naturvetenskaplig literacitet (scientific literacy) lättare skulle kunna nås. I linje med dessa mål, har forskningen föreslagit att NOS inkluderas i NO-undervisningen.

Att inkludera NOS i NO-undervisningen innebär att det skapas spänningar i förhållande till rådande undervisningstraditioner. Här blir lärare en viktig faktor eftersom de befinner sig i gränslandet mellan naturvetenskap och undervisning om densamma. I detta gränsland får policy, styrdokument och traditioner betydelse för vilken undervisningspraktik som blir möjlig. Avhandlingens metoder för att utforska lärarnas perspektiv är: enkäter, intervjuer och fokusgruppdiskussioner. Fokusgruppdiskussionerna, som var återkommande under tre år, är särskilt viktiga för att belysa olika perspektiv och spänningar. Ett teoretiskt ramverk som består av fem

övergripande NOS-teman utvecklades och användes som en guide för fokusgrupperna och delar av analysen.

Avhandlingen inkluderar fyra artiklar, med egna syften och specifika forskningsfrågor. Huvudresultaten från dessa artiklar sammanfattas och diskuteras i relation till policy och traditioner som omger NO-undervisning. Resultaten visar att den NOS-praktik som konstrueras genom lärarnas förhandlingar: a) syftar till en bred snarare än djup NOS-förståelse (d.v.s. inkluderar många NOS-områden, men undviker filosofiskt djup), b) är kontextualiserad och integrerad i laborations- eller kommunikationspraktiker, och c) syftar till att utveckla elevers intresse och engagemang samt att nå kunskapsmål som går utöver lärandet av naturvetenskapliga begrepp. Den här konstruktionen av NOS-praktik resulterar i starka spänningar i relation till traditionell NO-undervisning (t.ex. undervisning av begrepp och modeller), vilket i sin tur innebär att lärar- och elevroller utmanas. Däremot, blir NOS ett medel i arbetet med att utvidga laborationspraktiken och en katalysator i formandet av en kommunikationspraktik (t.ex. att reflektera kring naturvetenskap och dess relation till samhället både från ett inom- och utomvetenskapligt perspektiv). Motståndet mellan undervisningen av NOS och naturvetenskapliga begrepp medför att dessa inte integreras utan blir delar i formandet av parallella praktiker. Som En följd av denna uppdelning får eleverna möta olika bilder av naturvetenskap som sällan jämförs eller förhandlas. Ett förslag för framtida forskning och lärarutbildning är att skapa strukturer för att sammanfoga parallella praktiker som ett led i att minska spänningar och utvidga den begrepps-fokuserade traditionen.

ARTICLES INCLUDED IN THE THESIS

Article I

Leden, L., Hansson, L., Redfors, A., & Ideland, M. (2015). Teachers' Ways of Talking About Nature of Science and Its Teaching. *Science & Education*, 24(9-10), 1141-1172.

<https://link.springer.com/article/10.1007/s11191-015-9782-6>

Article II

Leden, L. & Hansson, L. (2017). Nature of Science Progression in School Years 1–9: a Case Study of Teachers' Suggestions and Rationales. *Research in Science Education*. doi: 10.1007/s11165-017-9628-0

<https://link.springer.com/article/10.1007/s11165-017-9628-0>

Article III

Leden, L., Hansson, L., & Redfors, A. From black and white to shades of grey: A longitudinal study of teachers' perspectives on teaching sociocultural and subjective aspects of science. *Accepted for publication in Science & Education*.

Article IV

Leden, L., Hansson, L., & Ideland, M. (manuscript). The mangle of School science practice: a case study of teachers' negotiations of NOS activities at different levels of contextualization. *In process*.

1 INTRODUCTION

... in the simplified image, science sorts things crisply into black and white, true and false, without any “shades of grey,” partial conclusions or residual uncertainties. (Allchin, 2003, p. 333)

The quotation above is an example of how images of science, according to science education research, are often presented in science teaching (e.g. Carlone, 2004; Feinstein, 2011; Zacharia & Barton, 2004). Through such images, science is presented to students as entirely objective and value free, and without any involvement from individuals or society. Science teaching deriving from this oversimplified image has a strong focus on science concepts and cook-book lab-work. This kind of science teaching practice has been questioned with regards to *why* science is taught and *whom* it is for. It has been shown to exclude a large number of students, as well as fail to reach the desired goals for scientific literacy. As an attempt to produce solutions, Science Education research has posed a number of suggestions, from different perspectives, of how to develop school science teaching. One of these lines of research focuses on the inclusion of “Nature of Science” (NOS) in science education. NOS teaching is also the focus of the present thesis.

The research field is involved in strong controversies regarding what NOS is and should be in relation to science education. However, despite diverging suggestions (drawing on the history, philos-

ophy, and sociology of science), all address the above oversimplified images of science in some way. This is done through finding ways in science teaching to emphasize the processes, people, norms and traditions that interact with scientific knowledge and knowledge production. Science education research regarding NOS has often a strong normative component (Allchin, 2014; Feinstein, 2011), which has led to a number of proposals on *what*, *why*, *how*, and for *whom* NOS should be taught. Much of the empirical research in this field has addressed how students' and teachers' views on NOS can be affected through different teaching approaches. And regardless of perspectives and controversies within the field, there is agreement with respect to the difficulties connected to including research-based suggestions in science teaching. Thus, similarly to other educational research fields there is a perceived gap (Broekkamp & van Hout-Wolters, 2007; Luft, 2010) between teaching practice and the aims and suggestions put forward by research.

To bridge the gap, the gap needs to be explored. Previous studies have approached the gap through examining teachers' NOS understandings, their NOS teaching practice, and their ways of coping with research-based suggestions. The present thesis continues the work of exploring the gap, but emphasizes *teachers'* perspectives on questions about NOS teaching that have mostly only been a matter for researchers. That way teachers' perspectives and suggestions become part of constructing what, how, why, and for whom NOS can play a role in science teaching. Here, teachers are considered as links between academic science and school science. Through studying their perspectives on NOS and NOS teaching, tensions between NOS and already existing patterns of, policies, traditions, and discourses become visible. In this thesis, the teachers expressed their perspectives in questionnaires, interviews, and during focus group discussions. In particular, the negotiations of the focus groups have contributed to illuminating perspectives and tensions. These tensions can provide important information on different directions for aligning and accommodating all the pieces in the school science puzzle.

1.1 Science teaching and NOS in a Swedish context

An important factor to be considered in this thesis is the Swedish context. In Sweden, science is a compulsory subject for students aged 7-16 (grades 1-9). The overarching aims for science education are formulated as three goals for the development of students' competencies. Below is an example from physics:¹

- use knowledge of physics to examine information, communicate and take a view on questions concerning energy, technology, the environment and society,
- carry out systematic studies in physics, and
- use concepts of physics, its models and theories to describe and explain physics relationships in nature and society. (Skolverket, 2011a, p. 120)²

NOS has not been a particularly emphasized teaching object in Sweden (Högström et al., 2006; Gyllenpalm et al., 2010a), although it has been part of national curricula for the past few decades (Johansson & Wickman, 2012). The teachers in the present study, who mainly received their teacher education more than ten years ago, claim that NOS is not a topic that has ever been made explicit to them during their education.

Nina: I think that an underlying aspect is that it [NOS] is not traditional science. We don't really know how to do or how to approach it. We know how to do facts and the scientific method, but this [teaching NOS] kind of appeared from nowhere.

John: Feels a bit new.

Nina: You are supposed to know it, but you have no education on how to work with it.

John: That's the thing, I guess.

Nina: I think that's a big part of it.

¹ The description is identical for biology and chemistry except for details regarding individual questions to be discussed (first bullet point) and which relationships should be explained (for the third bullet point, human body is added in biology).

² One of the teachers in this study reformulates these goals to be about "facts, lab-work, and discussions" (see Article IV), which then becomes a way to express these directions for all teachers throughout the project.

John: You have nothing to fall back on from your own time in [compulsory] school. We did nothing like this.

Nina: No, nor in your [teacher] education. (Focus group 3, year 2)

Furthermore, images of NOS in the present curriculum (Skolverket, 2011a) can be seen as contradictory, and the contradictions are seldom pinpointed or explained – teachers are in many ways left to their own interpretations. The Swedish national curriculum and an official commentary (Skolverket, 2011b; 2016) leave much room for interpretation, which means that various positions or foci can be justified. Thus, the teaching of science could move in different directions depending on how the curriculum is interpreted and negotiated. In the commentary on the curriculum (Skolverket, 2016) nature of science and the relation between facts and values are mentioned in the following way:

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, 2016, my translation, p. 31)

In the above quotation, it seems like the intention is to make the reader aware of the intertwinement of scientific knowledge, values and interests. In the quotation below, however, it is more likely that the reader gets the notion that facts and values are separate:

Pupils can talk about and discuss issues related to health, natural resource use and ecological sustainability, and differentiate facts from values... (Skolverket, 2011a, p. 112)

Such contradictions, as well as other images of science, have recently been a subject of debate in Swedish media. In January 2016, a group of scientists, philosophers, and debaters (Danielsson, Moberg, Sturmark, Wikforss DN, 2016-01-11) wrote a heated

opinion piece in one of Sweden's largest daily newspapers. They argued that the Swedish curriculum promotes a relativistic epistemology by, amongst other things, abandoning the scientific method. Part of this critique is based on the view that school science is mostly built on ready-made facts and that it would be an unreasonable wish to change that view. The debate led to a hasty revision of the commentary, where some writings – perhaps found to be particularly controversial – were substituted by others. One example is the following:

...one reason to emphasize 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 emphasize physics as a dynamic, creative and up-to-date subject in constant development – in everyday contexts as well as in working life, and research. (Skolverket, 2011b, p.7; author's translation, my italics)

In the new version, the part in italics was changed for: "...is to promote the notion of a subject that continuously develops scientific theories through new empirical data" (Skolverket, 2016, p. 7; my translation). No explanation for this particular change is provided in the text, but one would assume that the use of the word "facts" in a negative way may constitute the controversial part.³ Moreover, a straight forward connection between more/new data and progression is developed through this statement, which leads further away from the feared relativism. It is in the light of this context and climate of opinions that this thesis is written.

1.2 Aim

The overarching aim of this thesis is to longitudinally explore teachers' perspectives and negotiations on the role of NOS in science teaching. The exploration takes a point of departure in the didactical questions⁴ *what, why, how*, and for *whom*, which are ex-

³ Interestingly, in Article I, I quoted this part in order to provide a sense of what the Swedish curriculum aims to accomplish.

⁴ Here, didactical is used in the European sense.

plored from different angles and with different emphasis in the four articles included in this thesis.

As mentioned earlier, NOS in science education is an area where science education researchers have so far had much to say, presented through strong opinions as well as countless empirical results. Here, teachers' perspectives can become an important complement to researchers' perspectives, by contributing pieces to the puzzle of understanding why this gap occurs, and ultimately lead to suggestions of how the gap could be bridged. Thus, the bridging would rely on information and understanding from both sides of the gap.⁵ Therefore, the aim is to study teachers' perspectives and negotiations of what NOS is and how it could be taught. This needs to be explored from the accommodation and resistance that occur in relation to teaching traditions, learning outcomes and policies. The thesis attempts to provide a broader spectrum of nuances in a research field that can sometimes be perceived as fairly black and white regarding its suggestions of worthy NOS topics and fruitful teaching approaches.

The aim is studied through two comprehensive questions:

- 1) What kind of NOS teaching practices are constructed through teachers' negotiations over time?
- 2) How do teachers negotiate and accommodate the constructed NOS teaching practices with overarching goals and traditions of science teaching?

The aim is explored in the four articles included in this thesis. All articles have their own specific research questions that serve to illuminate different facets of teachers' perspectives on what, why, how, and for whom NOS should be taught (see Articles I-IV). Furthermore, all articles address tensions that occur between NOS teaching and existing patterns of school science teaching. Thus, each article makes partial contributions to both research questions.

⁵ Bridging from both sides means that perspectives from both sides are equally valid and that there is no single side that needs to transform its views into the views of the other side – instead, changes in both research practice and teaching practice could be achieved through engaging in a collaboration that entails mutual contributions and understanding.

The perspectives are approached from different angles, which explore: NOS-inexperienced teachers' ways of talking about NOS teaching (Article I); NOS progression (Article II); Challenges and opportunities of teaching sociocultural and subjective aspects of science (Article III); and contextualized versus decontextualized NOS teaching (Article IV).

1.3 Disposition of the thesis

The present thesis is a compilation thesis that includes four articles. All articles aim to illuminate different facets of NOS in science teaching by focusing teachers' perspectives. The articles are referred to as Article I, II, III, and IV.

The thesis commences by describing the theoretical and empirical foundations used in order to make meaning of teachers' voices and to answer the overarching questions of the thesis. These foundations deal with purposes of science teaching, traditions of science teaching, and NOS in relation to science teaching.⁶ They are separated into three chapters: one related to school science as a whole, and two focused on NOS in relation to school science. It has not been regarded as productive or even possible to make a separation of theoretical contributions from more empirically-based contributions as they are often entwined.⁷

The methodology chapter provides a detailed description of the project design, as well as reflections on the chosen approaches and the ethical considerations connected to these choices. Furthermore, the overarching analytical approach is presented. Finally, a short description of the included articles and their connections and significance for the thesis is followed by the concluding chapter. This discusses the results in relation to the two research questions and provides implications for practice. The full articles are included at the end of the thesis.

⁶ The presented NOS foundations are two types. One presents an overview of theoretical, ideological, and empirical underpinnings of previous NOS research; the other presents the framework that was developed and put to use during the present study.

⁷ However, some sections will have a more theoretical approach while others will present mostly empirical research.

2 SCHOOL SCIENCE

This section provides an outlook on questions regarding what, how, why, and for whom to teach science from the view points of policies, goals, and cultures of science teaching. This description is needed in order to make sense of the tensions that are expressed through the teachers' negotiations of NOS in relation to science teaching. The chapter starts with theories from curricular traditions as well as Science Technology and Society (STS) perspectives. The “mangle” (Pickering, 1995) is introduced as a metaphor for practices in process. Pickering (1995) has established “the mangle of practice” as a theory for describing how science practice is mangled through a “dance of agency” between humans and non-humans (i.e. materials and machines).

I find “mangle” a convenient and suggestive shorthand for the dialectic because, for me, it conjures up the image of the unpredictable transformations worked upon whatever gets fed into the old-fashioned device of the same name used to squeeze the water out of the washing. It draws attention to the emergently intertwined delineation and reconfiguration of machinic captures and human intentions, practices, and so on. (Pickering, 1995, p. 23)

Instead of focusing on material agency (see Pickering, 1995), structural, social and cultural agencies become the important components in this thesis. Thus, the mangle is utilized as a tool to describe how different teaching cultures are rubbed against each oth-

er, transformed, and accommodated in a dance of agency with traditions, discourses, and policies.

Here, school science is regarded as transformed from a starting point in academic sciences and mangled into school science – what I conceptualize as school science in the making. The chapter moves on to descriptions of scientific literacy and the diverging purposes of science education focused therein, and further on to research on science teaching cultures and traditions. These latter sections illuminate the intertwined nature of goals and science teaching patterns – that is, how certain content invites and hinders certain ways of teaching and vice versa.

2.1 School science in the making

It is reasonable to believe that school science is, and should be, something different than the knowledge production of authentic scientific practices. The processes of transforming academic knowledge to an educational context has been described in terms of *didactic transposition* (Achiam, 2014; Chevallard, 1989; Gericke, 2009) or as *alchemic* processes⁸ (Popkewitz, 2004). In the case of NOS, the academic knowledge that needs transforming emanates from more than one field. These fields include not only natural science itself, but also the academic fields that study science, such as philosophy, sociology and history of science. All of these fields are deeply intertwined while also being contrary to each other regarding choice of focus and diverging discourses.

Didactic transposition “takes place whenever somebody intends to disseminate or teach disciplinary knowledge to somebody else” (Achiam, 2014, p. 1). It has been described as following three steps (Achiam, 2014) where decisions are, necessarily, made in each step (see Figure 1). The relocation of knowledge from one institution to another means new conditions for the knowledge where “knowledge becomes adapted to *institutions* much as plants become adapted to their environment” (Achiam, 2014, p. 1). The first step is taken in a societal context where decisions are made re-

⁸ The alchemy of school science studies how school subjects are culturally constructed and thus influenced by developmental psychology, policy, and practical ideas of what can and should be taught.

garding which objects of knowledge from the research context should be chosen to be part of a curriculum. In the next step, the choices that are made in a societal context are transformed into what is taught in, for example, the science classroom. In the last step, the “taught knowledge” is transformed into what is actually learnt and thus, becomes learnt knowledge (Achiam, 2014).

Figure 1. The steps of didactic transposition (adapted from Achiam, 2014, p. 2)

In each step, the knowledge is adapted in ways that “may include reorganization, substitution, simplification, enrichment, and modality changes” (Achiam, 2014, p. 2) – an adaptation that is never trivial. It is probably fair to assume that the arrows are not only working in one direction but that adjustments and accommodations cause later steps to affect earlier steps in a circular way. Sensevy (2012) describes this as a system of teachers, students and knowledge where no part can be understood without the other – the relationships between these parts needs to be taken into account.

The metaphor of the mangle (Pickering, 1995) can certainly be used as a tool for understanding how frictions and tensions are created when teachers’ perspectives, goals, teaching strategies, policies; and so forth are rubbed against each other. Pushing through the mangle, practice is reconfigured in a struggle that can be described as a ‘dance of agency’ that leads to “reciprocal tuning” (p. 21). Thus, the mangling is part of the unavoidable steps of didactic transposition. Unavoidable due to the practical impossibility of students learning about scientific phenomena through authentic practices (Gericke, 2009). Moreover, the transformations are also

desirable as school science ought to be considered an authentic practice in its own right, with partly, if not entirely, other purposes than academic science – that is, educational purposes (Lundin, 2007; Popkewitz, 2004). However, as can be understood from the above description, the steps of the transformation are neither self-evident nor made in a vacuum; every step means that a plethora of directions could be followed. The transformations that are made are governed by historical contexts as well as by educational discourses and ideas about students' abilities – all further contents of the mangle. These contexts and discourses affect the possibilities for what can be said and even thought (Popkewitz, 2004). Taken together, all transformations that are made create school science cultures characterized by specific features, approaches, and goals that affect how teachers discuss their practice. The following sections focus on the goals and practices of science teaching. Both are important parts of the mangle and play a role for how teachers will talk about NOS teaching. As is evident in the subsequent section on scientific literacy (goals of science education), this is in itself an area of vivid negotiations.

2.2 Scientific literacy – purposes of school science education

The teachers who contribute with their voices to this thesis talk a great deal about the kind of knowledge that they want for their students (sometimes in relation to the goals that are presented in the national curriculum) – that is, the policy goals for science teaching.

In the research literature, as well as in policy documents and frameworks, *scientific literacy*⁹ is often mentioned as the purpose of science education. Debates surrounding scientific literacy have made an imprint on curricula as well as international large-scale tests such as PISA (Serder, 2015). This brings about questions like: What is scientific literacy? Why do we need it? What are the curricular implications? Even if scientific literacy has been universally

⁹ In the literature scientific literacy/science literacy have often been used interchangeably (Feinstein, 2011). *Scientific literacy* is the term used most often by science educators and covers the definitions of both vision I and II (Roberts, 2007; 2011). In this thesis, for the sake of consistency, the term *scientific literacy* is used throughout with the except of quotations using the term *science literacy* (e.g. in Feinstein, 2011).

welcomed as “good”, there is little consensus regarding the answers to the above questions (Hodson, 2008).

2.2.1 Different lines of research

Two conflicting views regarding scientific literacy have been described in the literature (Hodson, 2008; Roberts, 2007; 2011; Roberts & Bybee, 2014). In an extensive review of science literacy/scientific literacy, Roberts (2007) chooses to call these conflicting views *visions*. The first view, referred to as Vision I, aims for literacy within science. Hence, literacy is characterized as the knowledge of concepts, skills and attitudes that are important to the discipline of science and to future scientists. In Vision II, scientific literacy is related to situations outside science. It involves a person’s capacity to access, read and understand material with a scientific dimension and use it to inform decisions (Roberts, 2011). Thus, in the latter vision science becomes part of human affairs. Roberts (2007) argues that the definitions of the two visions are “idealized extremes” and as such a sort of artificial construct that is useful for analyzing science education with regards to starting points and end goals. This also means that even if the visions represent endpoints in a scientific literacy continuum, one does not exclude the other, but instead contributes with different elements of science education, elements that need to be balanced (Roberts, 2007): “Assessment programs and curriculum embodiments partake of these two visions in a kind of a mating dance wherein they complement one another” (Roberts, 2007, p. 730).

However, the debate and suggestions have often become polarized in a way that favours one vision over the other to an extent that the less favoured is only represented in a very shallow way. Roberts and Bybee (2014) followed up on Roberts’ earlier review by studying scientific literacy trends over the latest ten years. They concluded that recent policy trends are directed towards putting more emphasis on Vision I. This conclusion is supported by Feinstein et al. (2013) who claim that educational policy strives to steer students towards becoming future scientists. One example of an increased emphasis on Vision I are PISA frameworks from 2006 and 2015, which were examined by Roberts and Bybee (2014).

They argue that while the 2006 framework was focused on Vision II, PISA 2015 has reduced the emphasis on Vision II in favour of internal processes of science (Vision I). In Sweden, the recent critique against a curriculum (discussed in the introduction to this thesis) might be part of the same trend.

Views about science are communicated by teachers through what is said, what is not said and how it is said; described as companion meanings in Roberts (1998) and Östman (1998). Companion meanings express power relations through its views of science: “it is Absolute Truth (or not), it is accessible to only a few (or to many)” (Östman, 1998, p. 68). That is, companion meanings say something about what science is and who is invited to take part. A much broader spectrum of companion meanings is allowed in relation to Vision II science (Roberts, 2011). If companion meanings also (implicitly) say something about the goals of science education, then this means that the goals connected to Vision I partly differ from the goals of Vision II. Therefore, Roberts (2007) argues that the goals of Vision I could be included in Vision II, but that the reverse cannot be taken for granted.

2.2.2 Useful scientific literacy

Critical voices have been raised against the definitions of scientific literacy and how these have been used in policy documents and science education research. It has been argued that the definitions have no connection to what might actually be useful to the public, and only serves political goals aimed at recruiting new scientists for the wellbeing of the nation (Feinstein, 2011; Feinstein et al., 2013; Hodson, 2008). Feinstein (2011) argues that the usefulness of scientific literacy has been treated as self-evident with too little empirical backing and pleads for “salvaging science literacy”. He categorizes most research approaches as either *rhetorical*, meaning that they take for granted what scientific literacy looks like and what students need to know to be scientifically literate; or *logical*, meaning that they clearly describe what scientific literacy should be and then “logically deduces the knowledge, skills and attributes that might contribute” (Feinstein, 2011, s. 171). He further claims that only a few research studies can be categorized as *empirical* ap-

proaches in descriptions of what literacy is, as they are based on empirical studies of usefulness and the knowledge that is needed to be literate.

Two examples of empirical research on useful scientific literacy are Ryder (2001)¹⁰ and Lundström (2011). Ryder (2001) analyzed 31 different studies as a way to discern the science knowledge that was relevant to different people who were not science professionals. Lundström (2011) investigated teenagers' socio-scientific decision-making through video diaries. Both studies found that subject matter knowledge in the form of science concepts was difficult to use. Ryder (2001) reported that knowledge *about* science, which he defined as "knowledge about the development and use of scientific knowledge" (p. 7) in relation to trustworthiness, justification and interactions, within science and between science and society, seemed to be of greater importance.

Apparently, what is referred to as scientific literacy in some lines of research is by others, at best, regarded as lame attempts to make science education engaging and useful to all students (e.g. Feinstein, 2011; Feinstein et al., 2013). What then, are considered to be more powerful suggestions for useful scientific literacy? Feinstein (2011) argues that scientific literacy in science education should relate strongly to usefulness and relevance in ways that help students become "competent outsiders". Competent outsiders are persons who are capable of discerning when science is a relevant component in contexts of importance themselves and who have the ability to engage and interact with it (Feinstein, 2011; Feinstein et al., 2013).

A similar suggestion is made in Hodson (2008). He considers the possibility of values and literacy goals which are valid at all times and asks if they ought to be inscribed in every curriculum. He answers:

"Yes", if scientific literacy means what scientific resources draw on, where to find them and how to use them /.../ if the real function of scientific literacy is to confer a measure of intellec-

¹⁰ Ryder (2001) is also highlighted in Feinstein (2011) as one of the few empirical studies of useful literacy.

tual independence, to help people learn how to think for themselves and to reach their own conclusions about a range of issues that have a scientific and/or technological dimension /.../ because it liberates the mind. (Hodson, 2008, p. 16)

Hodson (2008) suggests that such literacy could be achieved through strongly contextualizing science teaching by, for example, using socio scientific issues or teaching and learning about NOS. One important aspect of contextualizing science teaching is the simultaneous development of basic, or fundamental, literacy (Norris & Philips, 2003).¹¹ Basic literacy has to do with reading and writing skills, and the ability to use these skills as tools for communication about science in different social contexts. One way of developing students' basic literacy in relation to science means that they increase their repertoire in ways of understanding and expressing themselves through gaining access to the specific language of science (Lemke, 2001; 1990; Liberg et al., 2011; Mortimer & Scott, 2003).

However, Hodson (2008) proposes even further steps, in which scientific literacy is placed in a sociopolitical frame, and where political and scientific literacy can interact to create citizens who dare to take action. Scientific literacy could then lead to a sort of "wisdom" that enhances ethical attitudes and changes values in the western industrialized society, as well as attitudes and values that, in turn, would lead to action and ways of dealing with poverty, environmental problems and social injustice (Hodson, 2008; Roth & Barton, 2004). The pursuit of accomplishing an "action-competent" child/student has been problematized by Ideland (2016), who argues that there is a risk that only specific actions, emotions and ways of participating are desirable. Thereby some students lead the risk of not being identified "as the child we entrust the future of the planet to" (Ideland, 2016, p. 96). Such arguments raise further questions concerning who science education and scientific literacy is for. These questions are of great relevance

¹¹ In this thesis, the concepts of basic literacy are of direct relevance for the results presented in Articles III and IV. Here, teachers talk about teaching challenges related to students' lack of reading and writing skills.

for teachers' discussions in all four articles included in this thesis. Questions regarding who science is for will be further elaborated in the following section.

2.2.3 Science (literacy) for all

Much research takes an ideological point of departure in "science for all" as the desired goal, where "all" can have very different meanings. Goals set for competent outsiders can also be useful to future scientists if science is taught in a large variety of different contexts (Feinstein et al., 2013). Moreover, people who, at times, are something else than outsiders (i.e. scientists or scientists-to-be) are also citizens who need to be able to interpret scientific controversies and take informed decisions in their daily lives (Hodson, 2008). Different goals mean finding a balance between Vision I and Vision II science (Roberts, 2007).

Many studies have referred to the question of who science education is for and to the question of power and social justice (e.g. Aikenhead, 2006; 2011; Barton & Yang, 2000; Brickhouse, 2001; 2011; Brickhouse and Kittleson, 2006; Carlone, 2003; 2004; Hodson, 2008; 2009; Jobér, 2012; Stanley & Brickhouse, 1994; Zachary & Barton, 2004). Östman (1998) studied how different meanings were formed in science education through analyzing the discourses in teaching vignettes and science textbooks. He argues that "Students can be empowered or not, with respect to science, depending on the qualities of the discourse they experience in science education" (Östman, 1998, p. 69).

In a more recent study, Jobér (2012) identified similar patterns through studying how students' ways of talking were valued in ways that generated rules for how to act and talk. Hansson (2007) used interviews and group discussions to study upper secondary physics students' world views and their ways of talking about the views presented in physics. She suggests that there should be room for discussions about the limits of science (see also Hansson & Redfors, 2007) and of how physics can be understood from the points of different world views and ideologies. Including discussions of how science can be interpreted from perspectives in different world views could result in more students feeling at ease with

science education (Hansson, 2007). The kind of “one-size-fits-all” mentality that is often practiced clearly does not fit all and Swedish students are losing interest in taking part in science education (Oskarsson, 2011)¹². However, both Swedish studies and international studies have reported on a resistance from “good students” when efforts have been made to alter the focus of science teaching from Vision I to Vision II (e.g. Carlone, 2004; Ideland & Malmberg, 2012). From all of these studies, it seems clear that the science-education costume needs to be adjusted so as to allow for various world views, experiences, and perspectives in order for all students to be able to engage with science. How these adjustments should be made in order to not exclude other student groups remains a topic for negotiation.

2.3 Cultures of school science teaching

The goals and visions that are chosen for school science education are translated into various teaching formats. Patterns of specific teaching traditions or cultures are thus formed. These cultures and traditions are tightly intertwined with the goals of science teaching. The discourses and policies connected to the previously discussed scientific literacy are also parts of specific school science cultures. Even though no single school science culture can be described, there are still specific features illustrated in the research literature that point to certain trends. These trends are particularly pronounced for physics teaching but generally apply to all science teaching. In a literature review by Zacharia and Barton (2004), three major perspectives on school science are described: traditional school science, progressive school science, and critical school science. They describe school science cultures as made up of ways of viewing the nature of scientific knowledge, ways of structuring school science teaching, and ways of viewing the overarching goals of science education. The categorization is broad and the perspectives are not completely distinct from one another (in particular, the second and third categories overlap) and share views of science and the teaching of science. *Progressive school science* is described

¹² Oskarsson (2011) analyzed ninth graders’ interest in science and science education through use of the ROSE-questionnaire.

as aimed at creating informed citizens who possess an understanding and habits of mind that can be useful in everyday life and that are shared by the scientific community. Students “have to ‘work with’ scientific ideas in order to generate their own deep and thoughtful understandings of how the world works” (Zacharia & Barton, 2004, p. 201). Progressive school science also aims to develop students’ understanding of how science is communicated and created within the scientific community.

Critical school science is described as viewing scientific knowledge as socially constructed and situationally bound. Furthermore, critical school science “links the construction and application of scientific knowledge with issues of power, culture, and ideology” (Zacharia & Barton, 2004, p. 201). Students’ learning is linked to action and interactions with the surrounding world and in everyday life. While progressive school science embraces both Vision I and II, critical school science emphasizes Vision II science.

However, what Zacharia and Barton (2004) refer to as *traditional school science*, in general, only connects to Vision I. Traditional school science is often described as the most common, or prevailing, school science culture (e.g. Aikenhead, 2006; Bartholomew et al., 2004; Duschl, 2008; Höttecke & Silva, 2011; Osborne et al., 2003; Roth & Barton, 2004; Zacharia & Barton, 2004). Hence, what follows from such culture deserves some elaboration. In traditional school science, science content is presented as a collection of facts or truths about nature. These truths are seldom scrutinized or discussed in the science classroom, with regards to *why* they are regarded as trustworthy. Thus, traditional school science tends to deal mostly with ready-made, “black-boxed” knowledge. Furthermore, it means that the processes surrounding the construction of knowledge – the interactions between science, society, and culture – as well as the values, norms or specificities of times and places become obscured. Science in-the-making (Latour, 1987) is seldom emphasized in the science classroom.

The teaching formats connected to such a view of science are described as strongly structured, teacher focused, and set on the transmission of knowledge (Bartholomew et al., 2004; Carlone, 2004; Höttecke & Silva, 2011). Carlone (2004) argues that such

practices privilege a: “dry, technical rational discourse; a tacit or explicit denigration of students’ knowledge and ideas; a goal of producing future scientists, rather than a goal of teaching science for all students” (p. 394). Thus, traditional school science is part of reproducing “powerful sociohistorical legacies” (Carlone, 2004, p. 394), which in turn, as previously discussed (see section 2.2.1), paints a picture of what science is and who is invited to take part (Jobér, 2012; Hansson & Lindahl, 2010; Linder et al., 2011; Östman, 1998). A review by Kelley (2007) focused on the discourse of the science classroom. He argues that studies of classroom discourses provide insights into how students are encouraged to take part, how power relations are constructed, and how scientific knowledge is portrayed. Many of the reviewed discourse studies reinforce the above described picture of traditional school science.

Another substantial part of traditional science teaching is the focus on structured lab-work, aimed at further establishing students’ conceptual understanding. This kind of lab-work strictly follows a manual with the purpose of getting correct answers that support the contents of the textbook (described in Article I; see also Zacharia & Barton, 2004). Another purpose is to mimic authentic science by providing students with insights into “the scientific method” and competence to handle specific “scientific” artifacts (Jobér, forthcoming; Roth & Barton, 2004; Rudolph, 2005). Lab-work, as described here, is a tenacious tradition that has its roots in misinterpretations of Dewey’s writings at the beginning of the twentieth century (Bang, forthcoming; Rudolph, 2005). Science educators transformed Dewey’s focus on an understanding of how trustworthy knowledge can be achieved into a stepwise description of “the scientific method”, which has been used ever since (Rudolph, 2005). The myth about “the method” that produces indisputable knowledge (McComas, 1998; Sismondo, 2010) is only one myth, albeit a particularly strong one, among many others that implicitly and explicitly follow from the traditional school science teaching described here. In Numbers and Kampourakis (2015), a collection of common myths is provided that are of both specific

and general character. Some myths of general character that have often been discussed in previous research are:

- *Myths about scientists* where the scientist is portrayed as heroic, virtuous and almost always a Western male (Allchin, 2000; 2003; Carlone, 2004). *He* is also presented as a particularly objective individual (McComas, 1998).
- *Myths about scientific progression* as linear and straight forward with no “partial conclusions or residual uncertainties” (Allchin, 2003, p. 333), with an emphasis on openness for new ideas and easily discarded theories if there are signs of refutation (McComas, 1998).
- *Myths about the boundaries of science*, which says that science can ask, deal with and answer all thinkable questions. That is, there are no limits to what science can do or achieve (McComas, 1998).

However, the way of judging myths as inherently “bad” is questioned in Hamlin (2017), who highlights the importance of reflecting on what the myths should be replaced by.

Roberts (2011) argues that “science teachers ‘grow up’ in a science education culture that generally reinforces Vision I” (p. 24). Consequently, it is not surprising that perspectives from within science often dominate classroom practice. As science teachers are deeply rooted and socialized into the traditions of science teaching it becomes part of their identity and the teaching described as traditional becomes standard practice, a practice that can be very hard to change (Aikenhead, 2006; Bartholomew et al., 2004; Höttecke & Silva, 2011).

In this thesis, elements that traditionally have not been part of the teaching culture are discussed by teachers. These discussions have to be understood in relation to the elements and teaching structures that make up the already existing cultures. Several Nordic studies have investigated the inclusion of new elements in science teaching through the framework of selective traditions (Williams, 1973). Some examples are provided in the following section.

2.3.1 Selective traditions

When new elements (such as NOS teaching) are introduced in science teaching practices, they need to be accommodated, adjusted or aligned with previous traditions in some way. In this process, the already existing cultures and traditions serve as frames of reference for what can and cannot be included in the formation of new practices (Englund, 1986; 2005; Williams, 1973). Williams (1973) uses the term *selective traditions* to describe this process:

...at a philosophical level, at the true level of theory and at the level of the history of various practices, there is a process which I call the selective tradition: that which, within the terms of an effective dominant culture, is always passed off as “the tradition”, “the significant past”. But always the selectivity is the point; the way in which from a whole possible area of past and present, certain meanings and practices are chosen for emphasis, certain other meanings and practices are neglected and excluded. Even more crucially, some of these meanings and practices are reinterpreted, diluted, or put into forms which support or at least do not contradict other elements within the effective dominant culture. (p. 9)

Content-directed traditions (i.e. traditional school science teaching, see previous section) have been described in Swedish and Danish investigations of teachers’ ways of talking about their teaching practice (e.g. Gyllenpalm et al., 2010ab; Johansson & Wickman, 2013; Sund & Wickman, 2008; Tidemand & Nielsen, 2017). Gyllenpalm et al. (2010b), as well as Johansson and Wickman (2013), interviewed teachers about inquiry-based science teaching. In these studies, content-directed traditions, as well as traditions focusing on students’ engagement and enjoyment were identified. However, this focus on content also affected the more “activity-oriented”¹³ traditions in ways that made students worry about formulating hypotheses as they might turn out wrong.

¹³ In the activity oriented tradition, practical work (i.e. lab-work) is justified by the teachers as a way to make science less theoretical and more fun (Johansson & Wickman, 2013).

In a recent Danish study, Tidemand and Nielsen (2017) used group interviews to elicit teachers' perspectives on SSI approaches to science teaching. Their study showed that even in connection to SSI, teachers focused strongly on content regarding both teaching and assessment. The authors argued that the focus on concepts might be a "coping strategy" in order to be able to handle diverging curriculum emphases – a way of aligning new elements with dominant practices. According to Lunde (2014), the incorporation of new elements such as SSI and NOS requires time and thorough negotiation. Otherwise, there is a risk that the new elements will only be incorporated in a shallow way, which means that the intentions and basic ideas will be lost to prevailing traditions.

This chapter has dealt with the policies and cultures that are components in the construction of what, how, why and for whom regarding school science. These components are needed in order to understand how Science Education research and the teachers in this study negotiate NOS teaching. A direct connection between the present and the following chapter is the much-used justification of NOS from a scientific literacy perspective (see Lederman, 2007). Different conceptualizations of scientific literacy accommodate NOS in different ways, which in turn results in different suggestions for practice.

3 NOS IN SCHOOL SCIENCE

This chapter provides an outline of research that has focused on NOS in relation to science teaching – the “nature of NOS teaching”. The chapter starts in theoretical considerations of “what NOS” and ends in empirical approaches to how and why NOS should be taught.¹⁴ The research field’s exploration of NOS has taken a point of departure in normative, ideological, and theoretical perspectives, as well as in more explorative approaches, which has meant collaboration and deep involvement with teachers. The chapter concludes by describing how the present study connects and adds to previous research with complementary perspectives on the construction of NOS teaching practices.

3.1 NOS and science education

When the field of science is transformed into science education the question of what science is needs to be taken into account. In doing so, science education has borrowed perspectives from the interdisciplinary field of Science Studies.¹⁵ Traditional school science seems to have borrowed perspectives from early positivist or falsificationist traditions. These traditions have, since the 1980s, been rejected in science educators’ debates concerning the direction for science education (Adruiz-Bravo, 2014).

¹⁴ In this field, the question of who NOS teaching is for has, so far, mostly been intertwined with the question of why.

¹⁵ In this thesis, Science Studies is understood as a broad spectrum of fields that study science from a variety of perspectives, such as philosophy, history and sociology of science.

Science philosophers have engaged in debates concerning scientific methods, moving from the positivism of the Vienna circle, to Popper and falsification, Kuhn's paradigms, Lakato's programmes, and further on to "anything goes" (Feyerabend, 1993), and Hackings new experimentalism (Chalmers, 2013). In the field of sociology of science, which has partly moved in parallel to philosophy of science,¹⁶ discussions have concerned science as a social activity, moving from "Merton's norms" to Kuhn's processes of socialization, and further to, for example, Latour's actor network theory (Sismondo, 2010).

Evidently, Thomas Kuhn is a central figure in both fields.¹⁷ Kuhn challenged many of the previously described myths in his 'Structure of scientific revolutions' (Kuhn, 1962), and encouraged people to think in different ways about science. He used a historicist perspective and rejected the myth of an oversimplified scientific progress following logical steps. Instead, he viewed normal science as working within paradigms (i.e. frameworks for how to approach a problem within a certain community), where processes of socialization were an important factor. Knowledge, in Kuhn's view, was not accumulated, but moved from one paradigm to another due to anomalies leading to crises that in turn created revolutions (Sismondo, 2010). The reason to specifically highlight Kuhn is that it seems that many NOS frameworks for science education are inspired by his work. Adruiz-Bravo (2014) provides an overview of how science education research has made use of different schools of thought. He argues that all approaches that could be considered to have a positivist flavour were rejected by science educators in the 1980s in favour of the new philosophy of science, where a historicist version and Kuhn took the lead. Science education researchers' limited knowledge of more recent perspectives may, according to Adruiz-Bravo (2014), be the main reason why such perspectives have had only limited influence on science education research. It could be argued that another reason for science educators to be enthusiastic about Kuhn might be due to his fairly moderate

¹⁶ Sociology of science is a much younger field, which means the parallel tracks do not go too far back in history.

¹⁷ Central, but also questioned and criticized in both fields.

challenge of traditional perspectives of science. It is also easier to study examples from the history of science than to study the complexities of current science in the making. As discussed below, science education researchers often appear to worry about moving too far, as if challenging the myths too much could mean that students' trust in science decreases or even vanishes.

Hence, science education researchers can also be part of creating the relativism-fearing discourse that was presented in the introduction to this thesis. The fear that science education might take a too relativistic approach was already described and questioned by Stanley and Brickhouse (1995). Even science education researchers with quite a radical view on science education, such as sociopolitical activism (Hodson, 2008; 2010), struggle with this uneasiness. However, Hodson (2008) discusses the need to balance between traditional and post-modern views of science when discussing curricular goals of science education. To choose either side, he argues, creates too strong a position. Still, lending perspectives from, for example, Feyerabend is considered too daring at least in connection to established scientific knowledge. Such considerations plead for modesty in the choice of topics and perspectives for science education (Hodson, 2008; Matthews, 1998; 2012).¹⁸ Which perspectives and aspects of NOS that are actually suggested for science education are presented in the next section.

3.1.1 What is appropriate to teach about NOS?

As previously described, research focusing on NOS in science education draws on multiple perspectives when transforming the various academic fields into school science. It is important to remember that transformations of knowledge are made over many steps (i.e. didactic transposition (Achiam, 2014) with several options possible for each step). However, the possible outcomes of each step are not unlimited, as they are always negotiated and processed against policies, discourse, and traditions (see section 2.1).

School science necessarily takes an outside perspective on science where meanings and activities have to make sense to the students –

¹⁸ An elaboration on modesty is presented in section 4.3.

what Lundin (2007) calls NOSS (nature of school science). Even so, NOS aspects that say something about “real” science are chosen for inclusion in curricula and in the next step transformed to something to be taught in a teaching context. The description below deals with the ongoing discussion in the science education research community regarding *what* ought to be chosen from a scholarly scientific context for the inclusion in curricula (i.e. the first step of didactic transposition; see Figure 1).

The discussions that take place in the research community constitute an important backdrop to the discussions on the same topic that take place among the teachers in the present research study. Important to note, however, is that the discussions below are primarily based on either theoretical constructs or on suggestions from experts other than teachers (e.g. scientists, science educators or philosophers of science). Thus, teachers’ perspectives regarding relevant NOS perspectives for science education have rarely been included.

That NOS ought to be a topic in science class has, according to several researchers (e.g. Jenkins, 2013; Lederman, 2007; McComas, 1998), been advocated by science educators since the beginning of the twentieth century. As most agree that there are many reasons to *why* NOS should be taught (see section 3.1.2), the main focus of the debate has been about *what* and *how* NOS should be taught in school. The conversation regarding the choice of relevant NOS aspects for school science is ongoing and quite heated.¹⁹ On one side of the debate are “the NOS tenets”, which have been used as a framework in numerous studies by Lederman and colleagues (e.g. Akerson & Donnely, 2010; Bell et al., 2016; Schwartz et al., 2004). Furthermore, these tenets have had great impact on science documents such as the Benchmarks for Science Literacy by the AAAS (1993/2009) (van Dijk, 2011).

The tenets-list, which is not totally fixed, often consists of seven tenets: (1) science involves human imagination and creativity, (2) scientific knowledge is subjective, (3) science is influenced by culture and society, (4) science is tentative, (5) science is empirical, (6) there is a distinction between observation and inference, and (7)

¹⁹ A recent special issue in the *Canadian Journal of Science, Mathematics and Technology Education* (2017, vol 17, no 1) is devoted entirely to the topic.

there is a distinction between theories and laws (Lederman, 2007). Other lists, which resemble the Lederman list, have been described in, for example, McComas (1998) and Osborne et al. (2003). It has been argued that even if the tenets do not provide a complete or even nuanced picture of science, they are suitable for guiding NOS teaching in a K-12 setting, since they provide NOS characteristics for which there is little disagreement among specialists (Lederman, 2007). Learning what the tenets suggest about NOS is considered to be a good starting point for challenging mythical pictures of science (Abd-el-Khalick, 2012a; Kampourakis, 2016a). There is, however, a need for elaboration through highlighting the complexity and intertwined nature of the NOS tenets, especially when teaching students in higher grades (Abd-el-Khalick, 2012ab).

Arguments raised against tenets, often called “consensus list” (Allchin, 2011) or “Lederman’s seven” (Matthews, 2012) by critics, have had various perspectives. The list has been described as containing declarative statements that students are to be indoctrinated into believing in – statements that lack perspectives, context and depth (e.g. Matthews, 2012; Allchin, 2011). The declarative status has, however, been rejected by its founders who instead argue that: it is a list among others and not suggested for mere memorization (Lederman, 2007). Instead, similar to most research on NOS, the goal is to accomplish functional literacy (Lederman & Lederman, 2014). Another argument is that the tenets describe science in a too general and unspecific way with regards to the specificities of different contexts and scientific disciplines (Ault & Dodick, 2010; Wong & Hodson, 2010). The differences between scientific disciplines go well beyond the practicalities of how things are done, to also include discourses and epistemological underpinnings (Rudolph, 2000; Knorr-Cetina, 1999; Schizas et al., 2016).

A further argument, briefly mentioned above, is that there is something suspicious about learning correct answers to statements that in many cases seem to have different answers depending on which perspective is taken. School science should not be indoctrination (Allchin, 2011; Matthews, 2012), but provide rich possibilities and multiple perspectives to help students understand and engage in debates (Erduran & Dagher, 2014; Hodson, 2008; 2010).

Questions have also been put forward (e.g. Hodson & Wong, 2014) regarding the relevance for students to learn about some of the tenets, such as the difference between a scientific theory and a law. There are different ways of defining theories and laws dependent on your scholarly belonging, and the terms do not seem to be relevant for all scientific disciplines or at all times. According to Schizas et al. (2016), laws may, for example, be important to discuss in relation to Newtonian physics, but are not applicable to evolutionary biology since researchers in this area look for the concrete, specific and unique rather than generalizations. Through interviewing scientists, Hodson and Wong (2014) found that to scientific practitioners themselves it is of very little relevance to be able to draw a clear line between theories and laws. Such arguments raise questions regarding the importance of emphasizing this distinction in science teaching.

Other approaches than the tenets-based NOS suggestions have been proposed in science education literature. In some regard, these suggestions are also structured around some form of categories. However, most of these suggestions include more detail or go beyond similarities to also emphasize differences (e.g. Erduran & Dagher, 2014)

One step away from tenets has been to elaborate the fairly short list of tenets into more detailed lists of features of science (FOS) (Matthews, 2012), the Nature of Whole Science (Allchin, 2011), or NOS themes (Martins & Ryder, 2015). In Allchin (2011), the issues are clearly connected to specific contexts/cases. Another way that has gained ground during the last few years is the use of a Family Resemblance Approach (FRA) to define NOS for science education (Eflin et al., 1999; Erduran & Dagher, 2014; Irzik & Nola, 2011; Van Dijk, 2011). This approach is inspired by Wittgenstein's family resemblance concept:

[the] 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)

Irzik and Nola (2011; 2014) used this approach to put forward categories providing “a structural description of NOS” (p. 596), which emphasizes both heterogeneity and resemblances between scientific disciplines. These categories have been used as a basis for further development in Erduran and Dagher (2014). The categories are: aims and values of science, scientific practices, methods and methodological rules, scientific knowledge, and science as a social-institutional system. In their suggestions, FRA categories (i.e. NOS aspects) are linked to science teaching both horizontally (connected to science content) and vertically (connected to grade level). In this way, the authors argue that students have the opportunity to encounter each aspect of NOS in every school year, connected to a variety of science topics at an increasing level of depth and complexity.

In addition, through a number of studies (e.g. Wong & Hodson, 2010; Hodson & Wong, 2014; Schwartz & Lederman, 2008; Tala & Vesterinen, 2015), science education researchers have interviewed scientists in order to gain their perspective, or rather perspectives on NOS. Scientists’ perspectives have then been used as a starting point for discussions regarding NOS in science education. The different studies by Wong and Hodson (2010) and Schwartz and Lederman (2008) showed that scientists’ perspectives were bound to individual context rather than discipline. These findings were used differently in the two studies. Schwartz and Lederman (2008) argued that the lack of discipline-specific NOS features supports the teaching of NOS in a general, tenets-based way. Wong and Hodson (2010) and Hodson and Wong (2014), on the other hand, argue that scientists’ voices are crucial in order to provide richer NOS understanding connected to authentic contemporary science and science in the making.²⁰ (Context and authenticity is further discussed in section 3.1.3.)

Despite the ongoing debate, some studies have taken a practical approach to the frameworks and mixed them in ways that suited

²⁰ Science in the making is discussed by Latour (1987) as all the things that are going on: “uncertainty, people at work, decisions, competition, controversies” (p. 4) before consensus is reached on a certain concept. Once consensus is reached, all of the earlier messiness is black-boxed and no matter how complex the paths to knowledge were, you “need to know nothing but its input and output” (p. 3).

their specific research contexts. Two examples are Maurines and Beaufils (2013) and Tala and Vesterinen (2015). In Maurines and Beaufils (2013), a framework was used that mixed NOS tenets with FRA dimensions. Tala and Vesterinen (2015), on the other hand, discuss different approaches as similar no matter if they stem from tenets or family resemblance. However, both the above studies proposed that the use of any framework should be contextualized through either an individual historical context (Maurines & Beaufils, 2013) or the context of contemporary scientists (Tala & Vesterinen, 2015). A suggestion for a mixed approach is put forward in a position paper by Kampourakis (2016a; see also Kampourakis, 2016b), who urges that the research community should move on from the debate and focus its efforts on school science practice instead. Kampourakis (2016b) suggests a mixed approach where benefits from multiple frameworks are made use of in the construction of a progression for students' knowledge. He suggests a starting point in the tenets or other similar frameworks, and further elaboration that includes perspectives from, for example, FRA as the students have already gained some knowledge. The present thesis is a further example of how the above described lively debate can be used as a basis for a somewhat mixed framework (see Chapter 4). Contrary to much of the previous research, the present thesis also provides a voice to teachers by highlighting their notions of what NOS should be taught in compulsory school (see Articles II & III).

3.1.2 Why NOS?

The question in the heading relates to the previously discussed questions of the goals and purposes of science education. The research literature offers many reasons as to why NOS ought to be included in science teaching (see below). However, as argued by Feinstein (2011), Kampourakis (2016a), and Lederman (2007), most are merely logical or intuitive, lacking empirical support regarding the development of scientific literacy:

It seems that further research is required on this topic in order to better understand what exactly understanding NOS contributes to science literacy (Kampourakis, 2016a, p. 668).

The reasons presented below are all connected to scientific literacy. In Robert's (2007) descriptions of Visions I and II, NOS has been connected to Vision I. However, in the rationales below, NOS is connected to different ways of viewing science teaching and scientific literacy – that is, they carry different messages, definitions and visions of literacy (i.e. both Visions I & II). Arguments for why NOS should be included in science teaching are:

- *Learning science content.* There is empirical evidence supporting the argument that students' learning of content knowledge is facilitated if they gain understanding of NOS (Driver et al., 1996; Matthews, 1994; McComas et al., 1998; Lederman, 2007). The literacy that is aimed for here has its starting point within science (Vision I).
- *NOS as a content in its own right.* This argument is based on the notion that NOS should be planned for as specific content, where students' understanding of NOS ought to be assessed as a cognitive outcome. Here, learning about NOS means learning about the processes of science and understanding of science as a part of our culture (Driver et al., 1996; Lederman et al., 2007; McComas et al., 1998). This argument for learning NOS could take its point of departure either within or outside science.
- *Interest in science.* It is argued that a focus on NOS might increase students' interest in science and science education (Aikenhead, 2006;²¹ McComas, 1998; Sjøberg, 2010). Students as well as teachers have reported on student engagement and enjoyment (Allchin, 2014; Clough & Olson, 2012). An interest in science could either mean increased motivation for further studies in science or engagement and enjoyment of science "here and now". Interest and enjoyment could of course lead

²¹ Aikenhead (2006) writes about "Humanistic school science". This cannot be directly translated into "NOS teaching", but there are similarities that make a comparison relevant. For instance, history and philosophy of science as well as the economy, politics and sociology of science have often been included in a humanistic science curriculum. These are all aspects that are also included in the NOS framework in this thesis.

to increased literacy, where the definition of literacy does not need to be fixed.

- *Usefulness.* This argument is based on the notion that developing students' understanding of NOS is important for the ability to make sense of science in everyday life as citizens and consumers through, for example, being able to interpret and take part in socio-scientific debates and make informed decisions in a democratic society (Allchin, 2014; Driver et al., 1996; Hodson, 2008; 2009). Contrary to the first argument, this argument for learning NOS has its basis in situations outside science (Vision II).

Three of the four arguments connect directly to students' learning and development of scientific literacy, albeit different forms of literacy with different starting points, learning trajectories, and partly different outcomes. The first two arguments can be more closely directed towards future scientists, while the last argument clearly addresses outsiders or all students. The third argument, which deals with interest in science, comprises both types of students: outsiders as well as future scientists.

Even though there is an assumed connection between teachers' views on the utility for NOS and their willingness to include it in their teaching, only few studies have actually examined teachers' perspectives on utility – that is, *why* NOS should be included in science teaching. One of these studies is Herman et al. (2015), who, by using interviews and classroom observations, connected the “type of utility value” that teachers expressed in relation to their level of NOS implementation. Teachers who were considered to be “low implementers” only had a vague notion of why NOS should have a place in science teaching. Herman et al. (2015) concluded that if teachers are to be willing to overcome the challenges connected to including NOS in their teaching, they must see a clear utility for NOS in connection to goals that are “important for life well beyond formal schooling” (Herman et al., 2015, p. 180). In contrast, Bell et al. (2016) found that teachers' main rationale for teaching NOS was that it supported the teaching of core science

concepts. A third example is an extensive research project described in Clough and Olson (2012) in which teachers were asked about their rationales for NOS teaching. The answers from six teachers resulted in a list of 13 rather diverging rationales that included increased student interest, increased understanding of science content, development of informed citizens, and teaching NOS because policy documents required it. However, in this study, as well as in the study by Bell et al. (2016), emphasis was placed on the connection between NOS and science content. These examples show that reasons also differ among teachers and that NOS can be included in science teaching in support of very different goals.

The *why* question is important in all articles included in this thesis, but specifically focused in Articles III and IV where opportunities and teaching traditions are discussed in relation to NOS teaching and the overarching goals of science education.

3.1.3 How to teach NOS

This section focuses on research suggestions regarding the question of how NOS teaching ought to be approached in the science classroom. As mentioned earlier, science teachers communicate messages about NOS through their use of language, textbooks, and lab manuals (i.e. companion meanings Roberts, 1998; Östman, 1998). Science educators have argued that these messages often provide narrow and stereotypical images of science. Different ideas for how to challenge these messages of NOS have been presented by several researchers within this domain.

A dominant line of research argues that the best way to develop an understanding of NOS is through *explicit, reflective* NOS teaching (Lederman, 2007); that is, teachers cannot rely on students to learn about NOS simply through engaging in scientific activities, such as doing lab-work (Bell et al., 2003). Instead, students need to be scaffolded through reflections and discussions about NOS (Lederman, 2007). However, explicit messages often compete with implicit ones. Hence, it sometimes seems as the argument for making NOS explicit is that it should erase the underlying implicit messages about NOS that students meet in traditional teaching. Consequently, to consider both these ways of communicating science to

the students could be important if the goal is to actually change traditional images of science (Oliveira et al., 2012; Ryder et al., 1999).

Another line of research has focused on the *context* of NOS teaching: should NOS be embedded in context (historical or contemporary cases, authentic inquiry and science content) or should it be taught separately in a decontextualized fashion (e.g. Clough, 2006; Driver et al., 1996). The question of context more often rests on logical or ideological foundations than on empirical evidence, which means that the arguments for teaching one way or the other are strongly related to the sort of scientific literacy aimed for. Hence, researchers who emphasize useful scientific literacy or science for citizenship often advocate contextualized NOS teaching. Rich contexts are considered to develop students' abilities to judge the trustworthiness of scientific claims, which is of relevance for understanding and participating in socio-scientific debates (e.g. Allchin, 2014; Hodson, 2008; 2009; Kolstø, 2000; Ryder, 2001).

On the other hand, Clough (2006) argues that NOS should be taught at different levels of contextualization as a way to challenge students' conceptions of NOS and thereby make it harder to dismiss or compartmentalize their knowledge. Many researchers also argue that teaching NOS in a contextualized way can be very demanding for teachers (Allchin et al.; 2014; Clough, 2006; Hodson, 2009). Therefore, another argument for teaching NOS at different levels of contextualization is that focusing only on highly contextualized tasks might deter teachers from NOS teaching (Bell et al., 2016).

In Clough's description, decontextualized NOS activities are defined as stand-alone/detached activities such as "black-box activities". A black-box activity serves the purpose of drawing students' attention to specifically selected NOS ideas. The benefit of a decontextualized approach has been described as the possibility to focus on certain general NOS aspects while not having the constraints of simultaneously dealing with scientific knowledge/content (see Lederman & Abd-El-Khalick, 1998). However, the focus on general NOS aspects have been criticized by researchers who argue that there is no general NOS knowledge (see debate above in section

3.1.1). Another argument is that decontextualized activities can be seen as add-ons that take time from other curricular goals (Clough, 2006).

At the other end of the continuum are highly contextualized NOS activities. These activities are in line with suggestions in Ault and Dodick (2010) and Schizas et al. (2016) who argue that NOS is deeply discipline and context specific, which means that the specificities of time, place, and individuals need to be taken into account. Examples of contextualized activities are:

- authentic socio-scientific issues (Hodson, 2008; 2009; Kolstø, 2000; Yacoubian, 2015)
- historical case studies (Allchin, 2014; Höttecke et al., 2012; Kolstø, 2008)
- authentic inquiry (Abd-El Khalick, 2013; Allchin, 2011; Clough, 2006; Duschl and Grandy, 2013)
- contemporary science contexts (Hodson & Wong, 2014; Rudolph, 2000)
- argumentation (Khishfe, 2012; 2014; McDonald, 2010)
- science content (Bell et al., 2016)²²

Even though a large part of the context discussion has been based on ideological considerations regarding the goals of science education, some studies have taken an empirical approach to the question. These studies have mainly focused on investigating teachers' or students' understanding of NOS in relation to the kind of NOS instruction they have undergone.²³

Some of these studies have investigated NOS understanding connected to context-rich activities (e.g. Eastwood et al., 2012; Heap & France, 2013; Sadler et al., 2007; Schalk, 2012; Garcia-Carmona & Diaz, 2016; Wong et al., 2014; Khishfe, 2012). Re-

²² In regards the last point, all contextualized activities have some level of science content.

²³ Consequently, the researchers' view of what counts as NOS knowledge has a role to play in these investigations. This means that an investigation studying participants' knowledge of the tenets would not be regarded as valid by a person disregarding the tenets as valid NOS knowledge (even if the tenets could be utilized and understood in different ways).

search has shown that students can gain NOS understanding through engaging in SSI-activities, and that the development of NOS understanding is intertwined with the development of functional scientific literacy and an understanding of argumentation (Sadler et al., 2007; Schalck, 2012; Khishfe, 2012). Eastwood et al. (2012) investigated the effect of *different* contexts. One of the contexts was SSI related and the other was content driven. Students gained NOS understanding in both contexts, but qualitative differences were reported regarding their understanding of sociocultural aspects of science. For instance, students who had been part of the SSI teaching were better at providing contextualized examples of their learning.

Other studies have focused on teachers' learning from context-rich cases. These studies have shown that pre-service teachers' and in-service teachers' understanding of NOS can be enhanced by engaging with authentic cases (Heap & France, 2013), reading news articles (Garcia-Carmona & Diaz, 2016), and working with SSI (Wong et al., 2014). Wong et al. (2014) and Garcia-Carmona and Diaz (2016) further report that teachers developed ideas for future teaching strategies when they engaged with context-rich and authentic tasks during their education.

A few studies have compared context-rich and decontextualized approaches (i.e. different levels of contextualization) and their respective impact on students' and pre-service teachers' NOS understanding (e.g. Bell et al., 2011; Khishfe & Lederman, 2006; 2007). Bell et al. (2011) investigated pre-service teachers' understanding of NOS and Khishfe and Lederman (2006; 2007) investigated ninth-graders' NOS understanding. All three studies used open-ended questionnaires as an assessment instrument and all came to the conclusion that, if NOS was taught through an explicit approach, the NOS knowledge was improved regardless of whether NOS was taught within a context or as a stand-alone topic.

In a NOS course for pre-service science teachers, Bell et al. (2016) used activities from different parts of the context continuum in an attempt to move beyond the dichotomy of highly contex-

tualized and decontextualized activities.²⁴ The pre-service teachers' development of NOS understanding and their intentions and rationales for teaching NOS in the future were analyzed using the VNOS-C questionnaire (Lederman et al., 2002) and interviews. The results showed significant gains in pre-service teachers' NOS understanding, which was argued to support Clough's (2006) argument for teaching along a context continuum. Furthermore, Bell et al. (2016) reported that, after taking the course, the pre-service teachers claimed to have intentions to teach NOS to their future students. Their main rationale for teaching NOS was that it supported the teaching of core science concepts.²⁵ A follow-up study (Mulvey & Bell, 2017) concluded that the NOS knowledge participants had gained during the course was also retained over time.

However, regarding a comparison between contextualized and de-contextualized approaches to NOS, few studies have explicitly asked for teachers' perspectives.²⁶ What are the possibilities and challenges, what learning options can be achieved, and what goals can be met through teaching one way or the other? In this thesis, Article IV is devoted specifically to these questions.

3.1.4 Projects focusing on classroom practice

Research has shown a strong concern regarding the images of science that are available in science classrooms around the world. Early research on NOS focused, to a large extent, on students' and teachers' NOS understanding. However, over the latest decades a change has been made towards a strong focus on classroom practice (Lederman & Lederman, 2014). Early studies of classroom practice concluded that a teacher's views of NOS did not necessarily say much about the kind of NOS that was taught in the same teacher's classroom (e.g. Akerson & Abd-El.Khalick, 2003; see also Lederman, 2007). This has led to extensive research efforts, including pre-service teacher courses and professional development,

²⁴ In this study, the level of contextualization was related to science content.

²⁵ That the pre-service teachers' main rationale for teaching NOS was to facilitate learning of science concepts is perhaps not surprising due to the course being developed around the specific connection between NOS and science content (i.e. the level of contextualization was, as previously mentioned, related to the degree of science content in the activity).

²⁶ To my knowledge none have.

directed towards the implementation of NOS in science classrooms (see, for example, Akerson and Hanuscin 2007; Höttecke et al., 2012; Lederman & Lederman, 2012; Clough and Olson, 2012).

The project Inquiry, Context, and Nature of Science (ICAN) is a large scale professional development project, described in Lederman and Lederman (2012). The project involved hundreds of teachers and thousands of students, and had a primary focus on teachers' understanding of NOS and NOS teaching. Teachers took separate courses on NOS and NOS teaching and their knowledge was evaluated through the VNOS-questionnaire and through micro-teaching lessons.²⁷ In this project teachers were taught a specific definition of what NOS knowledge is and how it should be taught. The overall conclusion from the project was that this long-term project developed teachers' knowledge about NOS and had an impact on their teaching from implicit or didactic²⁸ to, at the end of the project, explicit reflective teaching.

Another long-term project is described in Clough and Olson (2012). Two NOS courses and one NOS teaching course were developed for pre-service and in-service teachers. After taking the courses, six teachers were observed in their classrooms. Researchers studied to which degree NOS was implemented in accordance with instructions from the NOS teaching course (e.g. variation of decontextualized and contextualized tasks, explicit references to NOS, and use of NOS language). Teachers' NOS knowledge and rationales for teaching NOS were investigated through surveys and interviews. It was concluded that differences between high and low NOS implementers were due in large part to having more or less clear rationales for NOS teaching. A follow-up study by Herman et al. (2015) provided more room for teachers' perspectives. Interviews with 13 teachers showed that:

...several factors were associated with the extent that these teachers implemented NOS instruction, including the utility value they hold for NOS teaching, considerations of how people

²⁷ Micro teaching lessons were lessons that teachers taught to their course peers and received feedback. The lessons were video recorded and analyzed by the researchers.

²⁸ Didactic with the North American meaning of authoritarian teaching.

learn, understanding of NOS pedagogy, and their ability to accurately and deeply self-reflect about teaching. (p. 161)

An important conclusion from both of the above studies was that teachers have to be taught not only about NOS, but about NOS teaching in order to teach it themselves.

A third long lasting, large scale project is described in Höttecke et al. (2012). This project did not build on teaching material solely developed by researchers. Instead, it was characterized by a far-reaching cooperation between researchers and practicing teachers in developing teaching material intended for the implementation of history and philosophy of science (with focus on NOS) in science teaching. The intention of the collaboration was not only to improve the teaching material through cycles of discussions, implementations and revisions, but also to create a sense of ownership where both sides would agree on the adequacy of the material. In a follow-up study, Henke and Höttecke (2015) interviewed eight teachers about the challenges they had encountered while implementing the previously developed material. These challenges were related to the demands of preparing and orchestrating lessons, to students' attributes and abilities, and to institutional frameworks.

Other long-term, professional development projects have involved fewer teachers. A case study by Akerson and Hanuscin (2007) came to similar conclusions as the findings in the ICAN project (Lederman & Lederman, 2012): a long-term project can affect teachers' NOS views and change teaching practice towards a more explicit approach. A different approach was taken in Bartholomew et al. (2004): a case set out to identify "factors that influence teachers' practice when teaching *about* science" (p. 678). Eleven teachers took part in professional development courses where ideas about science and teaching examples were discussed (but not presented as prescriptions for best practice). The researchers made classroom observations and the teachers shared their experience in a focus group at the end of the project. It was found that teachers' positions on five dimensions of classroom practice had great impact on their teaching about science. These dimensions

were: knowledge about NOS, conceptions of a teacher's role, use of discourse, conceptions of learning goals, and nature of classroom activities. The conclusion was that "a significant change in the culture of science teaching" (p. 679) was needed. Suggested changes regarded both the extent to which NOS discussions were included in the teaching and the extent to which student engagement and ownership was taken into consideration.

A few studies have taken measures to ensure a deep understanding of teachers' experiences, reflections and struggles regarding classroom practice in relation to NOS. In an early study by Brickhouse and Bodner (1992), one teacher who had limited experience as a science teacher was followed in his teaching for seven months. Both formal and informal interviews were made in connection to the teaching. The data generated information about "beliefs about science and science teaching and how these beliefs influenced, or failed to influence, classroom instruction" (p. 471).

Some studies have focused even stronger on the voices of particular teachers through various action research²⁹ approaches. Two examples of action research studies that have included research-practitioner collaborations are Hanuscin (2013) and Krajewski and Schwartz (2014). Hanuscin (2013) studied the development of one teacher's pedagogical content knowledge for NOS. The study was a researcher practitioner collaboration where the teacher, after taking a NOS methods course, was mentored by a science educator for two years. The teacher reflected on her practice in interviews, in writing and through dialogue with the researcher. Critical incidents that had an impact on practice were identified through joint analysis of the reflections. A conclusion was that a NOS methods course was not enough to transform NOS ideas into teachable moments, but that reflection and dialogue was needed. A similar approach was taken in the study by Krajewski and Schwartz (2014). In this study, the teacher was the first author of the article (which, to a large extent, was written in first person). The study

²⁹ In Krajewski and Schwartz (2014), action research is defined as "the practice of teachers researching their own practice of teaching" (p. 546) with a goal to enhance reflection and improve practice.

focused on successes and challenges that followed from a teacher's attempts to include NOS in her everyday classroom practice. The authors identified a number of factors that facilitated changes in classroom practice. These factors had to do with the research format (action research), having access to NOS resources, and the identification of success. This is one of very few NOS studies that has emphasized the identification of success as an important factor. "Having success, and recognizing success, can lead to further attempts and further success" (p. 561).

A last example in this overview of research on NOS in classroom practice is Akerson et al. (2014), who continued the work of emphasizing teachers' experiences through yet another approach. The study was a self-study where the first author, an expert on NOS and NOS teaching, took the role of an elementary teacher during one school year. In collaboration with her fellow authors she studied identity, emotions and struggles connected to NOS teaching. The researcher/teacher experienced great difficulties in relation to time limits and students' differing abilities, but also found ways to overcome some of the difficulties by including NOS on several occasions during the school day. Such experiences contribute to making teachers' experiences count and could become important points of departure in future NOS courses.

This overview shows that research studies have incorporated teachers' reflections in different ways: as collaborators (Höttecke et al., 2012); as a sounding board for the implementation of specific NOS strategies (Akerson & Hanuscin, 2007; Clough & Olson, 2012); or as deep reflections on practice (more or less) not bound to specific professional development programmes (e.g. Brickhouse & Bodner, 1992; Hanuscin, 2013). It also shows that in many cases factors such as teaching cultures, and discourses of goals and rationales, play a role for how teachers talk about and implement NOS teaching. The following section discusses how the present thesis connects to this previous research and contributes with further facets in the understanding of teachers' reflections on NOS and its role in classroom practice.

3.2 Teachers' voices as influence and bridge builders

The extensive body of research on NOS in science teaching shows some of the importance rendered to this issue in science education. Previous sections have shown that research is brimming with ideas of what, why, and how NOS ought to be included in science education. A large number of early studies on NOS teaching have found that NOS perspectives are often not taught in accordance with suggestions in research. A common explanation to these findings is that teachers lack the knowledge about NOS that is required to teach it (for an overview of studies see the previous section and, for example, Lederman, 2007; Lederman & Lederman, 2014). However, the last section provided some insight into how research has attempted to handle the situation through putting ideas from research to work, for instance, in professional development courses. Research following from professional development and teaching interventions show that even for teachers who have taken part in extensive professional development programmes, the inclusion of NOS in classroom teaching can be challenging. Consequently, it is easily understood that a disconnect – a gap – between research and practice is perceived (Broekkamp & van Hout-Wolters, 2007; Luft, 2010). It has been argued that difficulties connected to the efforts of bridging the gap between research and practice can often be related to a one-sided research focus, as multisided perspectives are lacking – the practitioners, who are carriers of important perspectives, rarely take part (Broekkamp & van Hout-Wolters, 2007). As teachers are professionals with first-hand experience and knowledge of practice, there is a need to include their perspectives in policy work (Luft & Wong, 2014; Shulman, 1986; Wickman, 2014).

Teachers should be first authorities on the rationales and consequences of choosing certain content and methods. This is particularly important in a democratic society, in which they make these decisions with other stakeholders and in which these stakeholders need to be informed by teachers on didactic questions. (Wickman, 2014, p. 146)

Shifting focus from teachers' implementation of predesigned innovations and instead rendering professionalism to teachers by including their perspectives and involving them in design processes, could make research outcomes more relevant to practice (Guitérrez & Penuel, 2014). The previous section showed that action has been taken in that direction. Yet, a large body of the ideas surrounding NOS teaching are still shaped without the thorough involvement of teachers, or without taking their perspectives seriously.

This thesis seeks to explore the gap by listening to teachers' voices and considering them to be important pillars in a bridge that might be able to cross the gap. The present study was never intended to be a professional development programme. However, through teachers' recurrent negotiations in focus group discussions, insights were made and learning took place both with regards to the researcher and to the teachers. The project did not have a ready-made outset; neither the researcher nor teachers held any answers or sought well-defined truths, but were equally set on exploring. The interactions in this study have meant collaboration and reciprocal influence where previous research and the divergent perspectives of the participants have been mangled with my own understanding. The perspectives have influenced one another; none could have been left out, but the teachers' voices certainly constitute the most important and most interesting contribution.

4 THE NOS FRAMEWORK OF THIS STUDY

A dynamic NOS framework was developed during the project. It served multiple functions: As an organizer for NOS issues, as a guide for focus group discussions, and as an analytical tool. The NOS framework consists of five broad themes. During the entire study, I have thought of the framework as a chest of drawers and the themes as its drawers. At the beginning of the project each drawer only contained a small amount of issues, but as the project progressed more issues and perspectives were added and some were moved between drawers. The participants were also involved in filling the drawers with issues that they chose to pay attention to and I, in turn, made choices when some issues were selected to scrutinize in the focus group meetings. The choices, made both by me and the participants, necessarily changed during the project as we all learned more and were inspired by new experiences. This also means that with more knowledge of the history, philosophy and sociology of science, the initial choices that were made could have been different. However, as described above, using a framework that is not rigid opens for possibilities to expand and adjust along the way. The framework presented here thus must be seen as a kind of summary of my understanding of what could be relevant NOS issues for teachers and students. Therefore, it can be regarded both as a guiding framework and a result (or conclusion).

4.1 Lederman's tenets – a starting point

My point of departure in this project was the description of NOS as described by Lederman (2007). The description contained interesting points that I considered useful for starting discussions. I soon discovered that the use of tenets was subject to valid criticism (see section 3.1.1). However, as mentioned above, my approach to the NOS field was to collect and sort impressions that I thought made the tenets, now themes, richer. This did not seem a controversial thing to do with regards to the following statement in Lederman (2007):

It is important to note that the aspects of NOS described below are not meant as a comprehensive listing. There are other aspects that some researchers include or delete /.../ And any of these lists that consider what students can learn, in addition to a consideration of the characteristics of scientific knowledge, are of equal validity. (p.833)

The tenets (themes) were transformed and made my own by encouraging myself to become inspired by courses,³⁰ the participating teachers, the media, and so on. I also decided not to use the tenets that were more like statements than topics for discussion (*there is a distinction between observation and inference; there is a distinction between laws and theories*). The first claim is uncontroversial and can easily be included in almost any of the other themes, but as it is put it sounds more like something to memorize and thus it did not appear functional as a theme. The second claim about theories and laws is a bit more problematic (see section 3.1.1). Lederman (2007) provides a definition of the distinction:

³⁰ Four courses during my doctoral studies need to be specifically mentioned. The courses contributed by providing perspectives on science from the various scholarly disciplines of science education, STS and physics. The discussions they initiated, as well as the lectures and literature that were included, have been imperative for my own NOS understanding and for the development of the framework. These courses were: (1) "Interdisciplinary Studies in Science", tutored by Professor in Science Education Sibel Erduran; (2) "Sociological and historical perspectives on the natural sciences", tutored by Professor in Science Education Per-Olof Wickman; (3) "Introduction to science and technology studies", tutored by Professor in Science and Technology Studies Claes-Fredrik Helgesson et al.; and (4) a course designed for physics graduate students, intentionally provocatively named "The scientific method", tutored by Professor in Theoretical Physics Leif Lönnblad.

Laws are statements or descriptions of the relationships among observable phenomena. Boyle's law, which relates the pressure of a gas to its volume at a constant temperature, is a case in point. Theories, by contrast, are inferred explanations for observable phenomena (e.g., kinetic molecular theory provides an explanation for what is observed and described by Boyle's law). (p. 833-834)

As mentioned previously, there is a debate both regarding the definition and the relevance of this tenet. Another important aspect is that theories and, in particular, laws do not have a prominent place in the Swedish national curriculum. Instead, the curriculum emphasizes that "Teaching should contribute to pupils developing familiarity with /.../, models and theories/.../, as well as an understanding of how they are shaped in interaction with experiences from studies of the surrounding world" (Skolverket, 2011a, p. 120).³¹ This resulted in the construction of the theme *empirical and/or theoretical NOS* (see elaboration in section 4.2.2), which includes issues concerning, for example, the interactions between empirical investigations, theories, models, and laws, as well as other issues related to these issues. This theme, similarly to the others, is treated as a continuum.

4.2 Description of the themes

The five broad and often intertwined themes used as a framework in this study are presented below. Each of the themes represent a dimension that is extended between two extreme positions. This allows for the inclusion of multiple perspectives. The description of the themes draws on literature from the fields of Science Education (on NOS) and Science Studies. Drawing on Science Studies, science can be conceptualized from a range of different disciplinary bases such as philosophy, sociology, psychology, and cultural studies of science. Thus, contributing to the characterization of science and helping to elaborate on the perspectives of NOS. Duschl et al.

³¹ It needs to be noted that the teachers also had a say in this choice since they judged definitions of theories and laws as irrelevant to their students.

(2006) describe the primary focus of Science Studies as the understanding of science as an epistemic and socio-historical endeavour:

Science studies now recognize that scientists do not just collect data, they design experiments to collect the data and they refine and interpret both the data and experiments. In each case what they could do and what they actually do are influenced by their motivations, by the social, informational, and technological resources available, and by the available alternative theories and models. Scientists also write, read, and argue about data, models, theories, and explanations, and in each case there are social and cultural contexts that influence their interpretations or their choice of statements. (Duschl et al., 2006, p. 963)

Benefits of the imaginary drawers are that they are very allowing – they have no limits. Even so, the description below is by no means exhaustive – choices have necessarily been made, but the themes are open to revision and reorganization.

4.2.1 Theme 1. Absolute and/or tentative science

The theme has a starting point in “tentative science” (Lederman, 2007). Bell (2006) describes this as the tenet that is explained by all the other tenets, it simply says that scientific knowledge is subject to change and most of the other tenets help to explain why. This means that the description of this theme is necessarily shorter than the descriptions of the others. The paths from uncertainty to well-founded claims have been emphasized as an imperative topic for science education in, for example, Allchin (2011) and Ruhrig and Höttecke (2015). As the heading indicates, a variety of topics, such as continuity/change and certainty/uncertainty, are relevant in relation to this theme. The extremes could be described as absolutism and radical relativism, where both positions, as previously mentioned (see section 3.1), have been rejected by science education research. Static facts and absolute knowledge is often the implicit picture provided in, for example, textbooks – a picture that often-times has been referred to as mythical (e.g. McComas, 1998). Likewise, a relativist position, or the idea that everything is a social

construction, has been strongly rejected as a naïve or dangerous way to picture science (Hodson, 2008; Sjøberg, 2010). However, perhaps what is rejected would be better described as “radical skepticism or nihilism” (Stanley & Brickhouse, 1995) and not so much relativism described as:

...to acknowledge that we can only know what we know within some framework or frameworks, that we do not have access to universal forms of knowledge. (Stanley & Brickhouse, 1995, p. 353)

The processes of “science-in-the-making” to the “final” products of consensus science (i.e. ready-made science; Latour, 1989) can be exemplified from historical and contemporary perspectives. Richly contextualized cases are advocated as a way to illuminate the historicity of past events³² (Allchin, 2014), as well as the complexities of contemporary science in-the-making (Hodson & Wong, 2014; 2017).

4.2.2 Theme 2. Empirical and/or rational (theoretical) science

This theme is developed from the claim that scientific knowledge is based on empirical evidence (Lederman, 2007). However, such a claim is not enough to constitute the basis for discussions even if it is elaborated by arguing that the observations are interpreted and filtered through humans (Abd-El-Khalick, 2012b). Taking into consideration that different emphases on empiricism respectively rationalism are possible (Eflin et al., 1999), the theme is constructed so that it creates a continuum. The continuum deals with the role of empirical results in science (e.g. deriving from observations and experiments), as well as theoretical contributions and the intertwinement of these. The theme also includes other issues connected to scientific practices, such as organization and communication.

It is well-known that, in science teaching, the empirical position is emphasized, often through “the scientific method” (McComas, 1998). The references to “the method” in school science have been

³² Rudwick (2005) is a rich source of cases from early science in the field of geology.

heavily criticized by, for example, Lederman (2007), McComas (1998) and Rudolph (2005). Science education literature suggest that issues relevant for school science could be, for example, the role of experiments (Matthews, 2012); how evidence works and how it can be recognized as trustworthy (Allchin, 2011); and discipline specific differences regarding scientific activities and methodological rules (Erduran & Dagher, 2014). Furthermore, it has been proposed that such issues should be discussed in relation to a variety of authentic contexts (Allchin, 2014; Rudolph, 2000; Wong & Hodson, 2010). Inspiration and rich descriptions in this area can be found in, for example, Knorr-Cetina (1999), Latour (1987, 1999) and Pickering (1995).

There are certainly other topics of relevance for this theme, only some of which are mentioned below. Firstly, of relevance for scientific practices are knowledge about scientific institutions. These have undergone important changes during the twentieth century (Irzik, 2009). The earlier academic autonomy and freedom of the universities has changed and the intellectual property rights are not always centred at the universities, but as a collaboration between the state, the industry and the universities (e.g. particle physics at CERN). Secondly, the communication of scientific results deserves specific mentioning, since there is a general agreement of a mismatch between writing and doing science – scientists present their results embedded in arguments changing the order of steps in their research (Schickore, 2008). The stubborn clinging to “the scientific method” could have its origin in this mismatch. Thus, issues of communication, argumentation, rhetoric and transitions from investigations (or theoretical constructions) to literary reasoning are of importance (c.f. Hodson & Wong, 2017). Thirdly, when passing over to the next theme that deals with *objective and/or subjective science*, it is important to know that these themes are strongly intertwined through questions dealing with the role of theories (Chalmers, 2013), value-neutral investigators and methods versus social situatedness (e.g. Freedman, 2009; Kuhn, 1962; Longino, 1990)

4.2.3 Theme 3. Objective and/or subjective science

This theme has its basis in Lederman (2007), who, presumably inspired by Kuhn, has described scientific knowledge as theory laden and subjective due to various background factors, such as beliefs, experiences and expectations. The theme engages in questions that deal with the relation between objectivity, and subjectivity at different stages of the research process. Although absolute (objective) scientific knowledge is often regarded as a myth in science education research, reactions to the description of science as subjective can be fierce. Issues that have been suggested as topics for science education are, for example: theory-laden/neutral observations, background factors, and bias.

Objectivity is an area of particular interest to Science Studies – a discipline that loves “picking the objectivity balloon” (Shapin, 2012, p.170). Shapin (2012) argues that it is actually the subjectivity that should be of interest and that the reason for that is because: “our scientific knowledge is about the world and it is also irremediably about us as knowers” (p.171). Feminist theorists are among those who have shown great interest in this area (e.g. Freedman, 2009; Longino, 1990; and Ramazanoglu and Holland, 2002). It has, for example, been debated whether or not diversity among researchers has epistemological value due to ontological heterogeneity, or if it is only of political value, that is, democratizing knowledge even though it might not be brought closer to the “truth” (Freedman, 2009).

The theory laden nature of investigations, mentioned above, is often taken for granted by science education research – the paradigm in which you are located affects your way of observing and describing the world (Kuhn, 1962). It is easy to agree with this position due to case studies in, for example, Pickering (1995) and Kolstø (2008) contributing with stories from physics research where scientists have been unwilling (or perhaps unable) to change their chosen path. Furthermore, Keller (1995) shows that some phenomena are not even possible to observe if the scientist’s mind is not set on them. Other well-known philosophers besides Thomas Kuhn, who have been part of the theory laden line of research, are Imre Lakatos and Paul Feyerabend (Chalmers, 2013). However,

this theme also has a place for New Experimentalists, such as Deborah Mayo and Ian Hacking, who do not at all agree with the above position (Chalmers, 2013). On the contrary, New Experimentalism argues that there are strategies for making step-wise scientific progress through experimentation “independent of theorizing” (Hacking, 1983, p. vii).

4.2.4 Theme 4. Scientists as logically rational and/or creative

This theme is based on the assumption that human creativity is involved in all stages of scientific investigation and that it is particularly important in relation to interpreting data, generating conclusions and inventing explanations and theoretical models (e.g. Abdel-Khalick, 2012b; Lederman, 2007). It would be fair to say that the above assumption is uncontroversial in science education research. However, creativity is considered to be a lacking perspective in traditional science teaching where scientists are often described as using a well-structured predesigned approach – the (objective) scientific method. However, also outside school science the question of creativity being ubiquitous in science practice has been contested. Sahlin (2001) argues that not all scientists would agree that science is creative, but rather that it is hard, well-structured (even if not predesigned) work. He argues that stories or historical cases highlighting the creativity of individual scientists, lead the risk of being anecdotal at best, but more often purely false.³³ Furthermore, according to Sahlin, a person who understands or discovers something by chance ought not to be described as creative. Creativity is always target-oriented and results need to be rationally scrutinized, which points to an intertwinement of rationality and creativity (Sahlin, 2001). It could, however, be discussed whether such an intertwinement marginalizes the importance of creativity, and whether discoveries can stand on their own without the need for creativity to understand or interpret them.

³³ See also Allchin (2000) who discusses the common (and problematic) use of simplified and false accounts from the history of science in science education.

4.2.5 Theme 5. Socio-culturally embedded and/or universal science

This theme is necessarily broad due to a multitude of issues as well as its impact on all the other themes. It has its origin in Lederman (2007), who claims that:

...science as a human enterprise is practiced in the context of a larger culture, and its practitioners (scientists) are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion. The practice of acupuncture, for example, was not accepted by western science until western science explanations for the success of acupuncture could be provided. (p. 834)

Other science education researchers have highlighted specific issues, which could be argued to be part of the more general description above. Some examples are: ways of organizing research, communication and peer review (Abd-El-Khalick, 2012b; Allchin, 2011; Erduran & Dagher, 2014); interactions between science and society through politics and economy (Allchin, 2011; Erduran & Dagher, 2014); authority and prestige (Hodson & Wong, 2014); gender, class or racial bias (Allchin, 2011; Hodson & Wong, 2014); fraud (Allchin, 2011); motivations, personalities and mindsets (Allchin, 2011; Hodson & Wong, 2014); norms, traditions and language of scientific communities (Erduran & Dagher, 2014; Hodson & Wong, 2014; 2017); and competition (Erduran & Dagher, 2014).

In the above quotation as well as in the suggestions, the idea of an underlying universal ontological reality is not necessarily denied, it is simply ignored. Science relies on presuppositions such as there is order and regularity in nature, that human beings can develop knowledge about these regularities, and that they are consistent across time and space – that is, presuppositions about order, universality and comprehensibility (Hansson, 2007; 2014).

Thus, the theme contains a multitude of issues and spans the controversial and much debated continuum extending from “the argument that all culture can be subsumed by science and by the reverse argument at the other end” (Mosco, 2012, p. 102), sometimes referred to as “science wars” (Dadachanji, 1998; Mosco, 2012).

Questions of importance to this theme deal with the extent to which science is influenced by society/culture, and the extent to which science is universal. Similarly to the other themes, questions and issues can be discussed in relation to a variety of authentic contexts (Allchin, 2014; Wong & Hodson, 2010). Some contexts that could be productive for initiating discussions are: *postcolonial studies* of western traditions (as rational and enlightened) and power structures (Huggan, 2002; Longino, 2010); *gender studies* of, for example, language use in science (Martin, 1991); *economy and business* in science and the costs and benefits of commercialization (Irzik, 2009; Mosco, 2012); *religion and science* as opposing, interwoven or supporting (Hansson, 2007; Rudwick, 2005; Stenmark, 2004); and *norms and tendencies* within scientific communities (see, for example, *moral economies*, Daston, 1995).

Some lines of Science Studies discussions have turned against the dichotomy between science and society (Mosco, 2012). For example, in Latour (1999) and Pickering (1995) a constant interplay and intertwinement between science and society work together in the creation of ideas to understand the world – and bring an end to science wars.

4.3 Choices regarding the construction of the themes

This section provides information regarding the construction of the themes. Creating frames also creates boundaries – artificial, but real in their ways of affecting what can be seen and what cannot. Through taking an approach where broad, flexible continua (i.e. themes) were used, I aimed for an all-encompassing framework. No perspective would have to be excluded. Decisions simply had to be made regarding the choice of drawer. However, selections are always made. In this case, through excluding things that I simply have not encountered, things I have not understood or things that

have not spoken to me. Therefore, it is difficult to make a truthful description of all the things that have *not* been accounted for – it is hard to view beyond one’s own paradigm.

The decisions regarding what to highlight in the theme descriptions have been made in light of current positions in science education research. I have chosen not to include my own perspective on these issues (if/when I have one), since I argue that what is of main interest for science education is that opportunities are created for thorough discussions and the twisting and turning of perspectives. Even though there is no need for teachers to be neutral in these questions, it does not mean that the teacher’s perspective should be the only topic for discussion. Thus, I concur with Matthew’s (1998; 2012) argument that science education should not mean indoctrination, but that there should be critical discussion. Matthews (1998) further argues:

It is unrealistic to expect students or prospective teachers to become competent historians, sociologists, or philosophers of science. We should have limited aims in introducing epistemological and nature of science questions in the classroom: a more complex understanding of science, not a total or even a very complex understanding. (p. 168)

Matthews further claims that it is “commonsense pedagogical practice” that students “have to crawl before they can walk, and walk before they can run” (p. 169) and therefore, they should not have to deal with complex questions. Matthew’s position, although from another perspective, concurs with positions put forward by Lederman et al. (2014) and Abd-El-Khalick (2012ab), who argue that complex controversies are irrelevant to compulsory school science education (i.e. K-12). I partly disagree. Although choices necessarily have to be made, and these are influenced by a multitude of factors (see section 2.1), the perspectives that are offered to the students need to be scrutinized. Even if expectations and aims ought to be limited, teachers and students could both have an influence on the choice of perspectives. Hence, even if everything cannot be taught, it is neither necessary nor just to exercise censor-

ship through withholding certain issues from the students, but instead allows for the discussion and questioning of controversial issues.

Complex issues, diverging perspectives and different contexts might be a rich source for interest and meaning making (c.f. van Diljk, 2011; Hodson & Wong, 2017). Opening up for a more “pluralistic science education” could mean that taken for granted images and perspectives of science are avoided (Hansson, 2017). These thoughts concerning opportunities for reflection on multiple perspectives are what guided the construction of the themes.

5 METHODS – MAKING TEACHERS’ VOICES COUNT IN NOS RESEARCH

As is clear from the previous chapters, the research field of NOS in Science Education is a field with strong ideological concerns – at times bordering on black and white positions in a NOS teaching war. This thesis does *not* seek one-sided truths about NOS teaching, but the nuances of practicing teachers’ diverging perspectives on matters that have previously often only been framed by researchers. In studies where teachers’ perspectives actually have been highlighted they have often been described in relation to pre-determined adequacies of NOS understanding and NOS teaching.³⁴

The aim of this thesis is to gain insight into teachers’ perspectives on the role of NOS in science teaching. This has been carried out through a longitudinal approach and with the use of multiple methods. Although researcher-teacher collaborations have been described in the literature (see section 3.1.4), teachers have seldom had the opportunity to challenge and inspire each other in recurrent discussions on NOS teaching. This chapter provides an overview of choices and considerations regarding participants, study design, and methods. Design and methods are discussed in relation to benefits and deficiencies, as well as ethical considerations. The chapter ends with an overarching description of the analytic procedure.

This research project adheres to the ethical guidelines of the Swedish Research Council (2014, codex.vr.se). Principals and

³⁴ Some exceptions are described in section 3.1.4

teachers were informed about the aim of the project, that the schools and their participation would be treated confidentially, that data generated in the project would be used and presented in research contexts, and that they could chose to end their participation in the project at any time (i.e. guidelines regarding information, consent, confidentiality and utilization). Detailed ethical considerations are discussed in relation to each approach in the following sections.

5.1 Participants

During spring 2012, principals and teachers were contacted and teachers were asked to answer a questionnaire (VNOS-C, Lederman et al., 2002) that would serve as an introduction to a research project about science education. From the 39 teachers who agreed to answer the questionnaire, twelve (two groups) were asked to take part in the continuation of the project (Table 1 provides details about the participants). The choice of teachers was based both on trying to cover experiences that spanned the entire compulsory school (years 1-9) and on practical possibilities to arrange meetings for everyone involved.

The first group of teachers belonged to a school where the principal wanted all six science teachers to participate. However, this group left the project after two years,³⁵ which meant that the data from this group was not used in any analysis apart from the first article (which was based on the initial questionnaires and interviews). The other group stayed on for the entire project and was formed by teachers who taught at four different schools (albeit half of the teachers belonged to the same school). All but one had long teaching experience, i.e. 10 years or more. All participant teachers had permission from their headmasters to participate and spend time in focus group meetings during regular meeting/conference time, when possible. No extra time or other compensation was provided.

³⁵ That it was not the teachers' own desire to be part of the project could be one reason why this group did not manage to stay for three years (in combination with time constraints that were amplified when they had to also take part in a professional development project).

In the group of teachers that stayed on for the entire project, one of the teachers, Mary, was no longer teaching science after two years in the project and so she left the group. The teacher who replaced Mary in the focus group from the beginning of year three was Emma. This decision was based on ethical considerations since it would be inappropriate to exclude one of three science teachers at a school from taking part in ongoing collegial discussions. Furthermore, Emma's and Mary's voices have not been excluded from any of the analyses since they were part of shaping the discussions and contributed to negotiations in the group.

Table 1. Information about participants.

Pseudonym	Years in teaching*	School	Teacher education aimed at
Group 1			
Bob	37	A	Years 4-6, General middle school
Lynn	11	A	Years 1-7, Science, Math
Midge	16	A	Years 1-7, Swedish, Social-sciences
Mike	4	A	Years 7-12, General science
Tom	8	A	Years 4-9, Science, Math
William	2	A	Years 7-12, History, Environmental knowledge
Group 2**			
Agnes	16	B	Years 1-7, Science, Math
Carolyn	32	C	Years 4-6, General middle school
John	15	D	Years 4-9, Science, Math
Ella	17	E	Years 1-7, Science, Math
Emma	14	D	Years 4-9, Science, Math
Mary	8	D	Years 1-7, Science, Math
Nina	10	D	Years 4-9, Science, Math

* At the outset of the project

** Group 2 is the group that remained throughout the project

There are large differences in the educational backgrounds among the participating teachers. All participants had received a teacher education (in Sweden there are no science degrees beforehand), but the amount of science courses within the teacher education pro-

grammes differ. Two of the older teachers (Bob and Carolyn) had general teacher educations for all subjects taught in years 4-6. The younger teachers had teacher educations with a mathematics and science profile aimed at years 1-7 or years 4-9. There were also two participants (Midge and William in the group that left the project) with no science courses in their teacher education, but who taught science anyway.

5.2 Project design, approaches, and reflections

Previous research has shown that it takes time to come to grips with NOS. In the present study, the time aspect was taken into account when deciding on a longitudinal approach. Hence, teachers were provided time to explore NOS from different angles and their reflections and negotiations over time could be examined. Although what someone says does not necessarily correspond to that same person's inner views or actions, an understanding regarding contexts and different patterns of speaking can be gained from listening to and analyzing what, and how, things are talked about (Whinter Jørgensen & Philips, 2012).

By using different ways to access teachers' perspectives (questionnaires, interviews, and focus group discussions), possibilities were created to explore perspectives expressed in different contexts. Hence, as previously emphasized, the use of multiple sources and approaches is not intended as a way to provide one singular truth about teachers' perspectives on NOS teaching in compulsory school. Instead, it is a way to gain a more complex and multifaceted understanding of teachers' ways of talking about and making meaning of NOS teaching. Tracy (2010) uses the term "crystallization" as a way to describe the credibility of a qualitative research study. In crystallization, different facets of a problem are explored through the use of various sources, methods, and viewpoints; thus, gaining an in-depth understanding of the issue. She compares crystallization and triangulation as "two practices that align in craft but differ in paradigmatic motivation" (p. 843). She argues that

where triangulation “assumes a single reality” (p. 843),³⁶ crystallization seeks more complex understanding:

Different methods, data, or researchers often do (and perhaps should) yield different results. For example, research participants may espouse very different values in interviews than the values they enact in contextual interactions—with both sets of data being equally “true”. (Tracy, 2010, p. 843)

Through including elements in the project, such as teachers planning and implementing NOS teaching in their classrooms, the discussions were connected to first-hand experiences. The outline of the project is described in Figure 2 and the different parts of the project are described in detail below. A summary of all data is provided in Table 2.

Table 2. Overview of data used in the articles.

Data	Data units	Area of use
VNOS-C questionnaire	12	Analyzed in Article I
Follow-up interview	12	Analyzed in Article I
Focus group transcripts	12	Analyzed in Articles II, III and IV
Observations teaching sequence (year 1)	1	Background understanding for researcher
Observations teaching sequence (year 2)	1	Background understanding for researcher
Observations of implementation of Activity 1 (contextualized)	4	Backdrop to focus groups (Context for Articles III and IV)

³⁶ A reality that gains credibility through the use of multiple sources of data or researchers and reach the same conclusion.

Observations of implementation of Activity 2 (decontextualized)	4	Backdrop to focus groups (context for Articles III and IV)
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Fig. 2 Project design

5.2.1 Using VNOS as a research instrument

The VNOS-C questionnaire (Views of Nature of Science) was an early starting point in the present project and constituted part of the empirical material in Article I. It is an open-ended questionnaire developed by Lederman and colleagues (Lederman et al., 2002). The questionnaire has been used in several international research projects (see Lederman, 2007) in order to obtain information on teachers' views about NOS. The questionnaire has often been used as a tool for judging whether a person's views of NOS are adequate or not (a recent example is Bell et al., 2016). In the current project the questionnaire has been used for partly, if not wholly, different purposes and analyzed from a different starting point (described below). The questionnaire, which was translated into Swedish, consists of 10 questions, some of which are strongly context bound while others are more general (Swedish translation in Appendix A).

One purpose of using the questionnaire was as a first step towards understanding teachers' different "ways of talking" about NOS (see Article I). Another purpose was to find participants who would be willing to participate in the planned research project. By answering the questionnaire they could see a first idea of what they agreed to be part of. Moreover, the questionnaire provided a brief overview of the kind of issues that NOS could deal with, which was important for the possibility to ask questions about the *teaching* of NOS in a follow-up interview (the follow-up interview is described in the next section). The teachers used between 40 to 60 minutes to answer the questions.

As various VNOS questionnaires have been widely used in research studies for more than a decade (Allchin, 2011; Lederman, 2007), there has been enough time for rigorous evaluation and criticism (see Allchin, 2011; Guerra-Ramos, 2012). As the VNOS instruments are connected to "the tenets", the critique is entangled with the critique of these tenets (see section 3.1.1). Thus, as mentioned previously, one important part of the critique has to do with the broad and general nature of the questions,³⁷ which, as argued

³⁷ The general nature of the questions is related to the broad and general nature of the tenets coupled to them.

by Allchin (2011) and Schizas et al. (2016), does not leave room for exploring important differences among various scientific disciplines or context bound specificities. Furthermore, Allchin (2011) calls VNOS a “post-Positivist manifesto” (p. 526) and argues that it expresses dogmatic ideas of what is wrong and right in a debate that, in fact, has deep philosophical and sociological roots. This leads to the indoctrination of certain beliefs instead of fostering an understanding of how, for example, trustworthiness in science can be examined.

In Article I, the above-mentioned problems were counteracted by broadening the scope of the questions in follow-up interviews.³⁸ Secondly, the aim of this thesis (and the articles included in it) was not to find singular answers or judge responses and statements as adequate or not, but rather to explore and try to understand different perspectives. In Article I, teachers’ answers to the questionnaire are related to a continuum of ways of talking about NOS ranging from one extreme to another.

There is a need to ethically consider that several of the teachers in this study expressed that they felt uncomfortable answering something that they considered to be a test of their professionalism. They clearly did not believe the statement at the beginning of the questionnaire:

There are no “right” or “wrong” answers to the following questions. We are only interested in your opinion on a number of issues about science. (VNOS-C Lederman et al., 2002)

In this thesis judgements of right and wrong have been avoided. Instead, the answers from the questionnaire have been analyzed for teachers’ ways of talking about NOS and NOS teaching (see Article I for an elaboration). When I, during the follow-up interview, asked one of the participants if he thought that these kinds of questions could be interesting or valuable to discuss, he said: “well,

³⁸ Follow-up interviews are suggested in Lederman et al. (2002) as a way to further establish the categorization of answers as naïve or informed. However, in Article I, the interviews are used as a way to create further possibilities to twist and turn the questions and thus provide a more complex picture.

when I answered them I just felt panic and what the heck is this, but if you kind of, well... I guess it could be interesting to ponder about it.” Answering questions can of course be something that the participant experiences as uncomfortable. However, avoiding the uncomfortable can mean missing out on productive ways to start reflections and negotiations. The above quotation shows traces of both challenges and opportunities regarding the questionnaire.

Moreover, there is a risk that the “test-format” of the questionnaire deludes people to answer in a way that they believe is what the researcher asks for: something that resembles what they recognize as traditional school knowledge about science – that is, an ideal picture of science as absolute facts and truths. However, in a different situation, for example in interviews or focus group discussions, where the teachers presumably feel less anxious, contradictory ways of talking about NOS can be observed.³⁹

5.2.2 Follow-up interviews as a complement to the questionnaire or something completely different?

The twelve teachers who, after the questionnaire, agreed to participate in the project took part in a semi-structured (Kvale, 1997) follow-up interview. The interview was part of the empirical material in Article I. It served as a complement to the questionnaire in exploring teachers’ ways of talking about NOS. Moreover, it was a first step towards developing an understanding of teachers’ perspectives on the role of NOS in relation to the Swedish National curriculum and science teaching (i.e. how do compulsory school teachers talk about the teaching of different aspects of NOS?)

The interviews lasted between 30 and 70 minutes and were conducted up to four months after the questionnaire was completed. All participants had access to their formerly written answers. The teachers were asked to elaborate on their answers from the questionnaire in new contexts and with more examples. Hence, general questions and answers could be contextualized and exemplified, and more precise and context specific questions and answers could be posed in other contexts and/or more generalized. This approach

³⁹ Some of the considerations mentioned here are probably not exclusive to the VNOS-questionnaire, but would relate also to other open-ended questionnaires.

provided possibilities to explore multiple perspectives and became a further way to counteract the critique against the VNOS questionnaire.

In the second part of the follow-up interview the teachers were asked to talk about their opinions on what, why, when, how and for whom different NOS aspects/themes should be taught (or not taught). The interview guide for this part of the interview is available in Appendix B. All interviews were digitally recorded and transcribed.

It has been claimed that the questionnaire should be followed by an interview for at least 25 percent of the participants (Lederman et al., 2002). However, as participants often present very different standpoints in different contexts, where one can be as true as the other (Tracy, 2010), I argue that an interview with as many as possible of the participants is favourable in order to gain insight into the multiplicity. In the present study, the decision to interview all 12 participants was crucial for more than one reason. First, many of the participants claimed during the interview that they had never thought about these kinds of questions prior to answering the questionnaire (the same notion was expressed by the scientists in Wong & Hodson, 2010). Secondly, compared to previous studies, the present study had an altogether different purpose of eliciting multiple perspectives on each question as well as coupling these perspectives to teaching. Thus, both the questionnaire and the follow-up interview triggered ideas about what NOS issues could revolve around, which was needed before asking questions about the *teaching* of NOS.

However, it is important to be aware that in any interview or questionnaire what we get insight into is what the participants are willing to share at that particular time and context. Furthermore, the way questions are posed and the way the interviewer acts may also influence the participants (see Robson, 2011).

5.2.3 Focus groups

Questionnaires and interviews were only a starting point for this longitudinal project. The next step was to create possibilities for teachers to explore NOS and NOS teaching, and negotiate mean-

ing between themselves. Focus groups were chosen for the purpose of gaining insight into teachers' perspectives and transforming perspectives, as they gained experience from taking part in activities and discussions in the focus groups. Morgan (1997) "broadly defines focus groups as a research technique that collects data through group interaction on a topic determined by the researcher" (p. 6), In the current project the way of using focus groups also resembles what Wibeck (2010) describes as "participatory research". In participatory research, there is not just one meeting, but several focus group meetings taking place during a period of time. The purpose of the meetings is twofold: the researcher can gain insights into participants' views and experiences on a certain topic, while for the participants a learning process is triggered.

The focus group meetings (N=12) were more or less evenly spread over three years. Each meeting lasted for two hours and was carried out during the participants' working hours (with temporary exceptions for some participants). In connection to the meetings (before or during) participants were often provided with some working material (see Appendix C). The material consisted of short texts to read beforehand or tasks to work with during the meeting. Working material in the focus group function as a way to stimulate discussions (Wibeck, 2010). The framework that was described in a previous chapter (4) provided structure for some of the meetings. When the themes were used in the focus groups they often took the shape of short headings that could guide the discussions. Moreover, these headings were not put forward as continua, as in the framework, but more as short statements that the teachers were invited to discuss. However, it was made clear that a heading was only a label on a theme that had the potential to be filled with any issue the participants wanted to discuss. Some focus groups were planned and devoted to one or more particular themes (i.e. focus group 1 and 2, year 1, see Appendix C), and the texts that were written as inspiration for these discussions were also guided by the themes (see Appendix D, E & F). In some of the focus groups the themes were used as a guide for the discussions when teaching examples were analyzed, activities were planned or the teachers discussed NOS progression in compulsory school (analyzed in Article II).

An important part of the material that stimulated the focus group discussions was the planning of activities (briefly described in the next section) and the classroom implementations of these activities. All discussions during meetings were digitally recorded and transcribed. An overview of topics and material used in the different meetings is available in Appendix C.

The main strengths of using focus groups is that the interactions in the group create the data. These interactions can produce information on consensus and diversity, as well as insights into “complex behaviors and motivations” (Morgan, 1997, p. 15; Robson, 2011). Such information has been discussed as tensions in the articles included in this thesis. However, a weakness to consider is that the social interactions in the group can constrain the participants and their willingness to share their ideas (consensus-tendency) (Halkier, 2010; Morgan; 1997). This should, if possible, be considered when deciding who will take part in the group (which was not possible in the present study). Moreover, during the meetings the moderator has to take responsibility to make room for all participant voices. In the present study, some of the participants in the focus group knew each other well and had been working together for a long time, while others had never met prior to the first meeting. However, all of the participants were experienced teachers, were willing to share ideas and did not hesitate to question each other.

It is unavoidable that the moderator influences the actions of the group (Morgan, 1997; Wibeck, 2011). Influence through, for example, directing the focus towards certain topics is part of the definition of a “moderator”. In this project, the moderator also made decisions that caused teachers to plan and implement NOS sessions in their classrooms, which also affected teachers outside the meetings. Furthermore, the researcher indirectly influenced the group in the choices made concerning texts, tasks, and examples. In this case, efforts were made to produce texts where multiple perspectives would be visible (for example, using questions and prompts for reflection instead of declarative statements), and also to use tasks from many different sources. The participants were always given time to reflect upon and question the provided material. The

short texts were produced to be used during the first year (see Appendix D, E & F). They caused special concern as they had to be short (the teachers were promised they would never have to read more than three pages prior to a meeting),⁴⁰ they had to be understandable to someone who had not been asked to ponder about these questions before, and they had to be if not neutral, at least able to provide different viewpoints. The headings in the texts were based on the tenets (Lederman, 2007), but much of the content was formulated as questions open to reflection.

5.2.4 The activities

There is also reason to provide some information on the activities that the teachers planned and implemented, as they contributed with first-hand experiences on NOS teaching and constituted an important backdrop to the discussions during years two and three. As such they are important in order to understand how teachers discussed and made meaning of NOS in their teaching. The two activities were very different in nature. They did not only address different aspects of NOS,⁴¹ but were also at very different levels of contextualization (Clough, 2006; also see section 3.1.3).

For the first activity, the teachers cooperatively decided on format, learning outcomes, and specific NOS aspects that they wanted to highlight. This led to the development of a highly contextualized activity; students read news articles and information on websites about sugar and sweeteners (in grade 6) or energy drinks (in grade 8). The activity was implemented in two classes in grade 6 and two in grade 8. The duration of this activity was between 3 (grade 8) and 8 (grade 6) lessons. During and after the reading the teachers guided students through NOS reflections related to the texts. In these discussions, the teachers had decided to focus on sociocultural and subjective issues. These issues were, by the teachers, discussed as “underlying factors” (e.g. disciplinary background knowledge, personal interests and values, and political, economic or ideological interests). The discussions were followed by students taking part in debates or writing an argumentative text. In this part

⁴⁰ Reading more would require too much of their time.

⁴¹ Article IV includes information concerning NOS issues related to each activity.

of the activity the students were also expected to reflect on how sociocultural and subjective issues affect science. In grade 6 the debate was followed by the planning and performing of an investigation on the sugar/sweetener topic. The investigations were followed by NOS discussions.⁴²

The other activity was a much less contextualized black-box activity, adapted from Wickman and Persson (2009), which had been formerly shown to the teachers in the focus group. The duration of this activity was 1-2 lessons. The students were asked to come up with ideas for how the black box was constructed and later present and argue for their suggestions in front of the class. By putting students to work first individually, and later in groups, the teachers made it possible to discuss the impact of collaboration and how we can be affected by individuals around us. The teachers initiated NOS discussions both during the group work and at the end of the activity in a whole class context. They described the main focus during these discussions to be concern around how knowledge can be constructed from observations; the role of creativity in investigations and interpretations; how a person's status affects who you listen to; and how previous knowledge and expectations can affect your interpretations.

5.2.5 To be an observer in the compulsory school classroom

Two kinds of observations were made during the project. The first took place during the first and the third years and included the observation of all lessons during an entire teaching sequence. In this case the teaching sequence was meteorology. Nina taught during both occasions and no specific NOS discussions were planned in advance. The data from these observations have not been used in any part of the analysis, but serve as a way to become acquainted with what science teaching could be like in this particular teacher's classroom.⁴³

⁴² A detailed description where the implementation in grade 6 is presented as an inspirational example will be available in a forthcoming book chapter (Leden & Hansson, forthcoming).

⁴³ A teacher from the other focus group, Lynn, was also observed during the first year.

Other types of observations took place during years 2 and 3 when the teachers implemented the NOS activities described in the previous section. Four teachers were visited during each activity (see Table 3).⁴⁴ The observations became an important scaffold for me when I listened to the teachers' reflections on their teaching sessions in the focus groups. Even if these observations were mainly used as a backdrop, they were still important for my understanding of how plans were transformed into very different kinds of teaching situations in the various classrooms. The observations helped me develop a more robust insight into these particular teachers' classroom practices and generate a feeling for how students at different ages were approached in NOS discussions.⁴⁵ One way of getting to know more and/or something else about the events that actually took place in the classroom is to make observations. "You do not ask people about their views, feelings or attitudes; you watch what they do and listen to what they say" (Robson, 2011 p. 316). My role as a researcher was made clear in every classroom: (a) I was there as a researcher, (b) my main focus would be on the teacher and not on the students, (c) and as long as the teacher spoke I would remain seated and take field notes. The teachers were audio recorded through a microphone attached to their clothes.

However, even if the main purpose of the classroom visits was to listen to and observe the teachers in their NOS teaching, it was often necessary to take some note of what the students said in order to be able to relate this to the teachers' ways of responding or speaking. Thus, all students and students' parents were informed beforehand about my visits to the classroom. When the students

⁴⁴ All teachers who implemented the activity were visited in their classrooms. The first activity was implemented by four of the teachers. Of the remaining two teachers, one did not teach science at that time and the other had just started teaching at a new school with very young children (age seven). Regarding the second activity (i.e. the black-box activity), one teacher was so inspired when it was first given as an example that she immediately brought it to all classes in her school during a science day (this was a year before the others planned the implementation). The other teacher who was not visited was the same as in the first case. This time no particular reason was provided, which might imply that she felt uncomfortable with the idea of being observed in her classroom.

⁴⁵ However, field notes from Ella's and Carolyn's classrooms constitute the data for a book chapter, but is not included in this thesis (Leden & Hansson, forthcoming).

were working, we had an agreement that I could walk around in the classroom and look at the tasks they were working on. Although my role was as a researcher, when students asked for help with, for example, understanding an instruction or a word in a text, I offered help if appropriate (i.e. not interrupting the teacher’s aims of the lesson).

Table 3. Summary of observations of implemented NOS activities.

Activity	Teachers	Grades	Number of observed lessons
Contextualized	Carolyn	6	5
	Ella	6	5
	John	8	2
	Nina	8	2
Decontextualized	Ella	4	2
	Emma	7 (two classes)	2 + 1
	John	7	1
	Nina	7	1

5.3 Concluding ethical considerations: To record and write about teachers

Claiming to give voice to teachers is not a small thing and it could easily be interpreted as hubris. As teachers’ voices are not presented as raw material, the researcher becomes an interpreter and spokesperson of teachers’ perspectives. The way I make use of the teachers’ voices and the ways I combine different voices into themes of ways of talking, rationales, tensions or areas of concern are constructions from my interpretations. Making such constructions after having had the privilege to visit classrooms and to gain access to teachers’ valuable time gives rise to considerations on how to write it up. The writing can either consolidate or problematize traditions (Tracy, 2010) and can also cause the participating teachers to feel that an untrue picture of their reality has been constructed. Furthermore, it is important for the writer to carefully consider how results are presented and then envision how they can

be read as a way to avoid “misreading” (Tracy, 2010). In writing the articles of this thesis I have attempted to make different perspectives visible, both perspectives that align well and others that are contradictory. My intention has been to illustrate that there are multiple ways of talking about NOS and NOS teaching, and that none of the teachers in this study use only single ways of talking or of relating to their teaching practice. They all contribute to the joint discussion of which I have had the privilege to take part. Through such an approach/illustration a deficit picture is avoided and the focus can be directed towards tensions and opportunities instead. On some occasions, as in Article II, I had the opportunity to return to the focus group with my preliminary analysis and ask for reactions and elaborations – such a procedure can render a greater sense of ownership to participants. An ethical dilemma of writing, or in other ways disseminating results from a project of this kind, is that the teachers have made such a huge contribution, but still do not see public recognition due to ethical considerations regarding confidentiality.⁴⁶ A specific benefit of a longitudinal study is that you are always able to come back to the group and ask for clarifications, and the experience of getting to know reoccurring themes or specific issues that are particularly dear to the participants. In other words, you get to know the teachers you work with. This can certainly be beneficial, since participants may relax and open up for more controversial discussions. However, a more relaxed state can also make them forget that you are doing research, which might lead them to reveal more than they would actually care to share. Therefore, what is important to write and what should be left out need to be considered. The choice could also have been made to emphasize differences between the individual teachers or groups of teachers, which would have led to other ways of presenting results and presumably other conclusions.

The intention to make use of teachers’ voices made it necessary to record them in interview situations, in focus groups and in their classrooms. All teachers generously gave their permission to such

⁴⁶ This is a dilemma to which I have no solution, but a suggestion is that efforts should be made to thoroughly twist and turn different alternatives for ethical guidelines connected to different research contexts and forms of collaboration.

recordings. Some of the teachers told me that, at first, they felt quite uncomfortable being recorded, but that they forgot about it after only a short while. After a couple of times being recorded they said they did not even think about it anymore. However, on some occasions, when the discussions were tempered, a teacher would look at the recorder and make a comment about inappropriate words now being saved for the after world.

5.4 Multiple roles of the researcher

Sincerity is an important aspect of qualitative research and can be achieved through self-reflexivity and transparency (Tracy, 2010). In the previous sections, I have made an effort to be transparent about the different parts of the research process by discussing choices, strengths, and weaknesses. This section is devoted to my own role in the project (self-reflexivity).

In this project I have, to say the least, had multiple roles. I have handed out questionnaires, been the interviewer in individual interviews, been the moderator in all focus groups, and been the observer in many of the teachers' classrooms. At the same time I have been the one who decided on the kind of material that should be used in the focus groups. While having all of these roles I have also been the one to write about it all. These multiple roles could be troublesome. Firstly, it could be troublesome for the participants who have met me in so many roles and who have had to develop some sort of trust in me. Trust that is needed in order to talk more or less freely in the focus group discussions, and feel, at least partly, comfortable with having me in their classrooms, and in addition knowing that I would write about it all. Secondly, from the point of trustworthiness, it could be troublesome since being part of the design, carrying out the different steps of the study, as well as analyzing and writing it all up causes the different parts to become tangled. At the same time, being tangled strengthens the possibility of gaining deep understanding of teachers' perspectives in various situations, making room for nuances and avoiding simplified truths.

5.5 Analysis and points of departure

This section provides an overview of practical procedures of the analysis, such as transcribing. It also presents underlying perspectives and overarching features that have been guiding the analysis.

5.5.1 Transcribing

All interviews and focus group meetings were recorded and transcribed. Although time consuming, the act of transcribing provided an important insight into the data. Even though first impressions were made when the actual interview or focus group took place, these preliminary interpretations became clearer during the transcribing. Thus, transcribing provided ideas and an introductory shape for the analysis. In the first transcripts everything was transcribed verbatim, even small talk about the “fika”. However, in the later transcripts parts of conversation that clearly did not deal with the topic of this thesis were left out of the transcript in order to save time. Such parts were marked with the time and what the discussion was about. Even if the focus had never been on the individual teacher, the initials of the speaking teacher, or “M” for moderator, were noted in the transcript in order to make it easier to follow the discussion. Pauses were marked with “...” and sometimes commented as “long pause”. Sounds like laughter, moaning or giggling were also noted. These markers helped later on for me to remember the tone of the conversations, which was also a help in the analysis.

5.5.2 Analyzing teachers’ perspectives through their “ways of talking”

As this thesis tries to develop insights into teachers’ perspectives on NOS teaching, teachers’ ways of communicating their perspectives become imperative. The position used in this thesis is that it is not fruitful to try to access a person’s inner views (Potter & Wetherell, 2007; Winther Jørgensen & Philips, 2012), but instead listen to the way people express opinions. The things that are said can then be analyzed for patterns and themes. All communication is a form of social interaction, “our talk and writing do not live in some purely conceptual realm” (Potter & Wetherell, 2007, p. 9). This means

that even if the communication takes the form of answering a questionnaire (analyzed in Article I), the respondent is aware that there will be a reader/receiver at the other end and that this reader will draw some sort of conclusions from the responses (ethical considerations related to this are discussed in section 5.3).

In all communicative action the purpose is to create some sort of understanding and in this creation some things will be taken for granted (Linell, 1982). Thus, there is a risk of tacit consensus on understanding that could lead to certain topics not being thoroughly debated. In this study, such consensus can appear among the participants, but also among participants and the researcher – some things are taken for granted, and even more so after several meetings. In order to be able to gain deep understanding of the teachers' ways of talking, I attempted to ask questions about things that appeared as taken for granted. One example is provided in Article II when the teachers repeatedly talked about teaching at different levels by saying that "it gets deeper and deeper".⁴⁷

The perspectives and identities that become visible are shaped through interaction with traditions and cultures of school science teaching and the surrounding discourses regarding goals and approaches that are connected to these traditions (c.f. Roberts, 2011; Aikenhead, 2006; Bartholomew et al., 2004; Höttecke & Silva, 2011; Zacharia & Barton, 2004). This is the reason why research on traditions and goals constitutes such a large part of the background chapters in this thesis. As previously mentioned, the analyses have mainly focused on teachers' negotiations, contrary to statements made by individual teachers.⁴⁸ It is through analyzing the ongoing conversations (i.e. negotiations) that the interactions and tensions in relation to traditions become visible.

All four articles included in this thesis were based on qualitative content analysis (Kvale, 1997) of teachers' communications.⁴⁹

⁴⁷ There is always a risk that these questions have not been asked enough times and some of these times might become apparent first when the transcripts are written or even later during the analysis.

⁴⁸ Article I is an exception to this analytical pattern, since part of the analysis dealt with patterns regarding individual teachers' ways of talking about NOS.

⁴⁹ In Articles I and II other references and ways of describing the analysis were used. However, it is fair to say that a qualitative content analysis has been employed in all four articles.

Qualitative content analysis is defined as “a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns” (Hsieh & Shannon, 2005, p.1278). It has a focus on “communication with attention to the content or contextual meaning of the text” (Ibid., p. 1278). The analysis begins by trying to gain a sense of the whole material by repeatedly going through it (Hsieh & Shannon, 2005; Robson, 2011).

In the present thesis, all coding was made on written material in the form of transcripts with one exception.⁵⁰ A content analysis here means that questionnaires, transcribed interviews and transcribed focus group discussions have been scrutinized through the screen of the researcher’s eye. A detailed description of the analysis procedure is available in each article. However, an overarching description for all articles as well as a description of different points of departures for each article is provided here.

Hsieh and Shannon (2005) describe three approaches to qualitative content analysis (directed, conventional and summative), all of which are employed in this thesis. More than one approach is also used in each article:

- *Directed content analysis* uses predeveloped categories that are guided by existing theory (Articles I-III). Thus, this kind of analysis can strengthen or deepen our understanding of previous research in the area (Hsieh & Shannon, 2005; Robson, 2011). A limitation is that important things that fall outside the theoretical framework leads the risk of going unnoticed.
- *Conventional content analysis* searches for patterns and categories in the data without using preconceived categories (Articles I-IV). Through reading and re-reading the transcripts, categories and sub-categories are developed at different levels. In the present case, the categories were never fixed at once, but rearranged and changed several times. A challenge with this approach might be that the researcher fails to develop a complete understanding of the context or fails to identify key categories (Hsieh & Shannon, 2005). A benefit

⁵⁰ The VNOS-C questionnaire (Lederman et al., 2002) that was analyzed in Article I.

of this procedure is that patterns not expected in advance can be explored.

- *Summative content analysis* can be used to gain insight into changes over time (Article III) and frequencies related to, for example, recurring ways of talking (Article I).

The aim of Article I was to gain insight into teachers' perspectives on NOS and NOS teaching through studying their ways of talking. The data consisted of answers to the VNOS-C questionnaire (Lederman et al., 2002) and a follow-up interview where didactical questions were also asked. This means that the teachers, in this part of the study, were less likely to speak freely about what came to mind than in, for example, many of the following focus groups. That is, the ways in which they could answer had stricter frames in this part of the study. The analysis was also, at least in its first part (directed content analysis), strictly framed within the NOS themes. Thus, the participants might have had other things to say about NOS if another framework (or none) had been used. However, at this early stage of the project tighter boundaries might be relevant due to the teachers' unfamiliarity in relation to NOS. It is also relevant for discerning new ways of approaching the analysis of the VNOS questionnaire. Through the second part of the analysis (conventional content analysis) new patterns could be found within the themes.

Article II analyzed teachers' suggestions for a compulsory school NOS progression. The analysis was based on transcripts from two focus groups at the end of the project when the teachers had gained experience from discussions and NOS teaching. Similarly to the first article, it was based on strict frames for teachers' talk and thus partly placed external boundaries on their possibilities to express themselves. The limits here are based on specific directions for their discussion to be about *what* NOS⁵¹ should be taught at what stage (i.e. *when*, during compulsory school). The first part of the analysis used the themes as a tool for categorizing the teachers' suggestions.

⁵¹ The selection of NOS issues was related to the themes discussed in the focus groups during the three years. However, the themes had not been given to the teachers as end-products, as they had been part of creating what the themes meant to them.

During the second part, the transcripts were analyzed for teachers' rationales in relation to their suggestions.

Article III studied teachers' perspectives on opportunities and challenges related to the teaching of sociocultural and subjective aspects of science. The analysis was based on transcripts from all focus groups. It comprised varying forms of discussions, strictly framed as in Article II, as well as more loosely directed towards a broad topic (e.g. reflections on the implemented activities).⁵² Even if teachers at different times had been asked about challenges and opportunities related to NOS teaching, as well as asked to talk about NOS teaching in relation to specific themes, some topics were implicit and explicit parts of discussions across focus groups. The analysis in Article III was thus based on very different kinds of discussions dealing with a variety of topics, which only gave direction to the analysis after all transcripts had been read repeatedly. Here, I made analytical decisions based on a research gap.⁵³

The analysis in Article IV was based on insights made in the previous articles. Articles I and II pointed to the importance of already existing patterns of teaching traditions. From the analysis in Article III these patterns became even clearer and called for an analysis of its own – Article IV. The data for this article were based on focus groups (N = 5) that dealt with planning and reflection on NOS activities (see section 5.2.4). This choice was based on the ongoing debate in the research community about what might be the best approach to NOS (contextualized or de-contextualized). Hence, the different types of activities became the frame for an analysis where the transcripts were explored for resistance or alignment between the activities and existing teaching practices. Here, the “mangle” (Pickering, 1995) was used as an analytical tool.

It needs to be pointed out that in all articles, *my* choices and not the teachers' (at least not explicitly) have guided the analysis. However, my choices were guided by what I noticed to be recurrent themes, consensus topics and ongoing controversies. This way my choices were guided by what I interpreted as being significant

⁵² Note, however, that all focus groups had some level of framing (see Appendix C), otherwise they would not be focus groups.

⁵³ A gap related to the examination of sociocultural and subjective aspects of NOS.

issues to the teachers. Furthermore, my choices were based on questions from the research field that needed further exploration.

Articles II-IV have, partly, analyzed the same data: focus group transcripts.⁵⁴ However, different research questions have meant that the same data have been analyzed in different ways. The overarching research questions of this thesis are answered through summarizing the results from all articles (see Chapter 7). The didactical questions are used as a way to show how the teachers' constructed NOS teaching over time (from years 1 to 3). The "mangle" is then used as a tool to study how this construction aligns (or not) to existing patterns that the teachers refer to in their discussions. Thus, the analysis in this thesis connects the analyses from the various articles.

5.6 Limitations of the study

It cannot be argued that this study takes an entirely *inside* perspective on NOS teaching, since teachers' voices are interpreted in accordance with the researcher's understanding. It is, however, an effort to try to understand and make teachers' perspectives matter.

To claim that teachers' perspectives should be taken seriously ought to mean that they are included to a much greater extent in analysis and conclusions than was the case in the present study. These are aspects that I reflected on earlier in this chapter and which I return to in the discussion at the end. The study mainly builds on discussions, including a few teachers who, at the outset of the project, had no previous experience of NOS. Even though the teachers are few and belong to only a few different contexts, their voices have been interpreted from a larger context of policies and earlier research. By using rich descriptions in connection to the larger context it is possible to find similarities that concern other teachers in similar situations.

⁵⁴ Article III used all the transcripts and the other articles used transcripts from specific meetings.

6 ARTICLES

The aim of this thesis is to provide insight into teachers' perspectives on NOS teaching, and thus contribute more nuances to the research field regarding questions, aims, and approaches. Teachers' perspectives have been explored and presented in the four articles that are included in this thesis. In all articles, teachers' "talk" in questionnaires, interviews and focus groups has been the main source of empirical data. The rich data material has provided opportunities to study these perspectives from various angles.

My role in writing the articles has been as a first author in collaboration with co-authors (my supervisors). This means that I have been responsible for the main part of the work regarding design, meetings with teachers, transcription, analysis, and writing. However, the co-authors have made important contributions to all articles. In all articles, a first draft of the manuscript was written by the first author and was then further developed and discussed in collaboration with the co-authors.

- In Article I, Lena Hansson, Andreas Redfors and Malin Ideland were co-authors. Lena Hansson and Andreas Redfors contributed in the analytical process by reading and coding transcripts parallel to my own analysis as a step towards a valuable discussion and development of the analysis. All co-authors contributed through discussions on the contents and scope of the article, as well as comments on the text and format.

- Article II was co-authored by Lena Hansson who contributed through discussion of analysis and conclusions, and development of the text.
- Article III was co-authored by Lena Hansson and Andreas Redfors. Both contributed to discussions of the analysis and conclusions, and development of the text. In one part of the analysis (the third of five steps, see Article III), all three authors coded parts of the transcripts as a way to discuss possible categories.
- Article IV is still in progress and co-authored by Lena Hansson and Malin Ideland.

A summary of the articles is presented below. In this summary, the main focus is directed towards a description of data sources and results. Results from a longitudinal perspective are presented in relation to the discussion of this thesis (Chapter 7). The full articles are included at the end of this thesis.

6.1 Article I

Teachers' ways of talking about nature of science and its teaching:

This article (Leden et al., 2015) introduces the teachers who later became participants in the three-year project. Here, the teachers have no previous experience of discussing or teaching NOS. Thus, the article serves as a starting point to provide information about the perspectives with which the teachers enter the project. The article aimed to shed light on teachers' ways of talking about NOS and specific NOS aspects in relation to teaching regarding, for example, whether these are regarded as appropriate, desirable, or even possible to include in science teaching. The main rationale was that learning more about, for example, teachers' anticipated difficulties could have the potential to then understand why NOS teaching does not often become part of science teaching. Teachers' perspectives could also provide direction for teacher education courses. The point of departure was that NOS is part of the Swedish curriculum and that teachers have to deal with this, even if most of them have little training or experience of NOS teaching.

The data was based on the voices of 12 teachers who responded to the VNOS-C questionnaire (Lederman et al., 2002) and a follow-up interview. An important difference from previous studies was that the focus was not on judging teachers' answers as adequate or not, but to create an understanding of diverse ways of talking about NOS. Hence, the article contributed new ways of using an established data-collection instrument. The analysis and results further contributed by categorizing teachers' answers along a continuum of ways of talking about NOS and NOS teaching. The analysis showed that teachers drew on multiple perspectives when discussing NOS in general, but that their repertoire was more limited with regards to NOS teaching. These differences were clear on issues related to different sociocultural aspects of science, where the teachers made a great deal of statements about sociocultural NOS, but had very little to say in relation to teaching.

The results also identified that the emphasis on certain ways of talking differed for NOS in general and NOS in relation to teaching. An example from the theme "Absolute and/or tentative NOS" is that teachers often talked about NOS in general as "changing or uncertain". Yet, when talking about NOS teaching, they more commonly talked about "scientific knowledge as facts". The difficulties and advantages of NOS teaching, as put forward by the teachers, were discussed in relation to traditional science teaching. NOS was discussed as a "new" way of teaching and the teachers suggested that it could be connected to lab-work or discussions. Furthermore, the article reported on teachers' perspectives on NOS teaching in relation to different student groups. Teachers anticipated that there could be difficulties in relation to both the "good students"⁵⁵ and to students with limited language or social skills.⁵⁶ The ones who were expected to benefit from NOS teaching were the "more philosophical students" or the ones who lose interest when only required to memorize facts.

⁵⁵ Because, according to the teachers, "good students" are used to memorizing facts for the test.

⁵⁶ Here, the difficulties were related to the expected format for teaching NOS through discussions.

6.2 Article II:

Nature of Science Progression in School Years 1-9: A Case Study of Teachers' Suggestions and Rationales: The second article (Leden & Hansson, in press) aimed to shed light on in-service teachers' suggestions and rationales for what they consider to be appropriate NOS issues for different school years in Swedish compulsory school. The few previous studies that have presented detailed descriptions of NOS progression are based on theoretical constructs and/or theories concerning students' age-related abilities. In contrast, the study presented in Article II asks for teachers' perspectives.

The data for this article relied on two focus group meetings at the end of the project when the teachers had gained experience both from discussing NOS on several occasions and from implementing NOS activities in their classrooms (see Appendix C). The article presents these teachers' suggestions of NOS issues as well as their rationales for choosing the particular issues. The results show that teachers' suggestions for NOS progression often relied on adding more NOS issues at every stage, thereby creating the foundations of a broader but not necessarily deeper understanding of NOS.⁵⁷ When teachers added issues, the greatest differences could be found between years 1-3 and 4-6. This was, for example, the case for socio-cultural aspects where different world views was the only issue chosen for years 1-3, while a great variety of issues, such as economy and values, were suggested for years 4-9.⁵⁸ However, one important finding was that the teachers suggested at least some issues from all themes in the earliest years. The analysis of teachers' arguments for suggesting certain issues for certain school years resulted in the categorization of five rationales related to: students' *maturity and experience*, the need for teaching at *increasing levels of depth*, the idea that *practice makes perfect*, and the idea that any NOS issue can be taught at any stage if *choice of context* and *teaching approaches* are considered. An important finding was that

⁵⁷ Teachers did, however, argue from the point of increasing levels of depth, which was described as students' ability to "reflect in a deeper way".

⁵⁸ Teachers argued from the point of maturity and abilities for abstract thinking when choosing fewer issues for early school years.

sometimes the progression for NOS teaching was built more on varying context and approaches than on varying the NOS issues at different stages. The discussion highlights tensions between different rationales as well as possibilities and challenges to take into consideration in teacher education.

6.3 Article III

From black and white to shades of grey: A longitudinal study of teachers' perspectives on teaching subjective and sociocultural aspects of science: The third article (in review) takes a longitudinal view on changes in teachers' perspectives during the project. The article specifically focuses on teachers' discussions about sociocultural and subjective aspects of NOS and their potential to challenge black and white images of science in science teaching. In previous research, these aspects of NOS have often been less emphasized than other aspects and they have also been considered as particularly difficult and abstract to deal with, both for teachers and students.

The article analyzes *what* NOS issues teachers suggest over time, within the scope of sociocultural and subjective aspects. Furthermore, it analyses opportunities and challenges connected to including sociocultural and subjective aspects in science teaching. Thus, the focus is on teachers' ways of creating, developing, and making meaning of this theme⁵⁹ in relation to teaching. The analysis is based on the transcripts from all focus group meetings (N=12). The results of the analysis show that: (a) the number of suggested issues increased over the years, which meant that the teachers teaching repertoire regarding sociocultural and subjective issues expanded during the project; (b) the teachers' ways of contextualizing the issues changed from general and imprecise, to more tightly connected to socio-scientific or scientific contexts; (c) the number of both opportunities and challenges increased over the years. The most evident changes occurred from the beginning of year 2 when the focus group discussions became more closely directed towards concrete teaching activities. Many of the challenges can be recognized

⁵⁹ In Article III the sociocultural and subjective themes are merged into one.

from previous studies such as demands for abstract thinking and NOS as a time consuming “new” element in science teaching, where the latter has consequences for teachers’ identities. The reported opportunities can be summarized as being directed towards reaching overarching goals of science education⁶⁰ and the inclusion and engagement of more students. The discussion highlights tensions in the material specifically regarding opportunities and challenges. These tensions are further discussed as potential points of departure for science teacher education.

6.4 Article IV

The mangle of school science practice: a case study of teachers’ negotiations of NOS activities at different levels of contextualization:

The fourth article (manuscript) aims to explore how teachers fit different NOS teaching approaches (contextualized and decontextualized) to existing science teaching traditions/cultures. The question of how NOS teaching ought to be approached is much debated in the research field (see section 3.1.3). Previous studies have mainly investigated how different approaches to NOS teaching can affect students’, as well as pre-service and in-service teachers’ knowledge about NOS. However, teachers’ own ways of discerning learning possibilities, challenges and opportunities in relation to different approaches have seldom been thoroughly investigated.

The article builds on data from the focus group meetings where the teachers plan NOS activities, and share their experiences from the implemented NOS activities (see Appendix C). The “mangle” is used as an analytical tool for analyzing the teachers talk about the different approaches in relation to science teaching traditions. Through the mangle, patterns of resistance and accommodation become visible. The results show that teachers talk about science teaching as divided into three goals: learning facts, doing lab-work and developing the ability to communicate. These three goals are connected to different teaching traditions.

The contextualized and decontextualized approach to NOS teaching challenges, expands or becomes a natural part of the dif-

⁶⁰ These goals were described as directed towards, for example, developing students’ abilities to evaluate and critically examine science in the media.

ferent traditions to varying extent. Furthermore, the teachers seem to transform the decontextualized approach into becoming more contextualized. None of the NOS teaching approaches accommodate easily to “learning facts”. While, the decontextualized NOS activity becomes a way to broaden the lab-work tradition in moderate ways, the contextualized task is discussed as a way to explore a communication tradition under construction.

6.5 Connections between the four articles

All four articles deal with teachers’ perspectives on NOS teaching as they explore, negotiate and create forms for NOS teaching. Each article provides parts that are important for answering the overarching questions of this thesis. All articles contribute through illuminating and emphasizing different facets of the didactical questions: *what*, *why*, *how*, and for *whom*. Article I provides an introduction to teachers’ perspectives on NOS teaching (including all of the didactical questions), as well as on their perspectives on NOS disconnected from teaching. In Article II, *what* and *for whom* are discussed by creating suggestions for NOS progression. Article III takes a longitudinal perspective on *what* and *why* (within the scope of sociocultural and subjective aspects of science) in relation to opportunities and challenges. Teachers’ perspectives on the *how* question is scrutinized in Article IV. Even if a few facets are in focus in each article, they are always reflected and related against the others.

The articles also constitute snapshots from different times: where Article I provides a view from the very beginning of the project, Article II a view from a late point, Article IV from the beginning of the second year to the middle of the third year, and Article III provides an overview of all three years of the focus groups. To be able to understand teachers’ perspectives and ways of talking, the results in all four articles have to be reflected against traditions/cultures and goals of science education, as well as related to previous NOS research. These connections are made both by teachers themselves (in interviews and discussions) and highlighted from a researcher’s perspective in each article. The tensions, challenges and possibilities that are created due to the *mangling* of un-

common or new elements with well-known or old ones are discussed to various extents in each respective article.

The articles contribute with different and overlapping pieces, which together contribute to the field of research on NOS teaching. The teachers' perspectives provide insight into challenges, opportunities and tensions. These all have consequences for practice, which are discussed in Chapter 7.

7 DISCUSSION, CONCLUSION, AND IMPLICATIONS

This thesis deals with the “black-and-whiteness” related to NOS in science education at different levels – science teaching practices, policy debates, and science education research. Research has shown that black and white images of science often dominate science teaching. Here, science education research on NOS has taken on the quest to study how a more nuanced image of science can be created. Through this quest a gap between research and practice has become visible. Teachers’ perspectives are needed in order to explore and bridge this gap.

The thesis emphasizes the importance of recognizing teachers as professionals who, with first-hand experience and knowledge of practice, can contribute with understanding and suggestions for NOS teaching. Teachers’ perspectives are important as teachers are bordering between academic science and school science. Their reflections and suggestions are all part of a larger context of school science cultures and traditions at different levels: trends in society and media, and political and societal decision-making with an impact on, for instance, the curriculum.⁶¹ Thus, teachers’ perspectives are needed in order to provide implications for school practice, teacher education and research.

Hence, as a complement to the researchers’ suggestions concerning NOS teaching, the aim of this thesis is to explore teachers’ perspectives and negotiations regarding the role of NOS in science

⁶¹ The opinions presented in the debate article referred to in the introduction of this thesis is one small part of this ongoing discussion.

teaching. This is carried out through answering the two research questions:

- 1) What kind of NOS teaching practices are constructed through teachers' negotiations over time?
- 2) How do teachers negotiate and accommodate the constructed NOS teaching practices with overarching goals and traditions of science teaching?

As the didactical questions *what*, *how*, *why*, and for *whom* are central in the articles, the first part of the discussion is structured around these. The discussion around each didactic question illuminates:

- Teachers' suggestions (answers rq 1)
- Longitudinal changes during the project (answers rq 1)
- The resistance and accommodation between NOS teaching and already existing practices (answers rq 2)

In order to provide a broader picture and blur the artificial boundaries of the didactical questions, they are followed by a crosscutting section that summarizes tensions and challenges. These tensions and challenges form the basis for the implications and suggestions that follow the crosscutting section. The discussion ends by presenting an overview of contributions of this thesis and a concluding remark.

Previously in the thesis, the “mangle” (Pickering, 1995) has been used as a way to think about how practices interact. This chapter uses the mangle as a tool for discussing teachers' construction of NOS practice in relation to already existing practices. The mangle is not used as a heavily loaded theory of everything (Pickering, 1995), but as a metaphor that resonates with my way of thinking about practices in process. It helps illuminate accommodation, alignment, and resistance – what causes friction and what slides smoothly in place. The discussion does not provide a grand finale of answers or prescriptions, but contributes with a number of per-

spectives on tensions and opportunities that surround the role of NOS in science education.

7.1 Teachers' construction of NOS teaching (what, how, why, and for whom) in relation to existing science teaching traditions

A recurrent theme of this thesis is that the teaching of NOS is perceived as a “new” way of teaching, both with regard to the choice of topics and to teaching approaches (see Articles I, III & IV). The Swedish curriculum provides little guidance on how to approach things. Contrary to most other content in the curriculum, there are no strong teaching traditions to guide the teachers concerning NOS. The lack of traditions that surround NOS teaching (at least in Sweden: see Gyllenpalm et al., 2010a; Högström et al., 2006) makes space for adjustment in relation to existing science teaching traditions in different ways. New elements are related, negotiated and adjusted against existing patterns through selective traditions (Englund, 1986; 2005; Williams, 1973). As Williams (1973) describes it, new elements are accommodated “into forms which support or at least do not contradict other elements within the effective dominant culture” (p. 9). However, by studying teachers’ negotiations of how to make room for NOS in science teaching it becomes clear that not only the new elements are adjusted. They are accommodated together with, and in relation to the “dominant culture” – meaning a mutual tuning and transformation. Consequently, on many occasions challenges become opportunities for change and transformation.

Throughout the project the teachers talked about three directions for science teaching that were all tightly connected to the science teaching outcomes described in the national curriculum (Skolverket, 2011a; see section 1.1). These directions can be described as traditions in relation to “facts,”⁶² lab-work, and discussions” (see Article IV), where the dominant tradition is the “facts tradition”, which causes great friction in relation to NOS. The “discussion tradition” relates to various forms of written and oral

⁶² “facts” are what the teachers call a concept-based approach.

communication, argumentation and interpretation. It is an approach to science teaching which, so far, has less strict boundaries than facts and lab-work – it is a tradition under construction. It is in relation to these traditions that the didactical questions are negotiated.

7.1.1 Negotiations of NOS aspects (What?)

An initial selection of NOS issues or aspects has mostly been left to researchers, however, this has left the research field with a polarized debate (see section 3.1.1). When references have been made to teachers, they have been in relation to NOS issues observed in teachers' classroom practice. The included issues have often been compared to a norm consisting of the issues that the same teachers have been taught about in NOS courses (see Lederman & Lederman, 2012). However, teachers have seldom been invited to take part in the debate by providing their suggestions of what NOS ought to be taught. The present section adds to previous research by discussing how the teachers in this study suggested NOS issues that would be possible, relevant, and interesting to include in science teaching.⁶³

Teachers' suggestions (described below) of what NOS to teach are based on:

- Including a large variety of NOS issues, as well as ones that have been previously described as uncommon in science teaching
- Creating a progression for compulsory school by adding NOS issues at each stage
- Resistance and accommodation in relation to science concepts, students' abilities, and teachers' own knowledge

When the teachers' suggestions of NOS issues are mangled through the circumstances of the project and many years of teaching experiences, a large variety of NOS issues, connected to multiple contexts, appears. Many of these issues have been described as uncommon in science teaching. The teachers in the present study sug-

⁶³ For a specific description of issues see Articles I-IV.

gest them as a way to bring nuances to school science, where they state that science concepts claim most of the space. Here, resistance and accommodation in relation to dominant teaching practices are discussed through the example of sociocultural and subjective aspects of NOS.

The specific mention of sociocultural and subjective aspects is of interest since previous research has shown that they are particularly difficult to include in science teaching (e.g. Akerson et al., 2011).⁶⁴ They have been considered to be the aspects most contrary to traditional school science teaching (Zachary & Barton, 2004); they are un-science-like and steal time from the teaching of science concepts, which might be a reason for them to be considered as more challenging than others. Despite these demands, which were discussed by the teachers at the outset of the project (see Article I), the teachers chose to emphasize sociocultural and subjective aspects when planning their first teaching activity – that is, they deliberately challenged themselves (see Articles III & IV). The issues were also chosen as relevant, even for younger students (see Article II). There could be several reasons for taking on the challenge, of which none can be separated as the most important. Firstly, it might be due to a curiosity to explore these aspects discussed in the focus groups, but that according to the teachers were rarely addressed in their science classrooms. Here, there was a possibility to try something new within safer boundaries. Boundaries consisting of collegial planning and a research project urging them to expand their repertoires – the responsibility and decisions were not entirely their own. Secondly, there might have been a genuine wish to transform and broaden the dominant practice by exploring different paths to what school science is and can be.

The articles included in this thesis form a pattern from teachers' ways of suggesting NOS issues. All of the articles together, and Article III on its own, show that the teachers' repertoire regarding teachable NOS issues was developed from a narrow range at the beginning of the project (Article I & Article III), to a broad spectrum of issues by the end of the project (Articles II-IV). Article III

⁶⁴ Sociocultural and subjective aspects are also the specific focus in Article III.

showed that the teachers' planning and implementation of NOS teaching meant an expansion of the repertoire.

The progression that the teachers suggested for students' NOS learning (Article II) meant an expansion by adding *more* NOS issues. Thereby, possibilities for a broader, but not necessarily a deeper understanding of NOS was created. Previous research on NOS progression have mainly related the progression to specific NOS frameworks (e.g. Abd-El-Kahlick, 2012ab; Erduran & Dagher, 2014; Kampourakis, 2016b). These suggestions have approached progressions in different ways. Similarly to the teachers in the present study, Erduran and Dagher (2014) provide examples of a broader span of NOS issues and different contexts at later stages. Inversely, Abd-El-Khalick (2012ab) provides an example of a few selected issues⁶⁵ that are treated at a deeper level of complexity by including perspectives of why and how.⁶⁶ It is by no means self-evident that both breadth and depth are needed in a compulsory school setting. Matthews (1994; 2012) has argued that neither teachers nor students should be expected to have sophisticated NOS knowledge – modest goals ought to suffice – but that teaching must strive to provide time for students' reflection on multiple perspectives. Thus, the broad take on NOS that becomes a result of the teachers' suggestions is one way to expand and transform science teaching practice. There could be several explanations for this direction. Firstly, this is likely to be what the teachers judge as the most suitable way to include NOS due to concerns over students' abilities to deal with complex issues. However, it might also be the only way. It is possible that they might not have enough knowledge about NOS themselves to be able to create a progression based on different philosophical perspectives that could have added depth to the suggested NOS issues (c.f. Matthews 1998; 2012).

In sum, the inclusion of a multitude of issues slightly transforms the focus on science concepts. What this means in regard to the in-

⁶⁵ Based on the tenets.

⁶⁶ However, the paths to progression through broadening or deepening are intertwined – an addition of issues could mean a greater level of depth if various perspectives are included, a focus on depth through asking why and how could lead to an inclusion of more issues.

clusion of NOS in science teaching can only be understood in relation to *how* it is included.

7.1.2 Negotiations of NOS teaching approaches (How?)

Images of science and school science are mediated to students in the ways in which teachers choose to include NOS. Previous research have often studied the question of how NOS ought to be included through evaluating whether explicit/implicit NOS teaching (e.g. Khishfe & Lederman, 2006; 2007), various contexts (e.g. Eastwood et al., 2012) or different levels of contextualization (e.g. Bell et al., 2016) are most successful from a NOS learning perspective. Whether NOS learning is successful or not has either been a matter of logical reasoning (i.e. if we teach this it ought to lead to the literacy we strive for; e.g. Allchin, 2014) or an empirical question where NOS learning outcomes have been assessed (e.g. VNOS Lederman et al., 2002).

In the present study, the teachers have discussed NOS teaching as well as encountered NOS teaching through planning and implementing two different kinds of activities (see description of activities in section 5.2.4). These experiences were important elements in the discussions and suggestions regarding how to approach NOS in science teaching.

Clearly, the present thesis does not explore how NOS teaching should be performed in order to accomplish the most adequate NOS learning for students.⁶⁷ Instead, teachers have been given opportunities to contribute their perspectives on *possibilities* for learning linked to different approaches (Articles II-IV).

Teachers' suggestions (described below) of how NOS should be taught are based on:

- Contextualizing NOS teaching
- Including NOS through lab-work and “discussions”, but not in connection to learning science concepts.
- Resistance, accommodation, and transformation in relation to: the teaching of science concepts (time constraints and assessment cultures), teacher roles, lab-work traditions, and formation of a “discussion-tradition”

⁶⁷ This does not say that learning outcomes would not be interesting to investigate in various ways.

The NOS teaching practices that the teachers constructed can be described as deeply contextualized.⁶⁸ The teachers sought for authentic cases and topics to which NOS could be connected. As a consequence, the described teaching was directed towards Vision II science. According to previous research, this kind of teaching practice has the possibility to include a greater variety of companion meanings than Vision I (Roberts, 2011), which becomes one way to broaden the images of science in science teaching.

From the three traditions that the teachers talked about during the project, lab-work and “discussions” were regarded as possible to accommodate with NOS in various ways. However, the teachers seldom connected NOS with the teaching of facts (science concepts).

That teachers connect NOS to lab-work is contrary to previous Swedish studies. These studies have, with a focus on teachers’ perspectives on lab-work, shown that teachers do not naturally suggest lab-work as an opportunity to teach NOS (Gyllenpalm et al., 2010a; Högström et al., 2006). On the other hand, the present thesis had a different starting point (i.e. starting in NOS instead of the lab-work), which is likely to affect this connection. In this thesis, the teachers initially talked about lab-work as a natural occasion for implicitly making students become aware of, for example, creative elements in science through being creative themselves (Article I). Such implicit NOS teaching in connection to lab-work has been problematized in earlier research, as it has been shown that students do not learn NOS simply through taking part in lab-work (e.g. Bell et al., 2003).⁶⁹ However, suggestions for explicit NOS discussions connected to lab-work increased during the project (e.g. discussions regarding trustworthiness or reasons for diverging interpretations). Initial ways of accommodating NOS with lab-work remained throughout the project (see Article II), but the ideas of what lab-work is and might become developed and transformed in parallel to the NOS discussions – from cook-book lab-work to a

⁶⁸ Even the black-box task was being transformed into a slightly contextualized task (see Article IV).

⁶⁹ Again, the learning of NOS is connected to evaluating the learning of certain aspects of NOS).

more reflective and student driven practice (see Article IV).⁷⁰ That way, lab-work in the form where students plan and perform their own investigations was described as a possibility to also reflect on NOS (see Articles III & IV). Consequently, NOS and lab-work were mangled, transformed, and accommodated quite smoothly and also merged with other more unstable traditions, such as discussions.

NOS can provide a sense of direction for the “discussion approach”, which is considered by the teachers as necessary to develop according to demands in the national curriculum (Skolverket, 2011a). Similarly to NOS, the discussion tradition is perceived as a new element in science teaching and both require further negotiation. Thus, they are created in a dialectic transformation and creation where few pre-established boundaries exist. The teachers’ ways of talking about discussions transformed into ways of talking about and defining NOS (i.e. making students take part in argumentation exercises in science class became a way to include argumentation in the image of NOS), and NOS issues contributed ideas to form the activities of the emerging tradition (i.e. the issue of bias can be approached through an activity where different sources on the Internet are scrutinized). That way NOS becomes a catalyst for the discussion tradition, where the outcomes need to be negotiated in relation to the other traditions.

The teachers’ tendency to focus on contexts and approaches could mean that the teachers found the approaches and contexts more interesting or important to explore than NOS itself – NOS becomes a component for transformation and a means to expand teaching practices. However, there is also a possibility that NOS becomes invisible since there is great resistance, especially in relation to the traditions that surround the science concepts (i.e. the “facts-tradition”). An explanation as to why the teachers did not suggest facts as a suitable context for NOS could be that such a connection was not emphasized by the researcher during the focus

⁷⁰ This was not only a transformation instigated by the NOS project, but from national testing of inquiry, as well as some of the teachers taking a course on inquiry teaching. The latter’s demands on transformed inquiry knowledge was also a recurrent topic among the teachers in the focus group discussions.

groups. The concepts-based tradition has been described as relying on the teachers as “dispensers of knowledge” (Bartholomew et al., 2004), where students memorize concepts and produce answers to written tests (Bartholomew et al., 2004; Tidemand & Nilesen, 2017; Zacharia & Barton, 2004).⁷¹ In the case of NOS teaching, teachers have limited possibilities to view themselves as dispensers of knowledge (as previously discussed, their knowledge might be limited), and textbooks and curricula have seldom made a clear suggestion for what and how NOS knowledge could be included in science teaching. Furthermore, the teachers in this study have probably been slightly affected by the researcher’s position that there can be various perspectives involved when discussing NOS, which in turn might lead to resistance in relation to approaching NOS as facts.

However, certain patterns in the teachers’ discussions could be interpreted as an accommodation between NOS and the “facts tradition”, described as coping strategies in Tidemand and Nielsen (2017). Such patterns can be seen in Article III where teachers, to an increasing extent over the years, concretize NOS through discussing them in connection to “scientific practices”. That way NOS teaching could become more science-like. The only straight forward suggestion of alignment is that NOS should be included in written tests (see Article IV). As a coping strategy, it provides a form of circular argument for including NOS – NOS is taught because it is to be tested and NOS is tested because it is taught.

Merging NOS with lab-work and discussions means that something happens to the facts as well – its image becomes blurred by a counter image that takes shape within the other two teaching traditions. Consequently, friction occurs due to, for instance, time constraints (Articles I, II & IV) when lab-work and discussions expand at the expense of science concepts. On the other hand, the agency of facts could mean that it resists the other traditions and continues to have a dominating position. A continued mangling of NOS and facts could mean finding other paths to alignment, where a balance between concepts and NOS is found and the teachers’ feelings that

⁷¹ Of course, this is a simplified description of one particular school science tradition that does not exist on its own, but is mixed with other traditions.

the facts are put on hold might be reduced. A further mangling would also mean that rationales for science and NOS teaching are included in the mangle.

7.1.3 Negotiations of reasons for NOS teaching (Why?)

Previous research have developed arguments for including NOS in science teaching, either on an ideological basis or an empirical basis related to students' understanding or attitudes. Four major reasons were presented in section 3.1.2: learning science content, learning NOS, increasing student interest, and being useful for citizenship. This section adds to previous research by discussing how the teachers in this study discussed why there could be reason to include NOS teaching in science teaching.

Teachers' reasons (described below) for NOS teaching are based on:

- Notions of increased student engagement
- A desire to reach all curricular goals
- A desire to develop students' abilities to handle society (i.e. citizenship goals)
- Resistance and accommodation in relation to diverging visions for science teaching (i.e. Visions I & II; see Roberts, 2007; Roberts & Bybee, 2014)

Previous research has shown that having a clear rationale for teaching NOS is an important factor for including it in classroom practice (Herman et al., 2015). This is no surprise due to the tensions and efforts reported in relation to including NOS in science teaching – a clear rationale might make the challenges worthwhile. However, the rationale that has been most stressed in previous studies on teachers' classroom practice is that NOS could be taught as a way to facilitate students' understanding of science concepts (Clough & Olson, 2012; Bell et al., 2016). The previous section (7.1.2) showed that the teachers in this thesis did not connect NOS to certain concepts, which explains why the above-mentioned rationale is not emphasized by them.

Instead, at the outset of the project (see Article I), the teachers' main reason for including NOS was the idea that the science sub-

ject would become more appealing to more students if it was “a softer subject” – that is, less focused on facts (c.f. Aikenhead, 2006). These ideas are followed up in Articles III and IV, where the teachers have gained experience from NOS teaching. Their reflections (see the following section on whom NOS is for) on experiences of greater engagement among students and on inclusion of more (and different) student voices than usual, strengthens earlier research in claiming that traditional school science teaching can have an excluding effect on many student groups (e.g. Aikenhead, 2006; Carlone, 2004; Barton & Yang, 2000; Brickhouse, 2001; 2011; Hansson & Lindahl, 2010; Zachary & Barton, 2004).

However, during the project another reason for teaching NOS emerged as important: NOS as a means to reach overarching goals of science education. These were goals that were connected both to writings in the curriculum and to science for citizenship (or functional/useful scientific literacy, see e.g. Hodson, 2008; Roth & Barton, 2004; Ryder, 2002). Some of these goals were directed towards developing students’ abilities for: argumentation, critical thinking, source examination, and judgements of trustworthiness (see section 7.1.2) – goals that have often been connected to perspectives with a starting point outside of science (i.e. Vision II). The teachers argued that these goals were emphasized in the curriculum as well as included in national tests, but had still not received a major focus of classroom practice. As previously mentioned, this rationale for NOS teaching not only connects to curricular goals, but also to the teachers’ desire to prepare students for the “real world” through learning to handle a science that is not entirely black and white, and where no simple keys to correct answers are presented. Instead, NOS becomes a way to prepare for taking position and making informed decisions (see Article III).

In the teachers’ discussions, the above described goals and rationales for NOS teaching are negotiated in relation to other goals and structures of science teaching (i.e. learning concepts or aiming for good results on national tests). The goals emphasized by the teachers were mostly related to Vision II science.⁷² Resistance was

⁷² This is contrary to Roberts (2007) and Roberts and Bybee (2014), who often places NOS as a component, first and foremost, of Vision I science.

created when these goals were mangled with the teachers' everyday science teaching – described as based in Vision I science. Thus, while the teachers' goals for NOS teaching aligned well with what they regarded as “new” demands from the curriculum, NOS caused resistance in relation to other goals (i.e. traditional goals such as learning science concepts, which are still very present in both the curriculum and in habitual practice). Accommodation and alignment of these various goals need further negotiation in relation to a great deal of questions: How can time and space be created for diverging goals? What is the desired knowledge? How can it be learned? Can “hard facts”⁷³ do the job or does science have to be learned through taking part in discussions about scientific practices or socio-scientific issues debated in the media? Can they be combined (c.f. Feinstein et al., 2013)? These are tensions that remained in need of further negotiation within the teacher group.

7.1.4 Negotiations regarding students and NOS (for whom?)

In the science classroom, teachers and students are different pieces of the same classroom practice. That is, the structures and traditions that have been described in previous sections encompass both teachers and their students: “Both teachers and students are shaped by *school thinking*” (Article IV).⁷⁴ When the teachers talk about NOS teaching it is always in relation to their students.

Teachers' negotiations (described below) regarding whom NOS is for are based on:

- Considerations regarding students who are challenged by NOS teaching (“good students”, socially challenged students)
- Considerations regarding students who are benefitting from NOS teaching (“outsiders”, philosophical students)
- Resistance and accommodation regarding relations between outsiders/insiders, students/teaching traditions, and teachers/students

⁷³ John's expression in Article I.

⁷⁴ This is Ella talking about younger students who often ask more questions concerning things like “How can we know?” than older students. Ella argues this to be an effect of older students being more accommodated to prevailing structures.

Which students become challenged by NOS teaching? Challenges that were anticipated by the teachers at the outset of the project (Article I) were transformed into experiences after implementing the NOS activities (Articles II-IV). Most of these challenges – students’ abilities for abstract thinking and basic literacy, as well as inconvenience related to uncertainty – have been extensively reported in previous research (see section 3.1.4). In both Swedish and international studies, these challenges have been understood as a consequence of placing NOS teaching outside the concepts-based tradition (here, facts tradition) by creating student-centred practices where uncertainty prevails (e.g. Article IV; Ideland & Malmberg, 2012; Ruhrig & Höttecke, 2015). The teachers in the present study regard this new practice as particularly challenging for “good students” who are used to being good due to their ability to produce correct answers on written tests. However, they also express a concern for students who struggle to fit within the frames of, for example, group discussions (Article I).

On the other hand, the students who benefitted from an inclusion of NOS were typically described as the *other* student/someone who had not been able to accommodate to the traditional science teaching setting. In Article I, these students are described as the “more philosophical students” and/or those who become bored with the facts tradition (c.f. Aikenhead, 2006; see section 7.1.3 about student engagement above). Several explanations for increased student engagement are provided in the research literature. One possible reason is that a focus on science concepts might not be engaging if you cannot picture yourself as a future scientist – a transformed science practice contributes more to a “competent outsider” perspective (Feinstein, 2011). Another reason could be that students come to science class with various worldviews, which sometimes create great friction in relation to a scientific worldview (Hansson, 2007; 2014). When images of science are broadened it could mean space for students’ negotiations and ideas of how different worldviews, as well as different perspectives on NOS, can accommodate or exist in parallel to each other.

However, it is not easy to identify whether the increased student engagement that the teachers discuss (see e.g. Article III) is caused

by the changed contents of the science teaching (NOS) or its formats (transformed or expanded teaching approaches). Thus, engagement is intertwined with both.⁷⁵

When teachers are involved in adjusting and transforming their teaching practice, students also become part of this process. For some students it causes great friction, others accommodate and adjust or even benefit from the transformed practice. Students' reactions cause a new turn of tensions and accommodations in relation to teachers' accommodation and resistance. In creating structures for the NOS teaching practice, challenges are taken into account by the teachers. Two directions for teachers' negotiations can be discerned; accommodating NOS teaching so it fits better with students' expectations on practice, or trying to accommodate the students' expectations to the transformed practice. An example of the first direction is the suggestion of including NOS in written tests and thus accommodating to "good" students' requests for traditional test formats (Articles I, III & IV; c.f. Aikenhead, 2006; Carlone, 2004). An example of the second direction is based on the opinion that students need the ability to handle abstract NOS issues and uncertainty. Therefore, structures are suggested where students can start practicing at early stages so that they can slowly accommodate to a transformed science teaching practice and its demands (see Articles II, III & IV). Regardless of the direction of negotiations, the tensions will be solved for some students while they increase for others. Such concerns raise relevant questions regarding patterns of who (with respect to different student groups) are actually included and invited to take part in different teaching formats (Ideland, 2016). Tensions for teachers are created in the act of balancing between including some students and risking the exclusion of others.

⁷⁵ All NOS teaching that the teachers implemented used open-question, student-centered formats based on discussions, reflections and group work where no keys to correct answers were provided.

7.2 Crosscutting through tensions, challenges and consequences

This section summarizes some important tensions and challenges in the results of this thesis. A simplified summary of the NOS teaching practice that the teachers constructed would provide: A broad take on NOS by addressing a multitude of NOS issues in the contexts of lab-work and discussions with the purposes to: challenge black and white images of science, engage and include students, reach overarching goals of science (other than knowledge of concepts), and enhance literacy for citizenship. Even if this summary could be regarded as a most desirable point of departure for school science, tensions and challenges can be expected.

Tensions often become a consequence of trying to resist the black and white⁷⁶ school science practices, which in this thesis are represented by “facts” (i.e. short form for ready-made facts or science concepts). The “facts” are not only a body of science concepts, but an entire way of talking about how and why science teaching should be staged and for whom it matters. The facts as presented here cause tensions and challenges in relation to the suggested NOS teaching and teachers’ roles.

From the teachers’ discussions, the teaching that surrounds science concepts appears as important and dominating in science teaching. Meanwhile, the teachers resist science concepts by arguing that science teaching must provide a more nuanced picture of science. A tension is created when the two different pictures resist fusion. In this study, the teachers try to resolve the tension by creating structures for NOS teaching that do not cross the borders to the facts tradition – the nuances and the black-and-whiteness are placed on parallel tracks. Through this accommodation new tensions are created. One of these tensions has to do with time and space for concepts and finding balance between the parallel tracks (discussed in section 7.1.2 above). As a consequence, if the balancing act becomes too difficult, NOS might be disregarded and actually not included in science teaching practice at all – it was man-

⁷⁶ The “black-and-white” metaphor is also recurrently used by the teachers themselves.

gled, but fell out on the side of the mangle as a separate part, keeping traditional practice intact.

Another tension from the parallel tracks is that different images of science are created. When different images do not meet in teaching practice teachers and students are left to bring (or not bring) the pictures together, on their own. Therefore, parallel pictures of science can be maintained without students (and teachers) getting the chance to compare or reflect on them. A third tension from adjustments of science teaching is related to the teacher's role transforming from being a "dispenser of knowledge" (Bartholomew et al., 2004) to someone with much less well-defined boundaries (c.f. Aikenhead, 2006; Bartholomew et al., 2004; Höttecke & Silva, 2011; see also Articles III & IV).

Moreover, building NOS practice on the inclusion of a large variety of issues might mean creating a shallow contrary to a deep NOS understanding. These tensions and challenges will be addressed in the following section that discusses implications and suggestions for practice and future research.

7.3 Construction of NOS teaching practice – implications

This section discusses implications and suggestions for practice, teacher education, and future research based on the results in this thesis. The first part puts forward implications related to including NOS in a broad or deep way. The second part addresses the tensions between parallel practices of NOS and traditional school teaching. The third section provides general suggestions for teacher education⁷⁷ and future research.

7.3.1 From breadth to depth

Taken together, all NOS issues that the teachers suggest and discuss in Articles I-IV could contribute to a much more nuanced picture of science (and science teaching) than is usually described in the research literature. Including a large variety of NOS issues could be the most accessible approach, and thus a good starting point for NOS teaching. These teachers' suggestions of NOS issues

⁷⁷ Here, teacher education means and includes pre-service education, in-service education, and professional development initiatives.

could, in combination with detailed examples, serve as inspiration to other teachers and teacher students (see Leden & Hansson, forthcoming).

One of the above described challenges leads to the question: may a focus on a large variety of issues, lead to only a shallow understanding of NOS? It has been argued that there is no need for compulsory school students' NOS understanding to be advanced or deep (Mathews, 1998; Kampourakis, 2016a; Lederman, 2007). However, as previously mentioned, the teachers try to create depth through discussing different issues in relation to different contexts and through different approaches (see Article II). This could also be a way to create depth in teacher education. Still, as argued by Adruiz-Bravo (2007) and Abd-el-Kahlick (2012a),⁷⁸ teachers need knowledge at a different, deeper level than their students regarding NOS, as well as other science areas. Having access to deeper knowledge also means having access to more and diverging perspectives,⁷⁹ which provides an ability to choose and offer different perspectives for students to reflect on in the classroom setting. Previous research have discussed practices where only one-sided perspectives on NOS are presented or taken for granted, as problematic – and sometimes even as indoctrination (see Matthews, 2012; Allchin, 2011). Choices regarding which perspectives to focus on in the science classroom are always made, but perspectives that you are not aware of can neither be chosen nor neglected. Ideas for how depth regarding NOS can be created in teacher education, and how it is received, require further exploration.

7.3.2 From parallel tracks to merged traditions

That the teachers in this study connect NOS teaching to “lab-work” and “discussions” can be a beneficial starting point for in-service teacher education, since these are teaching practices with less defined boundaries than the facts-based tradition. Since both lab-work and, in particular, discussion approaches are under development, NOS can be incorporated and have a role to play in the

⁷⁸ Important to note is that these two researchers argue from different points of departure in regards to theoretical perspectives and NOS frameworks.

⁷⁹ See examples in the previous description of the NOS framework used in this study.

(re-)construction of these traditions. However, perspectives both from outside (Vision II) and from within science (Vision I) are needed (Roberts, 2007; Roberts & Bybee, 2014). As mentioned above, the merging of diverging perspectives is challenging, but leaving them unmerged seems to create other challenges. Therefore, teachers could use guidance regarding how to accommodate different visions and images to each other.

Previous studies have shown that contextualizing NOS within science content in teacher education can provide teachers with strong rationales for future NOS teaching (Clough & Olson, 2012; Bell et al., 2016). Concrete examples of how this can be done need to be provided and explored (see Hansson & Leden, 2016). It has been claimed that the combination of NOS teaching with concepts can lead to facilitating students' understanding of the concepts (c.f. Driver et al., 1996; Matthews, 1994; McComas et al., 1998; Lederman, 2007). Such combination might also reduce the feeling of a shortage of time for science concepts.

Moreover, research has shown that it is uncommon and difficult to make use of science concepts in, for instance, decision making (Lundström, 2011; Ryder, 2001). NOS teaching might contribute to finding ways to bridge, or align, Visions I and II in ways that aid the connection between concepts and reasoning. Furthermore, accommodation and combination could also make room for relating nuances to ready-made facts, which would open up for possibilities to negotiate the images of science instead of keeping them in separate boxes. This could also be a way to mangle and tune implicit messages of science with explicit messages, which is suggested in Oliveira et al. (2012) and Ryder et al. (1999).

A consequence of this reasoning is that science teacher education has a part in staging the merging, through implicitly and explicitly including NOS even in the science content courses (perhaps also here with a starting point in lab-work and discussions). If future teachers have encountered NOS perspectives in their own science content courses through, for example, discussions concerning uncertainty, values or limits of science, discussions about how concepts and models have been developed, or through evaluation and discussions of methods and differing interpretations during lab-

work, there will be another point of departure for accommodation in their own science teaching practice. However, this does not imply that explicit discussions/courses devoted to developing knowledge concerning NOS *teaching* ought to be excluded. Implications for such work are described below.

7.3.3 Further suggestions for teacher education and future research

This section suggests four important components for teacher education and future research: negotiations, concrete experiences, collaborations, and exploration of different NOS frameworks.

A conclusion from this thesis is that collegial discussions and negotiations (i.e. focus group meetings) contributed to an expansion of the teachers' perspectives and ideas (Articles III-IV), which is not surprising. This conclusion results in a suggestion for teacher education to make enough space for scrutinizing tensions and to currently negotiate existing traditions in order to make teachers aware of different perspectives and options for science teaching practice (see also Lunde, 2014; Wickman, 2014). Regarding new elements such as NOS teaching, thorough negotiations – starting with the question *why?* – are needed to include and merge it with existing practices. If negotiations are not staged, there is chance that the inclusion will only be shallow and the new elements swallowed by tradition – transformed to invisibility (Lunde, 2014). This thesis has shown that both previous research and the teachers in this study relate NOS, as a component of science education, to either students' engagement or scientific literacy goals. This relation has often been justified from logical (c.f. Feinstein, 2011) or ideological points of departure (see e.g. Allchin, 2014; Hodson, 2008; 2009). These points of departure are of course important for the above suggested negotiations. However, a further conclusion in this thesis is the importance of concrete experiences to be mangled together with the logical and ideological outcomes.

Practical experiences from planning and implementing activities can contribute with additional perspectives to ideologies and logic. Thus, a suggestion for teacher education and research is to provide space for concrete experiences that can illuminate both challenges

and opportunities. Many previous research studies have reported on the challenges that teachers experience in relation to the implementation of NOS in science teaching (e.g. Abd-El-Khalick et al., 1998; Höttecke & Silva, 2011; see also section 3.1.4). Conclusions from these studies make important contributions for what to take into account in science teacher education. However, there could also be a reason to take a starting point in possibilities or things that have been judged as easy (such as including NOS in a broad way, see section 7.1.1). The present thesis has an important role in providing such examples of possibilities. Identifying success and taking part in successful implementations has been identified as an important factor for further development of practice (c.f. Herman et al., 2015; Krajewski & Schwartz, 2014). To further develop, plan and test activities that have been inspired from what other teachers have argued to work out well, could also create ideas for further exploration of options and alternatives for science teaching practice. Developing practice through combining the above suggested experiences with mutual classroom observations among critical colleagues would lead to further negotiations. Such collaborations could also lead to practical suggestions for how to develop practice for students who struggle with the new (and possibly old) elements of science teaching.⁸⁰

A suggestion for future science education research, especially regarding NOS teaching practice, is to further develop structures for teacher-researcher and teacher-teacher collaborations. One important part, if teachers' voices and perspectives are claimed to be important and taken seriously, would be to strive for better symmetry between researchers and teachers regarding responsibility and ownership during all parts of the research process (Sensevy et al., 2013). This could be accomplished through, at the outset of the project, setting aside time for teachers to, for instance, take part in the interpretation of discussions, and in shaping the analysis. This would also mean that structures need to be developed concerning teachers' possibilities to take part in the dissemination of results without violating the demands of confidentiality.

⁸⁰ Such an approach was suggested by the teachers in the present study when they evaluated the project during the last focus group meeting.

Moreover, another suggestion for future science education research on NOS is to mangle different points of departure through scrutinising reasons for resistance towards other frameworks, as well as reasons for accommodating or not. Much of the present research in this field seems to be caught in two incommensurable paradigms – there is only resistance, no accommodation. Studying the tensions between frameworks and possible reasons as to why they occur from new perspectives might create a more dynamic research practice. Is there potential in different frameworks? Can they be mixed or used for different purposes at different stages (c.f. Kampourakis, 2016ab)? Are generalizations and myths only a “bad thing” (c.f. Hamlin, 2017) or do they sometimes have a purpose to fill? What could they be exchanged for? What do different frameworks help us see and what do they hide or complicate?⁸¹ Again, teachers could have an important role in the negotiations of what is useful and comprehensible to them and/or their students.

7.4 The empirical, methodological, and theoretical contribution of this thesis

This thesis approaches the research field of NOS teaching from an unusual direction. Even if teachers have previously been awarded a great deal of space and ownership in studies such as Höttecke et al. (2012), Bartholomew et al. (2004), and especially in action research (e.g. Krajewski & Schwartz, 2014), the present study focuses particularly on teachers’ *negotiations over time*. These negotiations have contributed to the research field with insights and directions for teacher education (see implications and suggestions above) regarding tensions, challenges, and opportunities that are created in relation to NOS practice suggested by teachers.

An empirical contribution is made regarding rationales for NOS progression, NOS issues and, NOS teaching approaches, as well as challenges and opportunities related to NOS teaching. NOS progression has previously mainly been discussed from a theoretical perspective. This study added information concerning teachers’ ways of suggesting NOS teaching for different stages, showing, for

⁸¹ This question, with a focus on deficiency, has of course been one part in the ongoing debate about frameworks (see section 3.1.1).

example, that these teachers suggest an early inclusion of NOS issues that have previously been judged difficult. Furthermore, the articles contribute with teachers' suggestions of numerous issues and approaches, which could be used as points of departure in teacher education and future research. In addition to these concrete suggestions for practice, the articles discuss a number of important challenges and opportunities where previous research has mostly only focused on the challenges.

A methodological contribution is made by providing directions for empirical investigations on NOS teaching, which do not have a starting point from a correct or best approach to NOS teaching. Even if previous research has made a large amount of valuable contributions regarding NOS teaching formats and examples, the present study expands the field by taking an explorative approach with teachers' perspectives in focus. However, that their ways of talking and their suggestions are not judged as right or wrong does not mean they do not have to be problematized. In this thesis, this is completed by relating the perspectives and suggestions to existing practices and studying resulting tensions. As part of the methodological work, Article I used and analyzed the VNOS-C questionnaire in a new fashion based on different ways of talking, as well as on relations between NOS in general and NOS teaching. This approach provides new opportunities for the use of VNOS questionnaires (as well as other questionnaires that have been exposed to the same forms of criticism).

A theoretical contribution is made through the creation and use of a flexible and inclusive NOS framework. This framework is based on the idea that different contributors and various levels of complexity should be allowed to provide relevance for the particular context. There was also a pronounced purpose to mangle existing frameworks, positions, and perspectives into one framework in an attempt to dismiss the NOS war and make use of what was at hand (see Articles I-III). This is not to say that this is the only example, as mixed frameworks have also been presented in, for example, Maurines and Beaufils (2013) and Tala and Vesterinen (2015).

7.5 Concluding remarks – the mangle of a research project

As a concluding reflection, it seems necessary to say something about how the present research project (as well as the writing of this thesis) can be seen as processed through the mangle.⁸² Beginning the project seemed simple enough: starting off from a fairly clear idea derived from a few NOS aspects.⁸³ The initial idea soon grew more complex under the influence of reading research articles from various perspectives, taking part in courses, and finding myself in different contexts involved in discussions with various individuals. Empirical data from the present study has been mangled with theories, previous research and the perspectives from supervisors and reviewers.

It is also essential to say something about my own stubborn (black-and-white) opinion that nothing is *just* black and white – I simply do not believe in neatly sorted opinions, perspectives and outcomes – shades of grey are, or have always been, involved at some point.⁸⁴ This idea adds a certain flavour to this project; for instance, regarding the idea that something good comes out of bringing more nuances to science teaching – the inclusion of more students or avoiding taken for granted one-sided perspectives. And that teachers' various perspectives have something to add to the understanding of NOS teaching. It is clear that my reluctance against black and white makes me tuned in to nuances and that, in turn, might have tuned teachers' discussions towards nuances as well.⁸⁵ Therefore, the cover image of this thesis becomes a metaphor for my notion that black and white perspectives, policies, frameworks and, positions are, or can be, processed through the mangle and come out as blurred shades of grey – rendering a more interesting taste to the world.

⁸² Which certainly cannot be seen as extraordinary for this particular project.

⁸³ Lederman's tenets as described in Lederman (2007).

⁸⁴ I realize that in the age of "alternative facts", anyone who is enthusiastic regarding nuances might be labeled a relativist. I would not feel comfortable with that epithet though, as I argue that an important aspect of nuances are that they are part of making research trustworthy and robust.

⁸⁵ The framework is, after all, built on continua of diverging perspectives.

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APPENDICES

Appendix A. VNOS-C questions translated to Swedish

Föreställningar om naturvetenskapens karaktär

Observera att utrymmet för svaren har minskats betydligt i dokumentet som presenteras här

Baserad på VNOS (C)⁸⁶
VNOS (C)

Namn: _____

Datum:

Instruktioner

- Besvara var och en av följande frågor. Ta med relevanta exempel närhelst det är möjligt. Du kan använda papprets baksida om du behöver mer plats
- **Det finns inga rätta eller felaktiga svar på nedanstående frågor. Det enda vi är intresserade av är din åsikt om ett antal frågor som rör naturvetenskap.**

1. Vad är naturvetenskap enligt din mening? Vad skiljer naturvetenskap (eller naturvetenskapliga discipliner som fysik, biologi etc.) från andra forskningsdiscipliner (t.ex. religion eller filosofi)?

⁸⁶ Referens:

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2. Vad är ett experiment?

3. Är experiment nödvändiga för utvecklingen av naturvetenskaplig kunskap?

- Om ja, förklara varför. Ge ett exempel för att motivera din ståndpunkt.
- Om nej, förklara varför. Ge ett exempel för att motivera din ståndpunkt.
- 4. I läroböcker i naturvetenskap beskrivs atomen ofta som en central kärna bestående av protoner (positivt laddade partiklar) och neutroner (oladdade partiklar) och med elektroner (negativt laddade partiklar) som cirkulerar runt kärnan. Hur säkra är forskarna på atomens uppbyggnad? Vilka specifika bevis, eller typer av bevis, tror du att forskarna använde för att avgöra hur en atom är uppbyggd?

5. Finns det någon skillnad mellan en naturvetenskaplig teori och en naturvetenskaplig lag? Illustrera ditt svar med ett exempel.

6. Ändras någonsin en naturvetenskaplig teori (t.ex. atomteori, evolutionsteori) efter att den utvecklats av forskare?

- Om du anser att naturvetenskapliga teorier inte ändras, förklara varför. Motivera ditt svar med exempel.
- Om du anser att naturvetenskapliga teorier ändras:
 - a) Förklara varför naturvetenskapliga teorier ändras.

b) Förklara varför vi bryr oss om att lära oss naturvetenskapliga teorier. Motivera ditt svar med exempel.

7. Naturvetenskapliga läromedel definierar ofta en art som en grupp organismer som har liknande egenskaper och som kan korsa sig och få fertil avkomma. Hur säkra är forskarna på sin karaktärisering av en art? Vilka specifika bevis **tror du** att forskarna använde sig av för att bestämma vad en art är?

8. För att få svar på sina frågor utför forskare experiment/undersökningar. Använder sig forskare av sin kreativitet och fantasi under sina undersökningar?

- Om ja – under vilka stadier av undersökningarna tror du att forskare använder sin fantasi och kreativitet: planering och utformning; datainsamling; efter datainsamlingen? Förklara varför forskare använder sig av kreativitet och fantasi. Ge exempel om det är möjligt.
- Om du inte tror att forskare använder kreativitet och fantasi – förklara varför. Ge exempel om det är möjligt.

9. Man tror att dinosaurierna dog ut för ungefär 65 miljoner år sedan. Av de hypoteser som forskare formulerat för att förklara utdöendet, får två stort stöd.

Den första hypotesen, formulerad av en forskargrupp, påstår att en stor meteorit träffade jorden för 65 miljoner år sedan, vilket orsakade en mängd händelser som ledde till utdöendet. Den andra

hypotesen, formulerad av en annan grupp forskare, påstår att kraftiga och våldsamma vulkanutbrott orsakade utdöendet. Hur är det möjligt att komma fram till **olika slutsatser** när forskarna i de båda grupperna har tillgång till och använder **samma data** för att dra sina slutsatser?

10. Vissa menar att naturvetenskap genomsyras av sociala och kulturella värderingar. Alltså, att naturvetenskap speglar sociala och politiska värderingar, filosofiska antaganden och intellektuella normer i den kultur där den praktiseras. Andra menar att naturvetenskap är universell. Alltså, att naturvetenskap överbrygger nationella och kulturella gränser och inte påverkas av sociala, politiska och filosofiska värderingar eller intellektuella normer i den kultur där den praktiseras.

- Om du tror att naturvetenskap speglar sociala och kulturella värderingar, förklara varför och hur. Motivera ditt svar med exempel.
- Om du tror att naturvetenskap är universell, förklara varför och hur. Motivera ditt svar med exempel.

Appendix B. Interview guide in Swedish and English (questions connected to teaching practice interview part 2).

Questions with a guiding purpose for the researcher, put to all teachers during the second part of the interview.

Frågor kopplade till VNOS och undervisningspraktiken/ Questions connected to VNOS and teaching practice

1. Kommer den här sortens frågor in i undervisningen? *Are these kinds of questions included in teaching?*
 - Experiment/*Experiments*
 - Modeller/*Models*
 - Kunskap i förändring/*Knowledge in change*
 - Kreativitet/fantasi/*creativity/imagination*
 - Sociala/kulturella aspekter/*Social/cultural aspects*
 - Olikheter i tolkning av data/*different interpretations*
2. På vilket sätt – exempel (implicit/explicit)? *In which ways – examples (implicitly/explicitly)?*
3. När (årskurser, speciella tillfällen)? *When (school years, specific occasions)?*
4. Andra funderingar kring naturvetenskapens karaktär som kan dyka upp i undervisningen? Något som eleverna frågat/visat intresse för? *Other reflections regarding nature of science that could be part of teaching? Something that the students have asked about/shown interest in?*
5. Är eleverna intresserade av den här sortens frågor? *Are students interested in these kinds of questions?*
6. För alla elever (svaga/starka)? *Is it for everyone (ones who have a hard time/talented)?*
7. För alla åldrar? *For all ages?*
8. Lgr 11 och hur detta kommer in där? *How is it included in the curriculum?*

Appendix C. Description of focus group activities and material

Meeting (year:group)	Summary description and distributed material
1:1	<p>Introduction</p> <ul style="list-style-type: none"> • Participant presentation • Reflections on pre-distributed text • Participants explore the national curriculum for references to NOS (NOS references are marked and debated). Discussion on how the marked passages become visible in teaching <p>Distributed Material:</p> <ul style="list-style-type: none"> • Pre-distributed text (introduction to NOS)* • Overview of goals in national curriculum
1:2	<p>Tentative, empirical, subjective aspects of science</p> <ul style="list-style-type: none"> • Participants' reflections on pre-distributed text with regards to both NOS in general and NOS teaching (what, how, when, for whom?) • Discussion about NOS teaching that can be appropriate for different school years • Participants take part in a card game (Cobern & Loving, 1998) where they are prompted to take position regarding statements about science. Each person gets three envelopes marked with "agree", disagree", and "uncertain". One card at a time is distributed. Participants discuss and debate the statement on the card – consensus is not the goal. Each participant place the card in the envelope of their choice. The envelopes are collected after the meeting. <p>Distributed Material:</p> <ul style="list-style-type: none"> • Pre-distributed text with questions and examples from tentative, empirical, and subjective aspects of science • Table with school years and themes for participants' documentation • 20 cards (adapted from Cobern & Loving, 1998).
1:3	<p>Creativity, socio-cultural contexts in science, observation /inferences, theories/laws/models</p> <ul style="list-style-type: none"> • Same approach as in meeting 1:2 directed towards new themes • Joint planning of second year of the project. <p>Distributed Material:</p> <ul style="list-style-type: none"> • Pre-distributed text with questions and examples dealing with creativity, socio-cultural contexts in science, observation /inferences, theories/laws/models

	<ul style="list-style-type: none"> • 16 cards (adapted from Cobern & Loving, 1998).
2:1	<p>Teaching examples</p> <ul style="list-style-type: none"> • Summary of discussions from year 1; • 3 examples of NOS activities are distributed and demonstrated by the moderator; • Participants discuss for each example: a) what aspects of NOS are visible in the examples, b) which aspects could be made visible in the science classroom, c) how?/for whom? • Participants discuss what NOS could be made visible in a common lab activity • Short discussion of what kind of activities and NOS aspects the teachers would like to try in their own classrooms. <p>Distributed Material:</p> <ul style="list-style-type: none"> • Excerpts from descriptions of classroom activities: <ul style="list-style-type: none"> • Excerpt from Black-box activity “the bucket” (Wickman & Persson, 2009), • Excerpt from SSI-approach “Can cell phones cause illness?” (Ekborg et al., 2012), + Newspaper articles about cell phones • Translated excerpt of historical case study “the battle over the electron” (Kolstø, 2008).
2:2	<p>Planning of NOS teaching</p> <ul style="list-style-type: none"> • Participants make up joint plans for NOS teaching: choose key NOS aspects and issues, connect to curriculum; decide on possibilities for assessment; • The group is divided in two (year 1-6 and year 7-9 teachers) where detailed lesson plans are made. The groups present their thought to each other by the end of the meeting. • Practical plans for dates and classroom observations are made. <p>Distributed Material:</p> <ul style="list-style-type: none"> • List of formerly discussed aspects and issues
2:3	<p>Reflection on implementation</p> <ul style="list-style-type: none"> • Each member shares their experiences from the implementation: details of the group, details from the activity, what NOS issues were targeted and how they were included, problems and achievements; • Teachers read 2 short descriptions of critical incidents** and discuss them from a NOS perspective; • Teachers get a task to prepare for the next meeting: to search for critical incidents in their own science lessons. <p>Distributed Material:</p>

	<ul style="list-style-type: none"> • 2 Written descriptions (translated) of critical incidents “Cells” and “Lamps” (Nott & Wellington, 1998)
2:4	<p>Critical incidents, teaching examples</p> <ul style="list-style-type: none"> • Participants describe and discuss their collected critical incidents**; • Discussion of 5 more critical incidents adjusted from Nott and Wellington (1998) • 3 new examples of NOS activities are distributed and demonstrated by the moderator (due to earlier request from the teachers). Followed by teachers’ discussion about NOS and NOS teaching connected to the examples. • Joint plans for next year: how do we proceed? Suggestions of trying a black-box activity at the beginning of the semester. <p>Distributed Material:</p> <ul style="list-style-type: none"> • 5 written descriptions (translated) of critical incidents “The magnesium incident”, “Rats”, “Contraception”, “Chemists”, and “Predictions” (Nott & Wellington, 1998) • Excerpts from descriptions of classroom activities: “Mystery tube” (Lederman & Abd-El-Khalick, 1998); “The scrambled sentence” (https://www.sciencelearn.org.nz/resources/432-scrambled-sentence); Card game: ”Which are scientific questions?” (created by the second author of this article and described in Author forthcoming)
3:1	<p>Planning of NOS teaching</p> <ul style="list-style-type: none"> • Participants make detailed plans for teaching a black-box activity “the bucket” (Wickman & Persson, 2009) that have been demonstrated to them earlier. Discussion of NOS aspects and connection to the curriculum. • Practical plans for dates and classroom observations are made. <p>Distributed Material: none</p>
3:2	<p>Reflection on implementation</p> <ul style="list-style-type: none"> • Short round of sharing of experiences from implementation of the black-box activity. • Reflections and comparisons between the black-box activity and the previously implemented NOS teaching session (year 2). • (Contrary to the other meetings, in this focus group meeting the moderator was prepared with a battery of detailed questions about the activities. Thus, the participants were not the owners of the discussion to the same extent as in former meetings). <p>Distributed Material: none</p>
3:3	NOS progression for compulsory school

	<ul style="list-style-type: none"> Participants get the task to, from the basis in their gained experiences, discuss what and how specific NOS issues are appropriate to teach at different educational stages (in a year 1- 9 perspective). Notes are taken by one of the participants. <p>Distributed Material:</p> <ul style="list-style-type: none"> Table with school years and themes for participants' documentation
3:4	<p>Loose ends</p> <ul style="list-style-type: none"> Discussions of teachers' ideas that have been recurrent in interviews, and informal discussions, but that have not been shared or thoroughly discussed in the focus group (e.g. washing powder lab, inquiry with many degrees of freedom). Revisiting progression: teachers discuss the researcher's preliminary analysis of their discussion from last time, make adjustments and put forward new suggestions. <p>Distributed Material:</p> <ul style="list-style-type: none"> Excerpt from transcript of follow up-interview where John describes a teaching activity "the washing powder lab" Table over preliminary analysis
3:5	<p>Summing up evaluations</p> <ul style="list-style-type: none"> Written prompts and diagrams for teachers to answer/fill in providing their thoughts on their individual journeys through the project. (Example: how was your attitude and confidence in relation to your teaching affected by different parts of the project on a scale from zero to five?) Short discussion and sharing of evaluations. <p>Distributed Material:</p> <ul style="list-style-type: none"> Written prompts and diagrams for evaluation
<p>*An agreement was met that pre-distributed material never should exceed 3 pages</p> <p>**A critical incident is defined as:</p> <p>...an event which makes a teacher decide on a course of action which involves some kind of explanation of the scientific enterprise. It may be an event like some practical work going wrong or it may be an event which raises moral and ethical issues about scientific knowledge or the conduct of scientists. These events are often stimulated by pupils saying and doing things, but they may also arise through the action of the teacher, particularly when a demonstration goes wrong. (Nott & Wellington, 1998, p.581)</p>	

Appendix D. Text 1, translated (focus-group meeting 1)

Teaching about Nature of science in compulsory school

Can scientific knowledge change? Will we, one day, be able to explain everything scientifically? Is scientific knowledge the only true kind of knowledge? Can science be combined with religious beliefs? Is scientific knowledge objective?

These are a few examples of questions that can be dealt with in discussions about the nature of science – questions that can be of importance to students' motivation and interest in learning science. Discussions about the nature of science deal with questions about what is typical for science, what the role is of theories and experiments, and what kind of values and assumptions that underlie scientific knowledge and scientific knowledge production.

Research in science education is coherent in emphasizing the importance of that students in compulsory school, within the frame of science education, should be taught about NOS. Teaching about NOS is considered to contribute to students understanding of what science is, how science differs from other disciplines and the degree of reliability of scientific results. With access to this kind of knowledge, the students are believed to be able to develop a critical approach to, and thus an ability to evaluate, claims from different sources (e.g. school, advertising, media) about what science has shown. Students also get possibilities to develop their scientific literacy and thus, their possibilities to take part in, and take a stand in important issues in society. Some research studies also suggest that NOS teaching could increase student motivation and interest in learning science.

What could the nature of science concept mean?

NOS brings to light questions about what is characteristic about, and what affects scientific knowledge and scientific knowledge production. Not everyone agrees that it is possible to describe NOS in a way that is valid for all sciences. However, several researchers argue that there is consensus regarding some overarching themes that are im-

portant and graspable for K-12 students. On the other hand there is still no consensus about which specific aspects should be part of each theme, or the amount of emphasis put on each aspect. Different research groups have tried to summarize these NOS themes in certain lists (tenets). These lists provide a very simplified picture of NOS and are only suggested as framework or as a point of departure for discussions about NOS. A very short version of such a list is provided below:

Themes within the framework of NOS

The list below is inspired by Lederman and colleagues.

- ✓ *Scientific knowledge as **tentative and subject to change**.* How certain or uncertain is scientific knowledge. What kinds of aspects affect change and development in scientific knowledge?
- ✓ *The **empirical basis** for scientific knowledge.* What role does observations and experiments play in scientific knowledge production? How do researchers work with observations and experiments? Do people do things in different ways within different scientific disciplines?
- ✓ ***Subjectivity** in scientific knowledge.* Do the researchers and research communities' points of departure play a role in the development of scientific knowledge? In what way?
- ✓ *The researchers' **creativity and imagination**.* Do the scientist's creativity and imagination play a role in the development of scientific knowledge? In what way?
- ✓ *Science in a **social and cultural context**.* Do social and cultural contexts have any influence on science? What kinds of aspects could be of importance?

In addition to these five themes there are a couple of questions also regarded important to reflect upon:

- ✓ *What is the **difference between observations and inferences**?*
- ✓ *What is the **difference between scientific theories and laws**?*

Teaching about NOS

School inspection and PISA studies show that Swedish students neither have very nuanced views of NOS, nor an understanding of the scientific processes, which prevent students from reaching all national goals. Some studies indicate that focusing NOS in science teaching could contribute to increasing students' understanding and motivation.

Several studies show that students do not gain understanding of NOS by just participating in scientific activities such as experiments and investigations. On the contrary, NOS needs to be made explicit by, for example, reflections and discussions (which could be connected to the aforementioned activities). NOS can be taught in its own right, but can also be taught in the context of other scientific content. No matter how NOS is taught, the teaching of different NOS aspects needs to be carefully planned, both concerning how and when to bring them up in the teaching. Different themes will be suitable in different contexts. There are many ways of reasoning about how to teach NOS in different groups, in connection to various contexts, and for different age groups.

Appendix E. Text 2, translated (focus-group meeting 2)

Teaching NOS in Compulsory School – readings before meeting nr 2

During previous occasions when we have met – when you answered questionnaires, during interviews, and during the first focus group meeting – the point of departure for our discussions have been a couple of themes:

1. *Scientific knowledge as tentative and subject to change.*
2. *The empirical basis for scientific knowledge.*
3. *Subjectivity in scientific knowledge.*
4. *The researchers' creativity and imagination.*
5. *Science in a social and cultural context.*
6. *What is the difference between observations and inferences?*
7. *What is the difference between scientific theories and laws?*

Choosing to try to divide a large and complex area into themes easily leads to a simplified picture. As we have previously discussed, it is not always evident which aspects belong to which theme, and several of the themes overlap. Furthermore, there are many different views and perspectives on what characterizes NOS. As a basis for our next meeting I have chosen to highlight themes 1-3 from a couple of perspectives. When you read the text you may very well add your own examples and questions. Hopefully you will also be able to contribute with ideas from your reflection notes.

Scientific knowledge as tentative and subject to change.

Research has shown that students commonly view scientific knowledge as absolute facts. Is this a reasonable or unreasonable perception? To what degree is science characterized by continuity and to what degree is it characterized by change? Some people, while discussing scientific knowledge, choose to emphasize continuity – much of what is written in today's textbooks will also be valid fifty years from now. Others choose to emphasize that scientific knowledge, both in practice and by principle, never can be fully

proved, and instead is always subject to change. It can be interesting to discuss if a balance between continuity and change can be found.

If scientific knowledge is changing – *what* does these changes mean, *how* do they happen, and *why* do they happen? Since we know that knowledge have changed through history, that models have been modified and/or replaced by new ones, these are the examples that are probably most commonly highlighted (e.g. the heliocentric worldview and the theory of evolution). These historical changes might not be very problematic for students to grasp or reflect upon? But what is it like – can more changes appear or are the theories complete now? What about contemporary science – science-in-the-making – is that science changing or tentative? How do students react to such a message? Is there any reason to learn science if the knowledge cannot be trusted?

The empirical basis for scientific knowledge.

The point of departure for science is that there is a material/physical world that is possible to investigate. Discussions about *how* scientists work to make the results from their investigations as reliable as possible can be connected to reflections from the theme above. There are a number of different aspects (e.g. different methods and the role of the research community) that can be interesting to reflect upon or to highlight in the science teaching.

When it comes to methods in science you sometimes hear about “the scientific method” – what does that mean? Is there one scientific method or are there many? Are there, for instance, different methods depending on the scientific discipline (e.g. physics or biology)? Do scientists always use experiments? Some people argue that it is important that students have knowledge about how to determine if claims, made through experiments and observations, are trustworthy. Many people argue that the critical review that scientific knowledge undergoes is one important aspect of the working method that needs to be emphasized.

Another part of discussions about working methods could deal with how research is organized concerning for example the single scientist, research groups, or large research centers. Scientists today can perhaps mainly be found in other workplaces (e.g. in industrial workplaces) than at universities. (Sometimes this is instead brought up as a part of theme 5 - science in a social and cultural context). In a number of reports students' ideas of a scientist is described as a white male wearing glasses, dressed in a white coat, and surrounded by test tubes. How well does that picture match today's scientists?

Another interesting question deals with the possible limits to what science can find out. What are the boundaries for science? Will we be able to investigate and answer everything one day? A concluding question, that will also constitute a bridge to the next theme, since it is very much connected to that theme, is if there can ever be neutral observations (observable facts) – or do we always observe something from certain points of departure?

Appendix F. Text 3, translated (focus-group meeting 3)

Teaching NOS in Compulsory School – readings before meeting nr 3

During previous occasions when we have met – when you answered questionnaires, during interviews, and during the first focus group meetings – the point of departure for our discussions have been a couple of themes:

1. *Scientific knowledge as tentative and subject to change.*
2. *The empirical basis for scientific knowledge.*
3. *Subjectivity in scientific knowledge.*
4. *The researchers' creativity and imagination.*
5. *Science in a social and cultural context.*
6. *What is the difference between observations and inferences?*
7. *What is the difference between scientific theories and laws?*

At our previous meeting we discussed theme 1-3 and as a basis for our next meeting I have chosen to highlight themes 4-7 from a couple of perspectives. When you read the text you may very well add your own examples and questions. You might also consider if and how these themes play a role in science education in compulsory school.

The researchers' creativity and imagination

Many people argue that even if science is based on observations and logical thinking, creativity and imagination is important in the scientific process. Some people argue that one of sciences' most important missions is to *create* explanations which requires a great deal of creativity. Others argue that the explanations are already there, ready to be *discovered* and that the scientists task is to find them.

Is it true that all scientists use their imagination and creativity? If so, when and to what extent – in the emergence of research questions, in the planning of the investigation, in the investigation or experiment itself, during the observations, during data analysis, during the interpretation, or during the reporting of the results?

It is quite common for people to believe that creativity is very important at the beginning of an investigation. Some people argue that creativity is important at other stages too, for example during data analysis and interpretation. One example of this might be *dark matter* in theories about the evolution of the universe. Dark matter has not been observed, but would solve the problem of, according to researchers' models, missing matter in the universe.

Science in a social and cultural context.

Some persons describe scientific knowledge as universally valid, while others instead describe science as deeply intertwined with the society and the culture in which the scientists live. Some people advocate research free from societal involvement, while others argue that the tighter the connection to society the better, since the research then can be more relevant to the society. In some contexts science is simply described as part of our cultural heritage.

Sometimes science has been perceived as contradictory to, for example, religion. A common view is that there, at least historically, has been a conflict between religion and science when it comes to describing and explaining the world. Some persons argue that this conflict still exists today. Can a religious worldview be combined with science? How can we meet students who feel that their religious views clash with science?

We have an American contemporary example of political, ideological and religious interference in science and research. In this example, the well-known journal *Science*, claimed that the Bush administration had interfered with research through misleading comments, changes, rejections and false reports. Some examples of areas that claimed to be affected by these ideological interests are: sex educa-

tion and contraception information (through deleting information on positive results from prevention programs), the evolution debate (through censorship), and environmental issues (e.g. revisions and manipulation of environmental reports). Can science be disconnected from society, ideologies, politics, economy, and culture? Is it desirable?

Also scientific theories and models have at times shown to be strongly connected to the spirit of the times (scientists are children of their times) and this is often only evident in retrospect. One example of this is how notions of male and female anatomy have affected the way of looking at certain phenomena. Notions of the female anatomy have for example affected observations that has led to descriptions of the female body with exaggerated hips and a small brain, which in turn was used as an explanation to why women were not suited to work with science.

Many people argue that science has been affected by white, western men and that this in turn has influenced the choices of research topics as well as the interpretations of results. Today science is, at least in principle, open to everyone even if practice tells another story. In addition, some people argue that it is important that people with different ideologies and with different opinions participate in scientific activities, to make possible a broad variety of questions, interpretations, and conclusions. Some questions might not even spring to mind or be considered interesting if there is not a plurality of persons participating in the scientific process. Still others argue that personal background and ideologies are insignificant to the research process and its results – the research process is considered objective and independent from the researcher's background.

Research funding is also of great significance to the scientific process. Research takes place in many places and has a broad variety of funding sources. What are the reasons for some research projects being granted a lot of money while other projects are not? Currently under development in the south of Sweden are, for example, a pair of costly accelerators (ESS and Max IV).

What is the difference between observations and inferences?

Many people argue that there is an important difference between observations and inferences, and that this difference needs to be emphasized and made clear to the students through the teaching of science. Lederman (2007) describes observations as leading to descriptive statements about phenomena that are directly available to the senses which are easy to agree upon (e.g. physical characteristics of a living organism). Inferences on the other hand go beyond our senses (e.g. explanations concerning the function of the physical characteristics). Inferences at a higher level could also mean developing models or explanations based on observations of complex phenomena. How you view this is associated with how you view objectivity and subjectivity connected to science – if objective observations is even considered possible (which was discussed during our previous meeting).

Is there a standard lab where this discussion about observation and inferences could be highlighted?

What is the difference between scientific theories and laws?

Some science education researchers emphasize the importance of students knowing the difference between theories, laws and models, while other researchers argue that there is no need to stress these differences. But what do these concepts mean? Are there any differences between the concepts and are there any differences concerning certainty or tentativeness in relation to theories, laws, and models? Is it important to know the difference, and if so how can it be discussed with the students?

It is commonly argued that theories, laws and models are totally different concepts with totally different functions. However, the concepts are used in a variety of ways by different persons from different research areas. One point of view is that scientific models are used to describe the nature, but at the same time you should be aware that the models provide a simplified description. There are many different kinds of models. Some models are for example formulated as

text others as mathematical relationships, while others are more concrete. A model can be viewed as a map, used because it is practical, which neither looks like reality nor provides an overall picture. In many cases different models are used to describe the same reality (e.g. a variety of different models of molecules).

Laws are often claimed to be relations between measurable entities (e.g. the ideal gas law $pV=nRT$). It can also be argued that “a law”, historically, is a concept used to describe relationship thought to be “true”. However, today many people would instead describe laws as mathematical equations. *Theories* can be described as a kind of interpretative framework which explains a larger part of reality. The kinetic theory is one example of such a framework needed to be able to formulate the ideal gas law.

One of the problems with these concepts is that they often have another meaning in an everyday context. The word “theory” is, for example, often used about something for which you only have a guess – ” it’s just a theory”, while in a scientific a ”theory” is instead used for high levels of knowledge about the world.

Which of the concepts theory, model, and law do you use in your teaching – with what meaning ascribed?

Subjectivity in scientific knowledge

In the pursuit to describe reality as accurately as possible objectivity becomes a question. How objective can an investigation or a research project be? Are there different parts of the research process (e.g. in problem stating, data collection, justifying claims, or application) that are more subjective than other parts? Should this be considered a problem or is it just part of science being a human activity?

Some people argue that science concepts, theories, models, and laws are altogether constructed by humans and not given by nature. This view can be very controversial to others, who consider science as providing an accurate picture of reality as it really is. Furthermore, there are also others who discuss a balance between science as objec-

tive or science as subjective in that they regard knowledge as constructed – with different possible constructions of reality – but that reality do provide freedom to construct whatever we want – there is a reality independent from us (which also can be discussed in connection to the previous theme)

As a point of departure for these questions this theme could be viewed from two perspectives. One perspective deals with "personal subjectivity" – the personal values, ideologies, experiences etc. of the individual scientist. Scientists may of course, as well as others, have needs, desires, limitations, and preconceptions. What does this mean considering the knowledge that is produced? How is this handled in a process seeking knowledge and truth? Are these human characters only disadvantageous or can they also be beneficial?

The other perspective deals with questions about to which degree research is driven by, or affected by, views in the research society or research group. Many people argue that research questions do not occur randomly, but instead are put forth within the specific systems of thought patterns/theoretical frameworks which are accepted within a certain discipline. Hypotheses and questions are in that way grounded in a specific worldview. One example of this could be the accelerator build at CERN with the purpose to search for the, theoretically predicted, Higgs particle.

The word subjectivity sometimes evokes strong reactions in discussions about science since objectivity and disinterestedness can be viewed as an ideal in research society. In spite of this it is evident that research groups often are very aware of the influence of bias on observations. In a scientific report it is also common to describe the theoretical perspective that has served as a basis for the research. In relation to this the emphasis on critical review could probably once again be highlighted.

ARTICLES I-IV

II

Nature of Science Progression in School Year 1–9: a Case Study of Teachers' Suggestions and Rationales

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Abstract The inclusion of *nature of science* (NOS) in science education has for a long time been regarded as crucial. There is, however, a lack of research on appropriate NOS aspects for different educational levels. An even more neglected area of research is that focusing on teachers' perspectives on NOS teaching at different levels. The aim of this article is to examine NOS progression in the light of teachers' suggestions and rationales. In order to obtain teachers' informed perspectives, we chose to involve six teachers (teaching grades 1–9) in a 3-year research project. They took part in focus group discussions about NOS and NOS teaching as well as implemented jointly planned NOS teaching sessions. Data that this article builds on was collected at the end of the project. The teachers' suggestions for NOS progression often relied on adding more NOS issues at every stage, thereby creating the foundations of a broader but not necessarily deeper understanding of NOS. Five rationales, for if/when specific NOS issues are appropriate to introduce, emerged from the analysis of the teacher discussions. Some of these rationales, including *practice makes perfect* and *increasing levels of depth* can potentially accommodate room for many NOS issues in the science classroom, while *maturity and experience* instead has a restricting effect on NOS teaching. Also, *choice of context* and *teaching approaches* play an important role in teachers' rationales for whether specific NOS issues should be included or not at different stages. The article discusses the implications for teacher education and professional development.

Keywords Nature of science · NOS progression · NOS teaching · Teachers' perspectives

Introduction and Background

For quite some time, science education researchers have argued that perspectives on nature of science (NOS) ought to be included in science teaching (Lederman 2007; Matthews 2012).

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Arguments are, for example, that NOS knowledge is an important part of scientific literacy (Driver et al. 1996; Hodson 2009), a pathway to understanding other science content (McComas et al. 1998), and a possibility to enhance students' interests in science (McComas et al. 1998; Sjöberg 2010). This has resulted in the inclusion of NOS in curricula and policy frameworks around the world (see Hodson 2014; Jenkins 2013). As a consequence, teachers must handle curricula that both explicitly and implicitly refer to NOS.

NOS teaching practices and teachers' and students' views of NOS have been investigated (Lederman 2007), as have teachers' perspectives on NOS teaching (e.g., Deniz and Adibelli 2015; Henke and Höttecke 2015; Leden et al. 2015). Despite the emphasis on NOS in research and curricula, numerous studies show that NOS is still not a natural part of science teaching. Research has thus far paid less attention to specific NOS issues that could be suitable for different educational levels (some exceptions are described below). Researching teachers' rationales for NOS teaching, and more specifically for NOS progression, could constitute one important facet in striving to understand the gap between research and practice. The present article thus takes a first step by reporting the results of a case study of six teachers' rationales and suggestions for appropriate NOS issues for different school years in Swedish compulsory school¹ (school years 1–9).

NOS Issues for Compulsory School

There is an ongoing controversy regarding the choice of relevant NOS aspects for school science. Suggestions have been put forth from various perspectives. One line of research has advocated lists of NOS items that could be relevant for K-12 students (Lederman 2007; McComas 1998; Osborne et al. 2003). Other suggestions have proposed more detailed descriptions like, for instance, features of science (FOS) (Matthews 2012), and the nature of whole science (Allchin 2011). Another line of research has been inspired by Ludwig Wittgenstein's family resemblance concept. With a family resemblance approach to NOS teaching, both heterogeneity and resemblances between scientific disciplines are emphasized and structured within specific categories. (e.g., Eflin et al. 1999; Erduran and Dagher 2014; Irzik and Nola 2011; van Dijk 2011). The framework of NOS themes used in the present study has its point of departure in the NOS tenets described in Lederman (2007). However, the themes have been developed with inspiration from the abovementioned debates as well as different science studies perspectives. A development means that the NOS themes become more flexible and broad, to allow for the inclusion of multiple perspectives and discussions of both general and context-specific characteristics of science (see below).

However, regardless of perspective, science education researchers agree that an important task for science education is to change or broaden students' perspectives on NOS. This is due to school science often having a narrow focus on logical and conceptual elements (Clough 2006; Duschl et al. 2006), causing students to hold a simplistic picture of scientific knowledge as absolute facts emanating from observations that automatically provide true answers about nature (Lederman 1992). In order to challenge these views, science education needs to provide students with a wide variety

¹ Compulsory school years 1 (age 7) to 9 (age 16). There are three stages in compulsory school, where each level has different goals. Goals are set for year 3, year 6, and year 9.

of perspectives on different aspects of NOS. These perspectives should be broadened and deepened over the school years. Some suggestions for NOS issues are visible in different frameworks such as Benchmarks (AAAS 2009), A Framework for K-12 Science Education (National Research Council 2012), and Next Generation Science Standards (NGSS Lead States 2013) as well as in curricula for different countries. In some of these documents (e.g., Benchmarks (AAAS 2009)), a structure for NOS progression is clearly presented.

Research on NOS Progression

Progression Concerning Students' NOS Knowledge In some research studies (e.g., Carey and Smith 1993; Driver et al. 1996; Perry 1999; Smith and Wiser 2015), age-related trends in students' views of NOS have been outlined. Driver et al. (1996) suggest some examples of appropriate learning activities from an epistemological perspective and from social contexts of science. Perry's (1999) developmental schemes concern stages of intellectual growth from dualism (right-wrong, good-bad) to different forms of multiplicity, moving on to contextual relativism—a scheme that outlines steps for students' meaning making of diversity of knowledge. The schemes are based on empirical studies of students in the college years, although Perry considers them to have more general implications. In his introduction to Perry (1999), Knefelkamp links different teaching approaches to Perry's developmental scheme. He argues that students in the early stages of Perry's developmental model need more guided structures and experiential learning than students in later stages. Furthermore, in science education research literature, subjective and socio-cultural aspects of science are often described as more difficult for young children to grasp than other NOS aspects (Akerson et al. 2011).

Different theories have affected the ideas of what students can learn at different stages (Bell 2006). One such theory is the biologically based Piagetian *stage theory*, and another is *cognition theory*' (Carey & Smith 1993; Smith et al. 2000). According to stage theory, students' abilities for abstract thinking affect their understanding of NOS and younger students' supposed inability for abstract thinking hinders a deeper understanding of NOS. Cognition theory has a more flexible view of what students can learn. Bell (2006) draws the conclusion that curricula often have been guided by stage theory, which might have set unnecessary limits to the development of children's abilities to learn to reflect on abstract NOS issues. He further argues that these limits may have contributed to narrow pictures of NOS. Despite this, he still advocates modesty (waiting with the most abstract concepts until later in the educational system) and that "science educators must consider the appropriate timing of nature of science instruction" (Bell 2006, p. 440). The present article takes on the task of *considering appropriate timing* by examining teachers' perspectives.

Research Suggestions Concerning a Progression for NOS Teaching In learning progression frameworks (Duschl et al. 2011), the main focus has often been on factual and conceptual knowledge, while NOS issues have only played a very modest part (Smith and Wiser 2015). In other lines of research, there are some rare examples of research on possible pathways to NOS progressions (e.g., Abd-El-Khalick 2012; Erduran and Dagher 2014). In Abd-El-Khalick (2012), a NOS progression is outlined with

increasing levels of depth and complexity from elementary school (where certain NOS aspects are addressed as general and unproblematic) to teacher education (where the NOS aspects are emphasized as interrelated and where controversial issues should be addressed). Abd-El-Khalick defends the level of generality in elementary school by arguing that this view is still more accurate than the mythical pictures of science that are often taught. He provides examples from *target NOS aspects* that should be addressed at different educational levels. Below is the example of *tentative NOS* where progression could be described as: first, students should know *that* knowledge can change, second, they should know something about *how* it changes, and finally they should also have some knowledge of *why* it changes (see Table 1).

Erduran and Dagher (2014) outline a NOS progression based on a *family resemblance approach* (FRA). In this progression, NOS aspects (FRA categories) are linked to science teaching both horizontally (connected to science content) and vertically (connected to school year). In this way, the authors argue that students have the opportunity to encounter each aspect of NOS at every school year, connected to a variety of science topics at an increasing level of depth and complexity. Below is an example of *vertical articulation* for social aspects of NOS (social-institutional system) in Erduran and Dagher (2014).

In both Abd-El-Khalick (2012) and Erduran and Dagher (2014), the recommended NOS aspects to address in younger years are similar to those addressed later in the educational system, but they should “be expanded upon in greater complexity and sophistication” (Erduran and Dagher 2014, p. 170). While Abd-El-Khalick focuses on the overarching target NOS aspects, Erduran and Dagher connect specific issues to different contexts. Choosing different science contexts for the NOS issues thus becomes another way to accomplish progression by broadening students’ understanding of NOS. In the above example (Table 2), an environmental context is chosen for the teaching of social aspects of science in primary school, while the context in secondary school is genetic engineering (Erduran and Dagher 2014).

Only a few studies report teachers’ reflections on appropriate NOS teaching at different levels. One example is Deniz and Adibelli (2015), which shows that what the teachers consider to be developmentally appropriate concerning NOS plays an important role in their choices regarding NOS teaching. In their study, the teachers related developmental appropriateness to either teaching approach (e.g., using more complex activities with older students) or to the NOS aspect per se (e.g., difficulties in teaching theory/law relationship to young students). Leden et al. (2015) found that the teachers expected that some NOS aspects would be too abstract or too difficult for young children to grasp (e.g., social aspects of science). Another example is Henke and Höttecke (2015), who studied teachers’ perspectives on obstacles during the implementation of history and philosophy of science in science (physics) teaching.

Table 1 Progression for tentative NOS as described in Abd-El-Khalick (2012, pp. 1048–1049)

Elementary school		Secondary school
Scientific knowledge is subject to change over time	Scientific knowledge changes in, at least, two fundamental ways: (1) it is expanded through accretion, and/or (2) discarded and altogether replaced with new knowledge.	Scientific knowledge is expanded, revised, or rejected because of two fundamental reasons: (1) new evidence is brought to bear [empirical NOS], and/or (2) existing evidence is reinterpreted in light of theoretical advances [Theory-laden NOS]

Table 2 Progression for understanding science as a social-institutional system in Erduran and Dagher (2014, abridged version pp. 169–170)

Primary school (environmental context)	High school (genetic engineering context)
Focus on scientific ethos, professional activities, and social certification. How does what they [the students] did in class resemble what scientists do? How do scientists establish their findings? Do they change their ideas? How different issues affect societal decisions (e.g., biotic diversity and land use).	Focus on scientific ethos, professional activities, social certification, and competition among scientists. How does what they [the students] did in class resemble what scientists do? How do scientists get better results? What societal impact does the topic carry? What ethical issues confront research in this area? Financial and political issues. Who owns the knowledge that the scientists produce? What role do legal systems and citizens play?

These teachers, as did the teachers in Deniz and Adibelli (2015), chose specific teaching approaches to meet students' needs in different school years. In Henke and Höttecke (2015), the teachers chose storytelling and everyday examples for teaching history of science (with references to NOS) in the early years.

The present article does *not* propose a theoretically developed progression for NOS through the specific learning progression framework as described in, for example, Duschl et al. (2011). Instead, we acknowledge that there could be multiple paths to progression (c.f. Johansson and Wickman 2011, 2012; Wickman and Ligozat 2011) and follow a line of research where teachers' perspectives are investigated (c.f. Deniz and Adibelli 2015; Henke and Höttecke 2015). Duschl and Wright (1989) suggest that teachers should be relieved from the task of choosing appropriate content on account of, for instance, lack of sufficient NOS understanding. However, since teachers by necessity become involved in such considerations every day, due to unspecific references to NOS in many curricula and a lack of robust teaching traditions in this area, we argue that it is of major importance to learn more about teachers' perspectives. Knowledge about teachers' perspectives can contribute with insights about the difficulties for NOS to become a substantial part of science teaching, as well as insights about how teachers' perspectives on NOS teaching at different educational levels need to be challenged and/or broadened. Such knowledge can in turn constitute important background information in the development of teacher education courses in the future, and in the long run become a tool to bridge the gap between research and practice.

Aim

As already established, research on what NOS issues are appropriate at different stages in the educational system is scarce. Even more scarce is research on teachers' perspectives on NOS progression. Therefore, the aim of this article is to shed light on in-service teachers' suggestions and rationales for what they consider to be appropriate NOS issues at different school years in Swedish compulsory school. The NOS framework that served as a point of departure for the teacher discussions is presented below. The research questions guiding this study are:

- What NOS issues do teachers suggest as appropriate at different stages in Swedish compulsory school?
- What are teachers' rationales for suggesting these issues?

Methods

Context

In Sweden, science (i.e., biology, chemistry, and physics) is studied by all students throughout compulsory school. Although NOS is included in the Swedish national curriculum, and has been for the last couple of decades (Johansson & Wickman 2012), the phrase *nature of science*” (in Swedish *naturvetenskapernas karaktär*) is not mentioned in the current curriculum (Skolverket 2011a). NOS aspects are, however, referred to both implicitly and explicitly in the curriculum and the intention to make NOS part of science teaching is strengthened by an official commentary on the curriculum (Skolverket 2011b). This is available for each subject and provided with the purpose to serve as a helpful tool for teachers when interpreting the intentions of the curriculum. In the commentary, the term *nature of science* is 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)

Participants

In order to investigate teachers’ perspectives in-depth, we chose to involve six teachers in a project that spanned 3 years.² The teachers were asked to participate in the project after having responded to the VNOS-C questionnaire (Lederman et al. 2002) and completed an extended follow-up interview about NOS and NOS teaching (see Leden et al. 2015). The participants were chosen with the intent that the group would comprise experiences that spanned the entire compulsory school (school years 1–9, ages 7–16). All participants were qualified for science teaching for the school years indicated in Table 3. The teachers taught at four different schools and all of them had significant teaching experience, i.e., over 10 years (see Table 3 for details). During the project, the teachers gained experience of NOS and NOS teaching from readings, discussions, and implementation of NOS activities, which enabled us to gain their informed perspectives at the end of the project. For more details about their experiences and the design of the project, see below and Leden et al. (2015).

Research Project and Data Collection

Teachers’ NOS Experience Based on Their Involvement in the Research Project The research project spanned 3 years and included 12 focus-group meetings, 2 hours (h) at a time (see Fig. 1 for an outline of the project and focus group activities). A fruitful way to trigger discussions among the participants is for them to have access to material with which to work in

² There is one exception to this. Emma has replaced another participant and has only participated in the last year of the project.

Table 3 Pseudonyms and particulars for teachers participating in the project

	Years in teaching	Teacher education aimed at school years
Agnes	18	1–7
Carolyn	34	4–6
Ella	19	1–7
Emma	14	4–9
John	17	4–9
Nina	12	4–9

the focus group (Wibeck 2010). Thus, in connection with the focus group meetings the participants were often provided with working material from the moderator of the discussions. This material consisted of short texts to read before the meetings or tasks to work with during the meetings. The texts and discussions were based on a framework consisting of seven NOS themes (the seven themes were later reduced to five themes based on the teacher discussions). The NOS themes were comprehensive and broad in order to allow for multiple perspectives and a large variety of NOS issues to be included as suggested in, for example, Allchin (2011) and Erduran and Dagher (2014). They have a starting point in the NOS tenets described by Lederman (2007), but were further developed and inspired by science studies perspectives as suggested in Duschl et al. (2006). The themes are briefly described below (for a more in depth description see Leden et al. 2015):

- *Tentative aspects of science* was concerned with continuity/change and certainty/uncertainty in relation to scientific knowledge. Both historical and contemporary examples coupled to different disciplines are of importance.
- *Empirical aspects of science* was, in addition to the significance of empirical contributions to science, broadened to include theoretical contributions and their interconnection with empirical contributions, and aspects concerned with scientific practices (c.f. Erduran and Dagher 2014). Relevant topics are, for example, the roles and relations between observations, experiments, models, and laws; trustworthiness; diversity of methods; and boundaries of science.
- *Subjective aspects of science* was concerned with subjectivity and objectivity in relation to scientific knowledge and at different stages of the research process. Relevant topics are, for example, theory-laden/neutral observations and background factors.
- *Creative aspects of science* was concerned with creativity and rationality in relation to the research process (from problem stating to interpreting observations and inventing explanations).
- *Socio-cultural aspects of science* was concerned with the extent to which science is influenced by society/culture, and the extent to which science is universal. Both historical and contemporary contexts are important to this theme as well as a number of perspectives such as: economy, politics, and social practices of different scientific disciplines.

During the second and third years, the teachers planned NOS activities that were later implemented in their own classrooms and thereafter reflected on in the following focus group meetings (see Fig. 1). One of the activities was highly contextualized and focused mainly on subjective and socio-cultural aspects of science through reading and discussing web-based information and news articles about a socio-scientific issue. The

Fig. 1 Outline of the research project

other activity was a black-box activity where the students encountered all of the above described aspects of science. Thus, at the end of the project, even if the teachers were not

experts on NOS, they had gained a higher level of experience in NOS and NOS teaching than could be expected from most teachers in Sweden.

Data This article builds on data from the recorded discussions from three focus group meetings (10a, 10 b, and 11; see Fig. 1) at the end of the project when the teachers had experience from both NOS discussions and NOS teaching. During the first two meetings, the teachers were brought together to suggest appropriate NOS issues for years 1–3, 4–6, and 7–9. The NOS theme framework (see above) served as a basis for the discussions. These two focus group meetings dealt with the same things, but due to practical reasons not all teachers had the chance to participate at the same meeting. During the third meeting, four of the participants had the opportunity to elaborate on and make changes to a summary of their former discussions (summarized in a table by the first author). The teachers clarified their meanings and provided further examples, but no major changes were suggested. The first author of this article was also the moderator of all focus group meetings. The meetings were audio recorded and fully transcribed.

Analysis

The first part of the analysis focused on the suggestions put forward by the group regarding different NOS issues for each educational level. It followed the phases of thematic coding analysis described in Robson (2011) and was based on repeated reading and coding of the focus group transcripts. The suggestions were coded using the themes described above as a lens. The coding was started in the focus groups by the participants themselves since the themes were used as a trigger for the discussions. However, during the continued analysis there was a need for re-coding, structuring, and interpretation due to the teachers', sometimes, unstructured debate. The teachers jointly made a few notes in a table, but most of their suggestions were verbal as they moved back and forth between topics. The interactions and negotiations among the participants provide data on consensus and diversity. This makes focus groups suitable for learning about taken-for-granted patterns, meaning making, and tensions within a certain group (Halkier 2010). In this study, diverging suggestions were, at times, put forward during the meetings. This article presents all suggestions that were up for thorough discussion (see Table 4). Diverging suggestions and discussions demonstrate that there are interesting tensions between different rationales. The analysis of focus group data needs to seek a balance that acknowledges the interaction between the individual and the group (Morgan 1997). The analysis in this article is directed towards the discussions taking place in the group and not on statements made by single teachers. Thus, quotations in the “**Results**” section are presented as part of a joint, ongoing discussion and individuals only become visible (represented by numbers) when clarification is required in a dialogue.

The second part of the analysis focused on the teachers' rationales for their suggestions. In this part of the analysis there were no pre-developed categories, but instead an empirically grounded analysis was performed (Glaser and Strauss 1967). The transcripts were searched for patterns in the teachers' rationales. A provisional categorization was made, followed by a repeated restructuring as a result of comparisons of the categories to each other and to the data. This finally resulted in the five rationales described below. NVivo was used as a tool in both parts of the analysis.

Results

In this section, we present the results of the analysis of the teachers' suggestions and rationales with respect to NOS progression in compulsory school.

Teachers' Suggestions of NOS Issues

A summary of the teachers' suggestions regarding appropriate NOS issues at different school levels can be found in Table 4. The teachers never suggested that the students should learn to memorize certain *facts* about NOS. Instead, they always discussed NOS as a useful tool when dealing with, for example, socio-scientific issues, argumentation, and critical thinking.

Overall, there were two different kinds of progression represented in the teachers' suggestions. In the most commonly described progression, the number of issues within each theme gradually increased over the years. This kind of progression was suggested for empirical and socio-cultural aspects of science (see themes 2 and 5, Table 4). It mainly generates possibilities for a *broad*er understanding of NOS. In the other kind of progression, the same issue was discussed in more complex ways through, for example, adding perspectives and by elaborating on *how* and *why* science is changing. Such a progression generates possibilities for a *deeper* understanding of specific NOS issues. This kind of progression is more rarely described by the teachers and never suggested for an entire theme, but is used only for a few specific issues: science as changing and the role of background factors (themes 1 and 3, Table 4).

For the first kind of progression, based on adding issues, the greatest differences in the teachers' choice of NOS issues could be found between years 1–3 and 4–6 (see Table 4). For years 1–3 fewer issues were chosen. This was, for example, the case for socio-cultural aspects (theme 5, Table 4) where different world views was the only issue chosen for years 1–3, while a great variety of issues, such as economy and values, were suggested for years 4–9. However, for years 4–6 and 7–9, only a few issues differed and sometimes there were no differences at all, as was the case for subjective and creative aspects (themes 3 and 4, Table 4). Important to note, however, is that the teachers actually do suggest issues from all of the above NOS themes to be taught at all stages.

The theme demonstrating the most obvious examples of the latter kind of progression was *tentative aspects of science* (theme 1, Table 4). For this theme, more complex perspectives were suggested over the years. One example is that for years 1–3 the students should, according to the teachers, know that scientific knowledge has developed during history, while students in years 7–9 should know that there are current topics that lack answers and where uncertainty prevails (e.g., diverging theories in frontline science). This means that students at different stages could be presented with different images of science; younger students will be presented with the image of a science in progress, while students at later stages will be provided with additional images of science as uncertain (Table 4).

Teachers' Rationales

To better understand why teachers suggest certain NOS issues for specific school years, the transcripts were examined for their motives. This part of the analysis resulted in the identification of five rationales:

1. *Maturity and experience.*
2. *Increasing levels of depth.*

Table 4 Summary of teachers' suggestions regarding NOS issues at different stages

NOS theme	NOS issues school years 1–3	NOS issues school years 4–6	NOS issues school years 7–9
1. Tentative aspects of science	<ul style="list-style-type: none"> • Knowledge has changed throughout history • Knowledge can change thanks to new instruments • Argumentation is part of establishing factual knowledge 	<ul style="list-style-type: none"> • Knowledge has changed in recent time. • Knowledge can change thanks to new interpretations • Argumentation is part of establishing factual knowledge 	<ul style="list-style-type: none"> • Knowledge can be uncertain and different theories can coexist • Values and political agendas can play a role in what and how scientific knowledge becomes established • Argumentation and communication is part of establishing factual knowledge
2. Empirical aspects of science	<ul style="list-style-type: none"> • Change one thing (variable) at a time during investigations • Differing results 	<ul style="list-style-type: none"> • Fair tests • How investigations can be improved • Discipline specific differences (concerning, e.g., instruments and methods) • Teacher uses the word “model” (from year 5) 	<ul style="list-style-type: none"> • Robust and trustworthy investigations • Sources of error • Controlling variables • Connections between procedures, data and conclusions • Discipline specific differences (concerning, e.g., instruments and methods)
3. Subjective aspects of science	<ul style="list-style-type: none"> • Prior knowledge can affect interpretations • Trustworthiness in connection to authority/status (from year 3) 	<ul style="list-style-type: none"> • Background (prior knowledge, values, social factors) can affect interpretations • Bias and fraud 	<ul style="list-style-type: none"> • Models and how they are connected to reality • Background (prior knowledge, values, social factors) can affect interpretations • Bias and fraud
4. Creative aspects of science	<ul style="list-style-type: none"> • Creativity in relation to planning investigations 	<ul style="list-style-type: none"> • Creativity in relation to: planning investigations, interpretations and conclusions 	<ul style="list-style-type: none"> • Creativity in relation to: planning investigations, interpretations, and conclusions
5. Socio-cultural aspects of science	<ul style="list-style-type: none"> • Differing worldviews at different times and places 	<ul style="list-style-type: none"> • Economic issues • Values • Religion • Differences in communication of scientific results to meet different interest groups • How are undesirable results handled? • Varying research foci in different countries 	<ul style="list-style-type: none"> • Economic issues • Values • Religion • Differences in communication of scientific results to meet different interest groups • How are undesirable results handled? • Trends • Can facts be produced to fit certain purposes?

3. *Practice makes perfect.*
4. *Choice of context.*
5. *Teaching approaches.*

The different rationales are intertwined and not exclusive. Each rationale is described below and illustrated with excerpts from the focus group discussions.

Maturity and Experience The teachers talked about their students in terms of having inherent attributes/abilities linked to their age or maturity. One such ability, often referred to by the teachers, was the ability for abstract thinking:

Because it's so amazingly abstract when you can't touch it or see it properly. So that to understand that models are just models, they [the students] probably actually need to be rather old because that abstractness is hard.

Due to the students' maturity, certain NOS issues and ways of talking about science were chosen as appropriate for different school years. Some NOS themes, specifically subjective and socio-cultural aspects of science (themes 3 and 5, Table 4), were considered particularly abstract. For that reason, the teachers often argued that they should be avoided in the earlier years (c.f. Akerson et al. 2011; Leden et al. 2015). Despite this, the teachers suggested some issues from these themes that could be comprehensible to younger children. One example is *differing worldviews* (theme 5) that could be made comprehensible (less abstract) through narratives or historical anecdotes (see also *teaching approaches*). This suggestion is also in line with demands in the national curriculum that teaching should deal with: "Narratives about science from earlier times, and the attempts of different cultures to understand and explain phenomena in nature" (Skolverket 2011a, p. 127). Meanwhile, other NOS themes, specifically empirical and creative aspects of science (themes 2 and 4), were talked about as just the opposite. They were suggested as appropriate for early years since they were regarded as concrete and could often be dealt with in combination with hands-on tasks (see concrete approaches in *choice of context*). Creativity in science (theme 4, Table 4) was even considered easier to teach to young students since they were talked about as being more creative and less worried about right and wrong. The teachers argued that young students have a fundamentally different way of handling creativity: "The younger they are the more imagination they have".³

Another way in which the teachers made suggestions related to age was their expectations of students' *experiences*: if the students are too young to have experienced certain everyday issues or scientific issues then they will not be able to understand the NOS issues that are connected to them. One example of this was that NOS issues related to political decisions (theme 5) were considered most suitable for the later stages of compulsory school, as younger students were not expected to have enough experience of political matters. Another example was NOS issues (e.g., scientific knowledge as uncertain, in theme 1) that, according to the teachers, were best addressed in connection to frontline science. In these cases, young students

³ This is, however, connected to the teachers' suggestions that, for young students, creativity in science is supposed to be taught through students' own experiences of creativity during, for example, the planning of investigations, and not connected to scientific research practices (see also Authors 2015). For the later stages, there were other suggestions connected to creativity (see Table 4).

were expected to have no/limited experience, and therefore this NOS issue ought to be dealt with in later school years.

Although arguing from the point of maturity and experience was common when the teachers justified their suggestions, it should be noted that the teachers emphasized that students in a certain school year could be at different levels of maturity. The association between age and ability for abstract thinking was also questioned: "...I think you should have high expectations on younger children /.../ I think that people generally underestimate younger children". Another example of questioning the relationship between age and ability is the following quotation where lack of creativity among older students is explained by school culture (through, for example, certain assessment traditions) rather than maturity. "Here [in years 7–9] it's somehow like, in some implicit way, I don't dare to be wrong because then I flunk".

Increasing Levels of Depth Another common way of talking about NOS progression was through arguing that the teaching of a specific NOS issue could be dealt with at different levels of depth depending on school year. This meant that many issues within each theme, according to the teachers, could be addressed at any stage if addressed at the appropriate level of depth. In the following quotation, the teachers talked about how to teach scientific knowledge as changing:

Teacher 1: ...it's like that all the time. They [the scientists] learn more and more.

Teacher 2: Yes, but I believe that students can have difficulties seeing precisely that. They more or less declare early scientists as stupid: "How could they believe that?"

Teacher 1: Well yes, but I believe that it is important that you can look at: this is what people believed before, now they believe this, what will they believe in the future...

Teacher 2: Well, I think you could take that discussion through all [school] stages and then as you say [referring to an issue discussed earlier] it gets deeper and deeper/.../

Moderator: Explain once more what you mean by deeper and deeper.

Teacher 2: That they can analyse and reflect in a deeper way, due to more knowledge and greater competence...

In the rationale, *increasing levels of depth* NOS progression became more explicit than in other rationales, in that the suggested issues should be treated at a greater level of complexity/depth at later stages. Most of the time, however, the teachers were not very precise in respect to what "deeper and deeper" meant for each specific issue. Yet, by studying the suggestions for tentative aspects of science (theme 1, Table 4), which was the theme discussed above, we can see that, in this case, the increasing level of depth could be related to a greater amount of reasons for scientific knowledge to change in relation to a variety of contexts.

Practice Makes Perfect Unlike arguing from the point of *maturity and experience* (where different issues are suggested for different stages) or *increasing levels of depth*, arguing from the point of *practice makes perfect* means the exact opposite: the same thing should be taught irrespective of stage. Even if some NOS issues, and sometimes entire NOS themes, were talked about as hard for the young students to grasp (see *maturity and experience*), the teachers still suggested that such issues should be taught at early stages. The teachers argued that by confronting students with abstract issues at early stages, they would be able to better understand these issues at later stages. One example of this is the following dialogue about using

articles as a basis for discussions about differing interpretations among researchers (theme 3, Table 4):

Teacher 1: Still you have to be trained. You have to be trained to get in to it.

Teacher 2: Yes, you could probably start early so that you somehow get used to it...

Teacher 1: But, it's not for certain that you could be particularly good.

Teacher 2: I don't really feel that you could wait until school year nine, but still, it feels like they would have the best preconditions to manage it. But then you have to have encountered it before in some way.

Teacher 1: Then you have to have started before.

Thus, in a way, through such a rationale, the teachers did not argue for a NOS progression in terms of the choice of issues—no differentiation was made. Instead, according to the teachers, the same issues ought to be repeatedly addressed so that the students in the end would have acquired more knowledge about them. Consequently, through this rationale, a progression for students' *learning* about NOS is discussed, even if no progression is suggested for the actual teaching.

Choice of Context The teachers frequently argued from the point of *choice of context*. Here, context should be understood in a broad way: sometimes it relates to the teachers' discussions about scientific context and sometimes it relates to specific examples or authentic cases. Through this rationale, the teachers did not suggest a progression for a specific NOS issue; instead, the same issue was suggested for all levels but connected to different contexts: "...you could in fact bring that up at any stage if only you have a good example...". Suggestions and examples of differing contexts were, however, often lacking in the teachers' suggestions, which is something that the teachers themselves identified as a problem—the "good example(s)" were absent.

The teachers connected the choice of contexts to notions of abstract and concrete (see also *maturity and experience*). They argued that concrete contexts were suitable for less experienced (young) students and connected to the students' own experiences, everyday examples, and "simple" science. Abstract contexts were associated with more experienced (older) students and connected to contemporary cases, advanced science, and science in the making.

...well, the older they get the more unfamiliar it should preferably be able to be, but of course it must be easier with a well-known situation also in school year nine...

Consequently, teachers chose concrete contexts for the early stages and more abstract ones for the later stages. However, as in the example above, the teachers could also choose concrete contexts for the older students in order to facilitate the addressing of an abstract issue.

A typical example of arguing from the point of *choice of context* concerns tentative aspects of science (theme 1, Table 4). For this theme, the teachers suggested different contexts for learning about scientific knowledge as open to change. For the early stages, the universe closest to Earth (the moon) was chosen as a context: "the moon—even the smallest kid knows what that is". For the later stages, the solar system and then the entire universe were chosen—further away from the student in both space and time, as well as connected to more complex science. The teachers argued that concrete contexts offer possibilities to start early with difficult topics such as being involved in critical thinking connected to, for example, subjective

aspects of science (theme 3, Table 4): “You can do it at primary school [school years 1–3] if it is [a] concrete enough [topic]”.

Connecting a certain issue to different contexts could be a starting point for NOS progression. The teachers argued that there is a possibility that more complex science concepts/areas could lead to more complex NOS issues.

I think these things go hand-in-hand because when the content becomes more abstract then it becomes more abstract in subjectivity—well, in explaining subjectivity [about subjectivity in science theme 3, Table 4].

Teaching Approaches The teachers talked a great deal about the importance of choosing appropriate teaching approaches for NOS teaching at each educational level. Different teaching approaches were, in the teachers’ discussions, connected both to stage and specific NOS issues. This connection played a role for when a certain NOS issue could be introduced. Consequently, if an issue could be taught through a concrete or hands-on-approach then it was suggested for the early school years, otherwise it would have to wait. One example is that teachers connected hands-on approaches to creative or empirical aspects of science (themes 2 and 4), which, according to them, make these aspects easy to start with at early stages. On the other hand, issues connected to socio-cultural aspects of science (theme 5, Table 4) were considered difficult to approach in a concrete way, and thus made them more appropriate for later stages.

However, in many ways, *teaching approaches* also resemble *choice of context* in that it became a way of discussing NOS progression without actually suggesting a differentiation concerning the NOS issues for different educational stages. That is, the same NOS issue was often suggested for all levels but with different teaching approaches. This could be understood as either a way to avoid suggesting a NOS progression, or as an implicit way of suggesting it.

Firstly, emphasizing teaching approaches could be a way to avoid having to make difficult decisions on a differentiated NOS.

...Well, I think that the level of the knowledge is probably not excessively higher /.../
Instead it’s more like you repeat it and maybe tell it in another way /.../ Perhaps you go through it more theoretically.⁴

Suggesting the same NOS issues but changing approaches could, however, create opportunities for an early start with difficult issues. One example is group work, which was often suggested for the early stages as the students would then be able to scaffold each other in discussions about abstract NOS issues.⁵

Secondly, suggesting different approaches could actually mean progression for NOS as well, although this is not clearly pronounced. Thus, even if the same NOS issue is suggested for all stages, the changed approach could mean that a deeper or more complex understanding is achieved. This is exemplified when teachers argue that the students will gain different levels

⁴ Here, theoretical is suggested as opposed to a practical approach (e.g., in the context of discussing molecule models, the teacher writes or draws pictures on the table, as opposed to role play among students).

⁵ This is something that the teachers in this study have experienced from trying activities in their classes connected to socio-cultural aspects (theme 5, Table 4).

of understanding if an issue is mentioned in a discussion led by the teacher, or if the students are urged to write their own article about it.

Discussion

Despite a long-lasting emphasis on NOS in science education research, NOS is seldom a self-evident part of science teaching. This article is an attempt to examine the gap between research and practice with a starting point in teachers' perspectives. From previous research (e.g., Deniz and Adibelli 2015), we know that teachers' considerations about developmentally appropriate NOS are important for their choices with regards to NOS teaching. However, although much research has been carried out on NOS teaching, there are only a few contributions to the field when it comes to NOS teaching at different levels in the educational system (among these are Abd-El-Khalick 2012; Erduran and Dagher 2014). The present article adds to previous research with deeper knowledge about teachers' perspectives on these matters. The teachers in this study have experience from many years of science teaching. Furthermore, as participants in a longitudinal research project (see above), they have regularly discussed NOS and NOS teaching, as well as developed, implemented, and evaluated NOS lessons in their science classes. With these experiences as a background, we asked them to talk about relevant NOS issues for different school years, and how a progression with respect to different NOS themes could be built into the compulsory school syllabus. Knowledge about teachers' rationales can help us understand factors that are taken into consideration by teachers and are important to them in their everyday practice. Thus, the results presented in this article constitute a valuable complement to the suggestions and theoretical discussions about NOS progressions in the science education literature. This knowledge can also serve as a basis when trying to meet pre-service and in-service teachers' needs in teacher education and in professional development courses. This is a first step towards trying to understand teachers' choices and rationales with regard to NOS teaching at different levels in the educational system. More studies in different contexts are certainly needed. Below the results are discussed in relation to previous research on NOS teaching.

Teachers' Suggestions

In science education literature, there are some examples of research-based suggestions for NOS progressions. As seen above, these suggestions include a broader span of NOS issues and different contexts at later stages (e.g., Erduran and Dagher 2014), and/or a deeper treatment of specific NOS issues (e.g., Abd-El-Khalick 2012). However, the paths to progression through broadening or deepening are intertwined and hard to separate from one another. To offer different perspectives on an issue could mean broadening through gaining understanding about more detailed issues, and deepening through creating possibilities for an increased level of complexity on the same issue.

Another issue discussed in the literature is at what stage NOS teaching could start and what kind of NOS issues could be introduced for young students (e.g., in elementary school). Abd-El-Khalick (2012), for example, provides rather general and un-complex suggestions for the early years. Other studies (e.g., Akerson et al. 2011) discuss socio-cultural aspects of science as particularly difficult to introduce to the youngest students. In contrast, the teachers in this study

sometimes suggest what they themselves describe as abstract and complex issues at earlier stages, since they argue that there are gains to be made by starting early (see also below). This is in line with the progression outlined by Erduran and Dagher (2014), who present a large variety of topics at early stages.

The results presented in this article show that the progressions suggested by the teachers primarily means adding more issues for later stages, than deepening the perspective of already introduced NOS issues. This builds a certain kind of NOS progression that broadens the students' understanding of NOS. Thus, it is not certain that the kind of progression that is visible in the overview of these teachers' suggestions will constitute a basis for a considerably deeper understanding of a specific NOS issue. In contrast, Abd-El-Khalick (2012) outlines a progression for a certain *target NOS aspect*. In the example of tentative NOS (see above), progress is stretching from scientific knowledge is changing to *how* and *why* this happens. The results discussed in this article show that such elaborations on how and why are less common, although not missing, in teachers' suggestions. However, it is important to note that teachers' suggestions must be interpreted in light of their rationales, as some rationales open up for a more complex understanding of the chosen NOS issues.

Teachers' Rationales

We have presented five different rationales that seem to guide the suggestions put forth by the teachers. Some of these rationales provide an obvious potential for the inclusion of NOS in classroom practice, while others will be more likely to hamper the inclusion of NOS.

Arguing from the point of *practice makes perfect* and *increasing levels of depth* could have a positive influence on NOS teaching—everything becomes possible. Through these rationales, a number of issues can be brought to the fore even at early stages—issues that could be returned to over the years either as some sort of repetition or at greater levels of depth. In contrast, there is a risk that arguing from the point of *maturity and experience* could have a negative influence on the introduction of NOS issues. However, this rationale is the most explicit way of outlining a progression for NOS—some issues are suggested for early stages and some issues for later—focusing on what is considered abstract and concrete for children at different educational levels. Following such a rationale, certain NOS issues are excluded from science teaching in the early years since they are considered to be too abstract. This is in line with stage theory and could perhaps lead to unnecessary restrictions/constraints to NOS teaching in general (Bell 2006) and to NOS teaching for younger students and certain NOS themes. We know from previous studies (e.g., Akerson et al. 2011) that subjective and socio-cultural aspects of science are often considered more appropriate for later stages in the school system. There could, however, be some reason to problematize this notion. One example of how multiple issues from the “social-institutional system” (as well as the other FRA categories) are proposed already in primary schools is Erduran and Dagher (2014). For NOS to become a part of science teaching in the early years, teachers will need examples where they can see this happening. Such “success-examples” could constitute one way to challenge perceived difficulties regarding maturity and experience. Thus, there is a need for more research about NOS teaching and young students (one example of research on NOS in the early years is Akerson and Donnelly 2010). There is also an urgent need for good examples of how NOS can be taught in a meaningful way in years 1–3.

Arguing from the point of *teaching approaches* or *choice of context* can cause constraints as well as possibilities for NOS teaching. Opportunities arise when teachers find certain ways to approach issues that are considered abstract. One of their suggestions, in line with Kniefelkamp in Perry

(1999), is more hands-on approaches for younger students. Constraints appear when teachers do not have access to adequate contexts/examples or approaches. It is also important to note that arguments from the point of *choice of contexts* or *teaching approaches* could mean two things for progression. It could mean that there is no specific NOS progression at all, since the same issues are suggested for all stages. The only thing that differs between the educational stages is that the NOS issue in focus is connected to different examples or addressed through different approaches. On the other hand, arguing from the starting point in *choice of contexts* or *teaching approaches* could contribute to a progression thanks to the broader span of NOS issues that might be brought to the fore in connection with different or more complex contexts. More complex contexts and approaches could also invite students to NOS discussions on a deeper level. However, if a more complex NOS discussion is to become a reality, then teachers must develop an ability to seize the possibilities that these different contexts open up. It has been argued that the ability to seize the moment (i.e., teaching NOS on the spur of the moment) is imperative if more nuanced images of science are to become a reality in science education (Hansson and Leden 2016; Herman et al. 2013). That the teachers challenged themselves during the focus group discussions can be seen in the tensions between different rationales. The teachers single out some aspects as particularly abstract and difficult to teach in the early years (arguing from the point of *maturity and experience*), but still argue that some of these aspects are important to introduce at an early stage (arguing from the point of *practice makes perfect*). In other cases, the different rationales support each other, for instance when teachers look for approaches or contexts (arguing from the point of *teaching approaches* or *choice of context*) that will provide possibilities to start discussing some issues early and then come back to these issues at *increasing levels of depth* (taught in different contexts with different approaches) at later stages.

As discussed above, the teachers argue that an inclusion of NOS is made possible through appropriate contexts and/or teaching approaches. Thus, if NOS is to become an important part of science teaching—at any stage—there is a need for instructional material. Much work has already been done in this area (e.g., Allchin 2012; Clough 2011; Henke and Höttecke 2015); however, these kinds of materials are not familiar to most teachers. Accordingly, teacher education needs to support teachers with examples of contexts and cases suitable for NOS teaching.

This article has followed a line of research in which teachers' voices are listened to and taken seriously. The results add to the understanding as to why inclusion of specific NOS issues, according to teachers, become possible or not in the science teaching at a certain educational stage. As teachers are important keys to what takes place in the classroom, their perspectives on both NOS teaching in general, and NOS progressions in particular, have to be taken into consideration. Teachers' suggestions and rationales provide important information for teacher education regarding productive ways to challenge both pre- and in-service teachers in their taken-for-granted practices. Some implications from the results in this article seem of particular importance. Firstly, after taking part in this research project, it was still difficult for the teachers to make clear suggestions for NOS progression when it came to adding complexity (i.e., deeper treatment of issues) over the years. One way to deal with this in teacher education could be to encourage teachers to explore different perspectives on NOS, both in relation to teaching and policy documents, and as a way to deepen their own understanding. This could provide possibilities for teachers to develop confidence to deal with conflicting perspectives and tensions related to NOS in their teaching. Secondly, in relation to previous research, one of the more controversial results in this study is that the teachers suggest an early start for some of the more complex topics. Thus, introducing abstract NOS issues in teacher education by providing pre-service teachers with the experience of planning, implementing, and reflecting on teaching, could challenge traditional ways of looking at the teaching of such

issues. Teachers' own experiences of success, as well as stories from other teachers' experiences, could significantly influence the development of practice. However, more studies focusing teachers' perspectives on NOS teaching are needed in order to create possibilities to bridge the gap between research and science classroom practice.

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III

From black and white to shades of grey: A longitudinal study of teachers' perspectives on teaching sociocultural and subjective aspects of science

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Abstract

Traditional school science has been described as focused on indisputable facts where scientific processes and factors affecting these processes become obscured or left unreflected. In this article we report on teachers' perspectives on the teaching of sociocultural and subjective aspects of the nature of science (NOS) as a way to accomplish a more nuanced science teaching in Swedish compulsory school. The teachers (N=6) took part in a longitudinal study on NOS and NOS teaching that spanned three years. The data consists of recorded and transcribed focus-group discussions from all three years. In the analysis, the transcripts were searched for teachers' suggestions of issues, relevant for teaching in compulsory school, as well as opportunities and challenges connected to the teaching of these issues. The results of the analysis show that (a) the number of suggested issues increased over the years; (b) the teachers' ways of contextualizing the issues changed from general and unprecise to more tightly connected to socio-scientific or scientific contexts; (c) the number of both opportunities and challenges increased over the years. The most evident changes occurred from the beginning of year two when the focus-group discussions became more closely directed towards concrete teaching activities. Tensions between the opportunities and challenges are discussed as well as how these can be met, and made use of, in science teacher education.

Keywords: challenges and opportunities; compulsory school; nature of science; NOS; sociocultural and subjective aspects; teacher education; teachers' perspectives; traditional school science

1 Introduction and background

Research has shown that science teaching often focuses on a body of concepts and that nuances, processes behind the concepts, and connections to society are absent. As a consequence voices have been raised to promote "knowledge about the whole science" (Allchin 2011) and "salvaging science literacy" (Feinstein 2011). One step in that direction has been made through articulating nature of science (NOS) as an important learning object in curricula and policy documents (e.g. the Swedish national curriculum (Skolverket 2011). Moreover, extensive efforts have been made to implement NOS in the science classroom (see e.g. Akerson and Hanuscin 2007; Lederman and Lederman 2012; Clough and Ohlson 2012). Even though teachers' perspectives are part of these studies more research focusing *specifically* on teachers' perspectives is needed in order to better understand how such efforts are received by teachers. In a previous study (Author 2015), we have shown that teachers perceived NOS teaching as something new. To change existing practices through for example including new elements in the teaching is often challenging. Previous research on challenges (e.g. Henke and Höttecke 2015; Höttecke and Silva 2011) has provided explanations as to why there often is a gap between research intentions and classroom practice. Teachers'

perspectives constitute an important part in the attempt to understand and examine this gap further. The present article contributes with longitudinal research on teachers' suggestions of what issues, within the scope of sociocultural and subjective aspects, could be considered meaningful and possible to teach in compulsory school¹. Six teachers were followed for three years in their teaching and in focus-group discussions.

The article adds to previous research by providing an in-depth report on these teachers' perspectives on both opportunities and challenges that follow from teaching sociocultural and subjective aspects of NOS. Through using focus-group discussions, challenges and opportunities were negotiated among the teachers, which provides data on both tensions and consensus. Moreover, the longitudinal approach contributes with insights into how perspectives and suggestions can change over time through taking part in reflective discussions about NOS and NOS teaching. These results are useful in the development of NOS courses for teacher education and professional development.

Below we present research that has been essential for understanding and interpreting the teachers' discussions. This includes research on the overarching goals of science education often under the label of *scientific literacy*. It also includes research that is situated within the field of NOS teaching, in this case: challenges and opportunities connected to NOS teaching and research on sociocultural and subjective aspects of NOS.

1.1 Aims and goals of school science

Traditionally, school science has been found to focus on a body of concepts and cook-book lab-activities with the aim to provide an insight into what is perceived as essential scientific concepts. In this kind of school science few interactions between science and society and culture come to light. Instead knowledge is presented as unproblematically discovered, uninfluenced by values, norms, interests or specificities of the times or places of its creators (Zacharia and Barton 2004). In other words, school science most often deals with ready-made science (Latour 1987) where consensus has been reached long ago. The uncertainty or messiness of science in the making is seldom emphasised (Ruhrig and Höttecke 2015). Through such school science, myths about indisputable, objective knowledge and heroic scientists are implicitly and explicitly communicated to the students (Allchin 2003; McComas 1998).

Goals of science education have often been put forward as *scientific literacy*. However, literacy comes in many shapes and the definitions of scientific literacy in the research literature are diverging. Extensive reviews on the topic have been made (e.g. Deboer 2000; Hodson 2008; Roberts 2007). The relation between scientific literacy and knowledge of science concepts has been debated. However, Roberts (2007) argues that most research on literacy finds it impossible to be scientifically literate without having any knowledge of science concepts. Two broad approaches to scientific literacy have been described in the literature (Hodson, 2008; Roberts, 2007; 2011; Roberts & Bybee, 2014). One of them takes its point of departure within science and the other starts in science related situations outside science, where the latter has often been referred to as *critical scientific literacy* or *science for all*. Roberts (2007) and Roberts and Bybee (2014) argue that one approach should not exclude the other, but instead contribute with different elements of science education, elements that need to be balanced. Unfortunately, the debate and suggestions have often become polarized in a way that favours one approach over the other to an extent that the less favoured is only represented in a very shallow way.

¹ Swedish compulsory school comprises years 1 (age 7) to 9 (age 16).

Furthermore, Roberts and Bybee (2014) followed up on Roberts' earlier review by studying scientific literacy trends over the past ten years and came to the conclusion that the recent policy trends are directed towards putting more emphasis on a starting point within science. This conclusion is supported by Feinstein et al. (2013) who argue that policy makers of today focus on producing science-ready students. However, if the goal for school science would be to be less alienating and bring about "competent outsiders" (Feinstein 2011), or to create an interest and engagement in more and diverse student groups a greater balance is needed (Zacharia and Barton 2004). The above discussions regarding the goals and aims of school science are far from novel, but have been a topic at least since the beginning of the twentieth century (Rudolph 2005). It is also evident that the diverging goals will be connected to very different forms of teaching, where the focus on concepts has been known to follow strict patterns of teacher centred transmission of knowledge (Batholomew et al. 2004; Höttecke & Silva, 2011).

An alternative to the above described strong focus on concepts has, as mentioned above, been described as an education aiming at "science for all" or "critical scientific literacy" (Hodson and Wong 2014) – that is, a science that could be embraced as functional, meaningful (Allchin 2011, 2014), or useful in one form or another in everyday life (Feinstein 2011), as well as being connected to students experiences and interests (Zacharia and Barton 2004) – that is a starting point in situations outside science. Such school science has been discussed in terms of developing students' abilities to deal with uncertain knowledge and conflicting evidence through, among other things, being able to make judgements about trustworthiness and credibility and to use media as a source. In many cases, it is suggested that this should be done through authentic and context rich activities (Allchin 2014; Feinstein et al. 2013; Hodson and Wong 2014). The project described here takes a point of departure in science education research on NOS. We argue, as many others (e.g. Allchin 2014; Hodson and Wong 2014, Yacoubian 2015), that NOS could be one piece in the puzzle of creating a more nuanced science for all, and in the long run lead to critical scientific literacy and competent outsiders.

1.2 Sociocultural and subjective aspects of science

In research studies on NOS, sociocultural and subjective aspects of NOS have either been less emphasised than other aspects or less progress has been made regarding teachers' or students' understanding (Wong and Hodson 2010). Thus, they have been considered as particularly difficult and abstract to deal with both for teachers and students (Akerson et al. 2011). In order to explore these aspects further, this article specifically focuses on teachers' discussions about sociocultural and subjective aspects as a way to challenge black-and-white images of science in their science teaching.

Sociocultural and subjective aspects of science have often been included in frameworks that put forward ideas of what can be considered to be important aspects of NOS. In this article, we have chosen to treat sociocultural and subjective aspects as one NOS category due to their inherent interconnection. An example is *personal values* that are often categorised as part of subjective aspects (e.g. Lederman 2007). These values are however affected by various issues, such as cultural backgrounds, ideologies and so forth that are often categorized as sociocultural issues. Thus, the two aspects are deeply intertwined and for the purpose of this study not necessary to separate.

Research literature on NOS in science education have presented various descriptions of sociocultural and subjective aspects of science. For the purpose of this article it is important to provide an account that shows some of the breadth in the suggestions from previous research. However, it is important to note that the suggestions from previous research are primarily

based on either theoretical constructs or on suggestions from experts (e.g. scientists, science educators, philosophers of science), and not, as in the present article, on suggestions made by practitioners in ordinary science teaching situations. Some examples of issues are:

- ways of organizing research, the communication of scientific results, and peer review (Abd-El-Khalick 2012; Allchin 2011; Erduran and Dagher 2014);
- interactions between science and society through politics and economy (Allchin 2011; Erduran and Dagher 2014; Lederman 2007);
- authority and prestige (Hodson and Wong 2014);
- theory-ladenness (Abd-El-Khalick 2012; Lederman 2007);
- cultural beliefs (Allchin 2011; Lederman 2007);
- gender, class, or racial bias (Allchin 2011; Hodson and Wong 2014);
- fraud (Allchin 2011);
- motivations, personalities, mind-sets (Allchin 2011; Hodson and Wong 2014; Lederman 2007);
- norms, traditions and language of scientific communities (Erduran and Dagher 2014; Hodson and Wong 2014);
- competition (Erduran and Dagher 2014).

Here, teachers' voices can make a very important contribution to the already existing body of research, through including teachers' perspectives on which sociocultural and subjective issues could be considered appropriate for compulsory school and the role these issues might play.

1.3 Challenges and opportunities

Needless to say, there are challenges connected to the introduction of new elements in the science classroom. Most teachers are deeply rooted in a school-science culture that has its starting point within science and uses the structured teaching formats connected to this way of viewing the goals of science education (Roberts 2011). This means that including new elements, both issues and teaching formats, which clash with this culture can be difficult since it creates uncertainty and challenges teachers' identity (Aikenhead, 2006; Bartholomew et al., 2004; Höttecke & Silva, 2011). In a recent study, Author (2015) reported on perspectives on NOS teaching put forward by teachers who had no previous NOS teaching experience. These teachers had a variety of ways of talking about NOS, but had a much smaller repertoire regarding NOS *teaching*. This was particularly evident for sociocultural and subjective issues of NOS. A short and by no means exhaustive list of other challenges that have been reported in the research literature on NOS teaching contains:

- a lack of teaching resources that can be embraced as adequate by the teachers (Abd-El-Khalick et al. 1998; Akerson and Hanuscin 2007; Hanuscin et al. 2011; Lakin and Wellington 1994, Höttecke and Silva 2011)
- NOS considered as an add-on even by teachers who regard it as important (Abd-El-Khalick et al. 1998; Clough and Olson 2012; Höttecke and Silva 2011)
- teachers are unaccustomed to, and insecure regarding, the teaching format and strategies (Bell et al. 2000; Herman et al. 2013; Lakin and Wellington 1994, Henke and Höttecke 2015, Author 2015)

- concerns about students' abilities to deal with abstract or controversial issues (Abd-El-Khalick et al. 1998; Aikenhead 2006; Brickhouse and Bodner 1992; Hodson 1993; Lederman 1995; Author 2015), and
- concerns for the "good students" who are accustomed to memorize facts for the test (Aikenhead 2006; Author 2015).

Research studies have examined what teachers perceive as opportunities with NOS teaching to a surprisingly small extent. One interesting exception is Herman et al. (2015) who connect the "type of utility value" expressed by the teachers to their level of NOS implementation. Low implementers were vague in their reasons for why NOS should have a place in science teaching. Considered as vague reasons were notions that NOS "brings it down to the human level" (Herman et al. 2015), and that science becomes more enjoyable and connected to everyday life. However, in order for teachers to be able to overcome the obstacles of breaking with traditional school science, through teaching about NOS, it is important that they see the utility for NOS teaching in the endeavour to reach more overarching goals of science teaching (Herman et al. 2015; Höttecke and Silva 2011). Such overarching goals have to do with students' abilities to take part in, or make meaning of, socio-scientific debates (Hodson and Wong 2014) and to create competent outsiders (Feinstein 2011) - that is, goals that are "important for life well beyond formal schooling" (Herman et al. 2015).

1.4 Aim

Few studies have focused specifically on the teaching of sociocultural and subjective aspects of science although many have mentioned the specific challenges connected to such teaching. Moreover, very few studies have thoroughly examined the *opportunities* of such teaching expressed by teachers. Therefore, the aim of this article is to longitudinally explore changes and trends in teacher reflections on the teaching of sociocultural and subjective aspects. In this exploration, we have looked for teachers' suggestions for relevant issues as well as their reflections on opportunities and challenges. Through learning more about teachers' perspectives, insights can be made that serve both pre- and in-service teacher education. Specific questions guiding the study are:

- What suggestions concerning the teaching about sociocultural and subjective aspects of science are raised by the teachers over the years?
- What opportunities and challenges concerning the teaching about sociocultural and subjective aspects of science are emphasized over the years?

2 Method

2.1 Context

In Sweden, science (i.e. biology, chemistry, and physics) is studied by all students throughout compulsory school. NOS is included in the current Swedish national curriculum (Skolverket 2011), and has been so also in former versions for the last couple of decades (Johansson and Wickman 2012). Different NOS aspects are referred to both implicitly and explicitly in the curriculum (Skolverket 2011), and the intention to make NOS part of science teaching is strengthened by an official commentary on the curriculum (Skolverket 2016). Commentaries

(Skolverket 2016) are available for each subject with the purpose to serve as a help for teachers when interpreting the intentions of the curriculum. In the commentary, the term 'nature of science' is 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 2016 authors' translation, p. 30)

Furthermore, these documents emphasize that science should be introduced as "...a dynamic, creative, and up-to-date subject in constant development." (Skolverket 2016, authors' translation, p. 7). However, even if NOS is included in the national curriculum it is important to note that there are no specific teaching materials developed that could provide teaching direction. Furthermore, previous Swedish studies by Högström et al. (2006) and Gyllenpalm et al. (2010) have shown that the teaching of NOS is seldom mentioned by Swedish science teachers when they speak about science teaching.

Since the present article specifically examines teachers' perspectives on the teaching of sociocultural and subjective aspects of NOS it is important to say something about how these are put forward in the Swedish national curriculum. In the overarching aims that cover science teaching in years 1-9 (ages 7-16) it is argued that "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 2011, p. 120). Furthermore, different age groups have specific goals, where sociocultural and subjective aspects are included for all age groups, but with partly different focus. In the early years (1-3) the teaching is directed towards: "Narratives about science from earlier times, and the attempts of different cultures to understand and explain phenomena in nature." (Skolverket 2011 p.122), while for years 7-9 the teaching should also cover public discussions about social issues involving science, comparisons between scientific theories and other descriptions, as well as how historical and contemporary discoveries "have been shaped and formed by world views" (Skolverket 2011 p. 124).

2.2 Participants

At the beginning of the project 39 teachers answered the open-ended questionnaire VNOS-C (Lederman et al. 2002). The questionnaire (which was translated into Swedish) was used with a twofold purpose. First to, be able to analyse how Swedish teachers talk about NOS and second, to give them a first idea about what kind of issues NOS deals with so that they would know what they said "yes" to when we asked them to take part in the continuation of the project. 12 teachers (two groups) who covered experiences that spanned the entire compulsory school (years 1-9) and who had possibilities to meet, were chosen to take part in a follow-up interview on NOS teaching. The analysis of the questionnaires and follow-up interviews (see Author 2015) served as a point of departure for the project. One of the two groups stayed on for the entire project. This group, was formed by teachers who taught at four different schools (albeit half of the teachers belonged to the same school) and all but one of them had long teaching experience, i.e. 10 years or more (see table 1 for details).

The teachers met for focus-group discussions that were all held at one school, where three of the teachers taught. One of these three teachers, Mary, stopped teaching science after two years in the project, which caused her to leave the group. The teacher, Emma, who replaced Mary in science teaching took her place in the focus group from the beginning of year three. This was a decision based on ethical considerations since it would be inappropriate to exclude

one of three science teachers at a school from taking part in ongoing collegial discussions. Although a longitudinal analysis is made in this article, we have made the decision to include also Emma’s and Mary’s voices in the analysis since they were part in shaping the discussions. An overview of participants is presented in table 1. All participants were qualified for science teaching for the years indicated in the table.

Table 1 Pseudonyms and particulars for teachers participating in the project.

	Years in Teaching*	Teacher education aimed at school years
Agnes	16	1-7
Carolyn	32	4-6
Ella	17	1-7
Emma	12	4-9
John	15	4-9
Nina	10	4-9
Mary	8	1-7

*at the outset of the project

2.3 Research Project and Data Collection

The research project spanned three years and included 12 focus-group meetings, 2 hours at a time (see Appendix A for an outline of the project and focus-group activities). The participation in the project was voluntary, and the teachers did not receive any compensation or extra time, all teachers were however granted permission to take part in the meetings during working-hours when possible. The first author was the moderator of all focus-group meetings. A fruitful way to trigger discussions among the participants in a focus group is for them to have access to material with which to work during the meetings (Wibeck 2010). In this study, the participants were given working material consisting of short texts to read before meetings (only during year one) and/or tasks to work with during meetings (see Appendix A for an overview of meetings and distributed material).

The texts and discussions were based on a framework consisting of seven NOS-themes (the seven themes were later reduced to five themes based on the group discussions). The NOS themes were comprehensive and broad in order to allow for multiple perspectives and a large variety of NOS issues to be included as suggested in, for example, Allchin (2011) and Erduran and Dagher (2014). They have a starting point in the NOS tenets described by Lederman (2007), but were further developed and inspired by both science studies perspectives, as suggested in Duschl et al. (2006), and science education literature. The two themes, sociocultural and subjective aspects, that are central for this article are deeply intertwined (see section 1.2) and, hence in this article, merged into one overarching theme. The themes are briefly described below (for a more detailed description see Authors 2015).

- *Tentative aspects of science* was concerned with continuity/change and certainty/uncertainty in relation to scientific knowledge. Both historical and contemporary examples coupled to different disciplines are of importance.
- *Empirical aspects of science* was, in addition to the significance of empirical contributions to science, broadened to include theoretical contributions and their interconnection with empirical contributions, and aspects concerned with scientific practices (c.f. Erduran and Dagher 2014). Relevant topics are, for example, the roles and relations between observations, experiments, models, and laws; trustworthiness; diversity of methods; and boundaries of science.

- *Creative aspects of science* was concerned with creativity and rationality in relation to the research process (from problem stating to interpreting observations and inventing explanations).
- *Sociocultural and subjective aspects of science* was concerned with the extent to which science is influenced by subjectivity and society/culture at different stages of the research process (Stenmark 2004). Thus the theme deals with questions about realism versus relativism as well as questions concerning the *science wars* debate (see Dadachanji 1998; Mosco 2012). Both historical and contemporary contexts are important to this broad theme as well as a number of perspectives mentioned in section 1.2 such as: theory-laden/neutral observations (Lederman 2007), economy (Irzik 2010), and politics (Allchin 2011; Erduran and Dagher 2014). Other perspectives of interest are cultural and social practices of different sciences – e.g. epistemic cultures (Knorr-Cetina 1999), and feminist theories (Freedman 2009; Longino 1990).

The texts aimed at putting forward different perspectives and were mainly built around questions that could prompt discussions. A translated excerpt from the text that was distributed before the second meeting exemplifies this:

In the pursuit to describe reality as accurately as possible objectivity becomes a question. How objective can an investigation or a research project be? Are there different parts of the research process (e.g. in problem stating, data collection, justifying claims, or application) that are more subjective than other parts? Should this be considered a problem or is it just part of science being a human activity? Some people argue that science concepts, theories, models, and laws are altogether constructed by humans and not given by nature. This view can be very controversial to others, who consider science as providing an accurate picture of reality as it really is. Furthermore, there are also others who discuss a balance between science as objective or science as subjective in that they regard knowledge as constructed – with different possible constructions of reality – but that reality does not provide freedom to construct whatever we want – there is a reality independent from us (which also can be discussed in connection to the previous theme) (Excerpt from focus group text)

Thus, during the project the teachers gained experience of NOS and NOS teaching from readings, discussions, and development and implementation of NOS activities. The longitudinal character of the project enabled us to study how the teachers' ways of talking about NOS and NOS teaching changed over time. The discussions during the focus groups developed differently. Mostly, the moderator prompted the teachers to talk about a couple of chosen topics and the discussion wandered freely among the participants with little interference from the moderator apart from ensuring everyone had their say. However, in a couple of meetings, where teaching examples were shown the moderator also made suggestions and elaborations. An excerpt from one of the focus groups is provided below (section 2.4, table 2). The excerpt intends to illustrate the character of the discussions as well as provide an insight into the interpretation and analysis.

In focus-group meetings, during the second and third years, the teachers planned NOS activities that were later implemented in their own classrooms and thereafter reflected on in the following focus-group meetings (Appendix A). One of the activities was highly contextualized and focused mainly on sociocultural and subjective aspects of science through students' reading and discussing of web-based information and news articles about a socio-scientific issue. In this activity, the teachers had prepared NOS questions that their students should use as a guide while reading the texts. The reading was followed by students writing an argumentative text (years 7-9) or taking part in a panel debate (years 4-6). The other activity was a black-box activity where the students encountered all of the above described aspects of science through teacher initiated group and whole-class discussions. Thus, at the

end of the project, even if the teachers were not experts on NOS, they had gained a higher level of experience in NOS and NOS teaching than could be expected from most teachers in Sweden.

2.4 Analysis

This article is based on data that consists of the recorded and transcribed discussions from 12 focus-group meetings. The interactions and negotiations among the participants in a focus group can be excellent for learning about diverging opinions, tensions, taken-for-granted patterns, and meaning making within a certain group (Halkier 2010). The analysis is based on qualitative content analysis of the focus-group transcripts (Hsieh and Shannon 2005; Kvale 1997). Initially the transcripts were read repeatedly in order to get a sense of the whole material (c.f. Hsieh and Shannon 2005). Then five steps were followed in order to answer the research questions. The first three steps are connected to the first research question: *What suggestions concerning the teaching about sociocultural and subjective aspects of science are raised by the teachers over the years?*

- 1) Identification of passages in the transcripts where teachers discuss the teaching of sociocultural and subjective aspects.
- 2) Identification and categorization of specific sociocultural and subjective issues within these passages.
- 3) Identification and categorization of contexts, *general* (no clear connection to science), *socio-scientific* (science in society), and *scientific practices* for each issue.

The last two steps are connected to the second research question: *What opportunities and challenges concerning the teaching about sociocultural and subjective aspects of science are emphasized over the years?*

- 4) Identification of challenges and opportunities that the teachers discuss in relation to teaching of the identified issues.
- 5) Categorization of identified challenges and opportunities.

A directed content analysis (Hsieh and Shannon, 2005) was used to code every occasion when *teaching* of sociocultural and subjective aspects were mentioned (step 1). Note that sociocultural and subjective aspects were only coded when they were related to teaching, and not when teachers discussed these aspects of science in a more general way. In a conventional content analysis patterns and categories emerge from the data and no preconceived categories are used (Hsieh and Shannon, 2005). This kind of analysis was used to get a more nuanced picture of how the teaching repertoire was filled with sociocultural/subjective issues during the project (step 2 and 3). In the next step the chosen passages were revisited and categorized as challenges and opportunities (step 4). Finally, the challenges and opportunities were analysed and coded according to recurrent patterns in the group discussions (step 5). The coding in step 2, 3, and 5 also made it possible to discern certain changes over the years.

Below (table 2) we use an excerpt from a transcript in order to provide an insight into the character of the discussions in the focus groups and to further explain the analytical steps and coding of the transcripts. The excerpt is from the transcribed discussion of focus group 3 year

2 (see Appendix A) where the teachers began by taking turns in briefly describing their experiences from the implementation of the text-based² activity

² *Text* here refers to web-based information and news articles as opposed to textbook texts specifically designed for the students

Table 2 Transcript excerpt with example of analytical process.

Transcript excerpt (Coded parts in bold)	Issues (step 2) and contexts (step3)	Challenges and opportunities (step 4 and 5)
Nina: I did like this when I introduced, they got four articles, two that were positive and two that were negative towards energy drinks, and we read them together here in the classroom and talked about if they [the articles] were positive or negative and what they [the students] thought were positive and negative in the different articles, and then we discussed this about underlying factors and reasons for interpreting the result the way one does and there was actually someone in the class who started talking about underlying factors without me saying anything. Ella: That's great!	Issue : values and viewpoints, Context: scientific practices	Student related opportunities: abilities for discussions; understanding of NOS
Nina: [Nina talks about practical details] /.../ I feel they thought it was difficult. They do take position for and against energy drinks. Then I haven't had the time to study how they justify it or how they use the texts, but at least they have an opinion. But I experience it as if many thought it was difficult [to know] how to write and what to write, both the weak and the smart or they who [usually] think it's easy and they who think it's hard. The group is pretty weak and there are many who do not pass, so it's a pretty difficult task for them I think, yes.		Student related opportunities: practiced taking position (abilities for discussion, develop critical thinking /reflexivity) Student related challenges: reading and writing difficulties
John: /.../ there are many, particularly boys, who are not very interested in too much unnecessary writing, so I experienced some resistance against writing. But I also believe that it might not just be resistance against writing but rather that they actually thought it was hard, because basically we have not worked very much with this type of tasks at all, to read up on a subject, then take position, and then justify your position through information found in a text. They have tried a few much simpler tasks before. The part where they take position for or against allowing energy drinks and put forward a few arguments, the ones I have had time to read, they have managed that. The difficulties for them have been the follow-up questions, for example, who can be interested in that this research is actually conducted, and are there different stakeholders and so forth. Those three bullet points were meant to start you thinking and then they should be integrated in the text to further strengthen your position. But I haven't noticed anyone doing that, they have just answered them as question 1, question 2 question 3. Like totally disconnected. No one has kind of used it. Nina: in their text? John: In their text, and perhaps that's not so darn strange, because at least in science class we have not worked like this. This does not mean they haven't practiced it in Swedish class. Nina: They are used to having it presented as questions.	Issue: economic interests that has to do with companies and organizations Context: scientific practices	Student related challenge: reading and writing difficulties; NOS too abstract (difficulties with the follow-up questions); difficult to discuss/argue and take position Structural challenge: breaks with science teaching tradition Student related opportunities: Practiced taking position (develop abilities for discussion, critical thinking /reflexivity)

In the first step, passages of the transcripts were chosen for further analysis when they showed teachers' discussions on teaching sociocultural and subjective aspects of science. The passage chosen here starts with Nina's description and reflection on the implementation of a text-based activity in her grade 8. The rest of the excerpt contains other teachers' comments on her description as well as John's description of his experiences from the same activity.

In the second step, sociocultural and subjective NOS issues were coded and categorized. First Nina talks about "underlying factors" without specifying what these could be. Thus they are not categorized as a specific issue. However, she also talks about discussing "reasons for interpreting the result the way one does" which is categorised as specific *viewpoints and values* of the individual researcher. Later in the excerpt John talks "about who is interested in that this is investigated at all, and are there different groups and so forth", this was categorized as *economic interests* that has to do with companies and organizations.

In the third step, all issues were scrutinized for qualitative differences based on how they are contextualized in teaching situations. Three different contexts were identified: *general* (no clear connection to science), *socio-scientific* (science in society), and *scientific practices* (scientific knowledge creating practices). Both the above issues were categorized as *scientific practices* meaning that sociocultural and subjective factors were discussed as affecting the processes, practices, and outcomes of science.

Challenges and opportunities were identified in the fourth step and further coded as specific opportunities and challenges principally related to students, teachers, or structures (step 5). In this case it is important to note that opportunities are not always explicitly expressed, but have been interpreted, by the researchers, as an implicitly expressed opportunity or benefit that follows from the teaching of sociocultural or subjective aspects. In the example, students' ability to engage in (and initiate) discussions about underlying factors: "someone in the class who started talking about underlying factors without me saying anything" followed by "That's great!", was coded as student related learning opportunities (abilities for discussions, understanding of NOS). Another student related opportunity was that they were able to express their position which could be considered as a development of their reflexivity as well as abilities for discussions. Students' difficulties regarding a teaching approach that demanded reading and writing abilities was in this excerpt discussed by both Nina and John and coded as a challenge related to the students. Other student related challenges had to do with their difficulties to take position, discuss and come up with arguments (discussed by both John and Nina). John also argued that the specific NOS questions were difficult for the students to grasp (too abstract). That students are not used to work with this kind of tasks in science class, and that they are more used to "have it presented as questions" is coded as structural challenges that has to do with the science teaching traditions present in these classrooms.

In the results section below, teachers' suggestions of issues as well as categories of opportunities and challenges are summarized in tables 3 and 4 in order to provide an overview of the changes over the three years. The focus-group discussions are exemplified by translated transcript excerpts. The analysis and presentation of focus-group data needs to seek a balance that acknowledges the interaction between the individual and the group (Morgan, 1997). The analysis reported here is directed towards the ongoing discussions and not on statements made by single teachers. However, even if quotations in the results section are presented as part of a joint, ongoing discussion, pseudonyms for participants are presented when clarification is required in a dialogue. The computer software NVivo was used as a tool throughout the analysis.

3 Results: Challenging traditional school science through sociocultural and subjective aspects

During the entire study the teachers returned to the issue of nuances in science. Yet they argued that in the science classroom they often teach science in a black and white manner (c.f. Authors 2015):

Mary: ... then we have to explain to them that we cannot deal with all the tiny details. Instead we do it black and white. There are other scales, but not at this level, not for these school years.

John: Simplified models.

Mary: Yes, absolutely, and I think it's important so they won't think this is the spoken truth, there can be nothing else, end of discussion. I think that's important, that [they know] at this level we follow this model. (1:2)³

In this article, we specifically focus on the teachers' discussions about sociocultural and subjective aspects as a way to challenge the black-and-white image of science that often prevail in the science classroom. Below we present their suggestions of relevant issues and their discussions of opportunities and challenges and how they changed over three years.

3.1 Teachers' suggestions of relevant issues

A task for the teachers during the entire project was to suggest concrete ways of how to put their ideas to work in the science classroom. In their discussions, the teachers focused to a great extent on the possibility to, in their science teaching, highlight what they talked about as "underlying factors", meaning sociocultural and subjective issues that are part of science in one way or another. These issues were either addressed in a general way or specified. When discussed generally the teachers, without mentioning any specific issues, argued that it would be beneficial if the students could discuss "underlying factors". Several specific issues were identified, for structuring reasons these were grouped and categorized in four overarching categories: economic interests and aims, ideologies/viewpoints/tendencies, knowledge/experiences, and social rank/status/organization of practices (specific issues and overarching categories are summarized in table 3). These were issues and categories that according to the teachers could serve as a basis for deepening the discussions about why researchers sometimes do not agree on interpretations, or why a specific method is chosen rather than another. An example of an issue that was coded as *social rank, status and reputation* is Ella's description of the discussions that were part of her implementation of the black-box activity:

Ella: You know, at a certain age they have one hundred percent trust in their teacher, then they start questioning. And some pals are not trusted at all /.../ if a guy or a girl comes along who doesn't have very high status, and who often doesn't say very much, they [the others] won't listen, and they need to become aware of that.

Agnes: Although, it's really hard to discuss that. Then you will almost have to observe another group. Otherwise it becomes so revealing.

Ella: Yes, well no, you can't do that, but it's the same thing as in this discussion, but then I chose to bring it up from the perspective of a research group: Can it be like this in different research

³ All quotations are marked by two numbers: the first number represents the year of the project the second number represents the number of the focus group. Thus, 1:2 means year 1 of the project, focus group meeting two.

groups as well? And I brought that discussion up that in year five, and they really started discussing, you know like: well it has to depend on if someone has made a clever discovery before, or if you are a famous inventor or scientist, then it's clear that you will listen more to that person because he knows what he's talking about (3:3)

The issues presented here represent overarching suggestions that span the entire compulsory school. For a detailed description of these teachers' discussion of age appropriate NOS teaching see Author (in press).

Table 3 Teachers' suggestions of sociocultural and subjective issues relevant for science teaching

Category	Specific Issue	Year 1 Focus group			Year 2 Focus group				Year 3 Focus group				
		1	2	3	1	2	3	4	1	2	3	4	5
Economic interests and aims	Related to companies and organizations	x	x		x	x	x		x	x	x	x	
	Investigations bought for certain purposes					x	x		x				
	Related to different parts of the world								x				
Ideologies, viewpoints, tendencies	Values and viewpoints	x	x		x	x	x	x	x	x	x		
	Differences due to different times	x			x			x		x	x		
	Worldviews	x								x			
	Political interests, decisions and regulations		x	x		x							
	Differences due to different religions		x		x					x	x		
	Differences due to different cultures		x			x	x			x			x
	Societal trends					x			x	x	x		
	Western and non-western countries: differences					x	x			x	x		
Knowledge and experience	Different frames of reference	x	x			x		x	x		x	x	
	Social backgrounds				x						x	x	
	Prevailing theories				x		x	x	x	x	x	x	
	Different scientific disciplines					x	x				x	x	
	Bias /prejudice					x				x	x	x	
Social rank/status/ organization of practices	Critical review of results, critical thinking	x	x		x		x			x	x		
	Social rank, status and reputation	x	x			x	x	x	x	x	x		x
	Scientists are like ordinary people		x										
	Organization of knowledge-producing practices				x		x	x	x	x	x		

In table 3 it is shown that several issues are regarded as suitable for teaching in compulsory school. The checkmarks indicate that a certain issue was up for discussion on at least one occasion during the particular focus group. Over the years, the teachers came up with new suggestions of issues that could be dealt with in the science classroom. Thus, their teaching repertoire regarding sociocultural and subjective issues expanded during the project (table 3). This is particularly evident for the knowledge and experience category, where *different frames of reference* was the only issue discussed during the first year, while in the second and third years further issues such as *scientific disciplines* and *social background* were suggested. In one exceptional case the issue was not recurrently discussed but instead only discussed during the first year: *scientists are like ordinary people*. Moreover, it is possible to discern certain "favourite" issues, such as *social rank, frames of reference, values and economic interests,*

which the teachers chose to discuss on several occasions and during the entire project (see table 3). The table further shows that some focus groups had a tendency to produce more issues than others, for instance, focus group 3:3 which is exceptional in that way. During this focus group the teachers owned most part of the discussion and specific reading material or teaching examples were not provided by the researcher on these occasions (see appendix A).

3.1.1 Connecting sociocultural and subjective issues to different contexts

The teachers' ways of suggesting how the specific issues ought to be included in science class changed dramatically between year one and year two (see Fig. 1). However, no major changes appeared between years two and three. Figure 1 presents the proportions of how these different approaches were discussed during the three years in relation to all categories presented in table 3. The three quotations below serve to exemplify the different ways of including sociocultural and subjective issues in the science classroom. For clarity, they have all been chosen from the same category *ideologies, viewpoint and tendencies* (see table 3).

The first year the teachers more often talked about sociocultural and subjective issues in *General* and imprecise ways. Using this general way of speaking meant that the suggested issues had no clear connection to science, but rather was a way of trying to get to grips with how to include such issues in the science teaching. This is exemplified in the quotation below where the teachers have been asked by the moderator to discuss how subjective aspects could be included in science teaching.

Ella: You can take a simple thing like their [the students'] conflicts. The exact same thing has happened and both of you were there but you experience it totally differently. (1:2)

Moderator: It can kind of be connected to an everyday context?

Ella: They are very aware of that.

Mary: But then I believe that it can be different to include it. They are aware of it in everyday situations and such, but then I think it can be difficult to get them thinking about why it is like that in science as well: they are scientists, they are supposed to be objective and so on. They can't really see that it's the same thing. (1:2)

However, as the project proceeded their suggestions became more concretely connected to science, either through socio-scientific issues or through references directly to scientific practices (see Fig 1). Quotations like: "[You can address sociocultural issues] maybe a little bit in sex education /.../ that you have different views on things in different parts of the world. (1:3)" were categorized as *Socio-scientific* meaning that sociocultural and subjective aspects were discussed in connection to science in society through decisions, position taking, and applications (e.g. socio-scientific issues (SSI)). Other quotations, like the example below, were categorized as *Scientific practices* meaning that sociocultural and subjective aspects were discussed in connection to how scientific knowledge creating practices (i.e. problem stating, planning investigations, conducting investigations, interpreting results, communicating results) are affected:

Nina: It can be when you [the student] are about to plan a lab or even when you are about to draw conclusions and [they discuss] the underlying factors, that you can think differently depending on which culture you are from [coded as *differences due to different cultures*, table 3]. And who says what – that you might trust people differently depending on who they are [coded as *social rank, status, and reputation*, table 3]. (3:5)

Fig. 1 Number and percentage of issues categorized as connected to general, socio-scientific, or scientific practices contexts during the projects.

3.2 Opportunities and challenges over the years

A large portion of the discussions during the project came to deal with the challenges and opportunities that the teachers anticipated or experienced in relation to teaching about sociocultural and subjective aspects of science. In focus groups 1:2, 1:3, 2:3, 3:1, and 3:2 the moderator specifically asked the teachers to discuss what they had experienced as, or what they thought might be challenges and opportunities. However, opportunities and challenges were natural topics also in the other focus groups. The opportunities and challenges; that were discussed over the years, are presented below and also summarized in table 4. In the analysis opportunities and challenges were categorized as either related to person (students or teachers) or to structure. Furthermore, broad sub-categories were organized by the researchers. For instance, the category *increased engagement and interest* comprised a variety of statements related to students such as engagement in discussions, enjoyment, and pride due to being able to master a difficult task. This broad categorization is visible in table 4. As in table 3, a checkmark in one focus group shows that the subcategory was up for discussion at least once during the particular focus-group meeting.

Table 4 Challenges and opportunities connected to teaching about sociocultural and subjective aspects

[illegible]

3.2.1 Opportunities and challenges discussed during the first year of the project

During the first year of the project the main opportunities that the teachers discussed were that teaching sociocultural and subjective science could provide a way for the students to get to grips with the idea that science is not just black and white. This is connected to the opportunity of meeting curricular demands on science teaching as something more than the teaching of facts (table 4, *Embraces teaching goals other than facts*) which these teachers talk about as a more prominent feature in the latest curriculum.

Carolyn: It is not enough knowing everything about the photosynthesis... it is much clearer now [in the curriculum] what is expected.

John: Not so much memorization, cramming and repeating, but instead you can do a lot of other stuff

Carolyn: and that is connected to the things we talk about here, views [in science] and what that is and critical thinking and source criticism and all that. (1:1)

The challenges discussed during the first year (summarized in table 4) had to do with the assumptions that students would have difficulties handling science as something more than concepts, and that they would get worried if the black and white picture of science was disrupted. In the excerpt below (focus group 1:2) the moderator has connected to a discussion among the teachers about conflicting evidence and has asked what would happen if conflicts were avoided and science was taught in a black and white fashion:

Ella: I guess that would be very convenient.

Moderator: um

Carolyn: Yes!

Ella: because then you won't have to wrestle with those thoughts

Carolyn: But things aren't only black and white! So I don't know but

Mary: I think it matters on what level the students are and not just age level but

Ella: No

Mary: We should not think in relation to grading, but they who have a more developed, well, they have gotten further, while for some students who almost cannot pass, for them it would probably, like you say, be rather convenient and kind of like: now we know how it is, it feels safe... (1:2)

The quotation further shows that the teachers argued that sociocultural and subjective aspects are abstract and thus would be difficult to grasp for many of the students. Also, teaching formats, in which students would have to take initiative in discussions, were considered a possible challenge. Furthermore, the teachers expressed that they themselves struggled to get to grips with understanding the sociocultural and subjective aspects as well as understanding how to teach about these aspects in the science classroom (table 4, *Lacking knowledge about NOS teaching, Lacking knowledge about NOS*). There was also some confusion regarding whether or not sociocultural and subjective issues could be considered to be proper science (table 4, *Breaks with science teaching traditions*).

3.2.2 Opportunities and challenges discussed during the second and third years of the project

There is a considerable change in the amount of opportunities and challenges discussed by the teachers after the first year (see table 4). The opportunities that were described during year one remained, but more opportunities were added at the beginning of year two, when the teachers were presented with teaching examples and started planning their own activities. This

meant that at the beginning of year two the teachers talked about expected opportunities such as increased engagement and the development of critical thinking and reflexivity (table 4). After implementing the activities, the teachers argued that concrete gains such as the development of abilities for argumentation and increased participation among students, were achieved (see table 4).

There was an incredible lot of discussing going on in grade 6 about how it actually works regarding if science can be ordered [for certain purposes]; which research reports that are published; and the results from them, if they can be trusted or not. And that discussion, I think it was really rewarding, they [the students] became more critical.

Moderator: Okay, it awoke that kind of thoughts

Ella: Yes, it did and I thought it was awesome to see that there were so many, and so many who are otherwise often silent, that were thinking, raising their hands and engaging. So, I thought that was pretty cool (3:2)

The expectations of, for example, increased interest and engagement were also met as seen in the quotation below where one teacher tells the focus group of her experience of engagement (table 4) among her students (see also table 3 *Critical review of results, critical thinking;*

Organization of knowledge-producing practices):

Carolyn: One of my students said at lunch time: 'But who checks that the ones who do research have done it right?' And I said that if you are a researcher you have a result and then you have to answer for it to other scientists. 'But isn't there someone kind of superior who can tell that: No there you have researched wrong!'. They [the students] are so used to handing in things that get assessed you know, but I said that they [the scientists] have to present their work maybe to get a certain job, or for other researchers to review it!.../ That was an interesting thought among them.

Moderator: Absolutely.

Carolyn: That's how they went on, these wonderings, from the morning [when the science lesson took place] right up till lunch time.

Ella: It has started many thoughts! (2:3)

After having tried the NOS activities the teachers also talked about experiences of emotional benefits for themselves such as the teaching being inspiring, fun and thought provoking, not only for the students, but also for the teachers. A couple of teachers even reported that they had gotten positive feedback from parents and students and thus felt that their own status as teachers had increased. First and foremost, however, during year two and three the opportunity of steering the teaching away from only teaching facts became more clearly articulated through discussions about possibilities to attend to all curricular goals such as source criticism and communicative skills. These goals were, according to the teachers, often forgotten and NOS teaching was welcomed as a much-needed way to approach them. Similarly, to the opportunities, also the challenges remained, and more were added throughout the project as the teachers put their ideas to work. One of these challenges was the students being uncomfortable due to the lack of right answers:

Carolyn: [when not being provided with right answers] they get totally confused and they almost become angry

Emma: They don't like uncertainty (3:3)

However, this is exactly what the teachers were striving to challenge by teaching sociocultural and subjective aspects in their classrooms. Thus, in the continuation of this quotation we can

sense that this challenge is turning into one of the overarching opportunities of teaching sociocultural and subjective aspects in the first place:

Carolyn: No, they don't [like uncertainty]. That's what I'm trying to make them get used to (3:3)

New challenges were also added that were connected to the concrete teaching situation. These could be challenges connected to students' reading and writing abilities (table 4) or challenges connected to the teachers' limited time for planning new activities. The activities became time consuming both as regards the time spent on finding interesting topics/developing the activity and the time spent on the task in the classrooms. Much of this is time that is, according to the teachers, traditionally spent on teaching facts. However, as we have seen, the teachers in this study have a somewhat ambivalent relationship to the teaching of facts. Furthermore, during the second and third years their identities as experienced science teachers were greatly challenged when they had to try activities in their classrooms that made them feel that they had less control than usual. Their classrooms were messier and noisier; the teachers were insecure in their roles as discussion leaders, and as persons who no longer provided immediate answers – they did not feel like real science teachers anymore (table 4 *breaks with science teaching traditions*). In the excerpt below John shares his experiences from working with news articles where his students were supposed to write a text that included a discussion of sociocultural and subjective issues.

John: This was the first time that I know of, where they [the students] found themselves in this situation, but they might have practiced it a little in Swedish class. And when I was sitting here about to assess this task, I felt that I myself was on shaky grounds and felt, heck, how much Swedish teacher am I supposed to be.

Ella: Yes, that too yes.

John: Then this almost felt like too much and that it became more of a task for Swedish class than a science task. And then you start wondering: well, am I old fashioned to think it should be more science or has the character of the subject changed and I haven't really been able to keep up (2:3)

Moreover, as we see in the quotation above, the insecurity regarding the teaching of sociocultural and subjective aspects also included the assessment of students' knowledge. However, similarly to the earlier example regarding uncertainty, the assessment was discussed as something that could be turned into an opportunity through becoming an important way to provide more weight to NOS teaching.

3.3 Summarizing the results

In summary, the results connected to the first research question show that: (a) the number of suggested issues increased over the years; (b) the teachers' ways of talking about issues changed from general and unprecise to more tightly connected to socio-scientific or scientific contexts. The results connected to the second research question show that: (a) the number of opportunities and challenges increased over the years; (b) there were tensions and intertwinements between some of the opportunities and challenges in a way that made some of the discussed challenges also be exactly what the teachers were striving to achieve (e.g. the discussion regarding students' abilities to deal with the lack of right answers).

In relation to both research questions, the most evident increases and changes occurred from the beginning of year two when the focus group discussions became more closely connected to teaching activities.

4 Discussion

The teaching of NOS has been a major focus in science education research for the past couple of decades and efforts have been made to broaden the images of science that are often put forward in a school-science context (Lederman 2007). Challenges connected to NOS teaching have been thoroughly investigated (e.g. Abd-El-Khalick et al. 1998; Akerson and Hanuscin 2007; Brickhouse and Bodner 1992; Clough and Olson 2012; Lakin and Wellington 1994, Hodson 1993; Höttecke and Silva, 2011; Authors, 2015 Lederman 1995). Such research on challenges have contributed with explanations as to why there is a perceived gap between research intentions and classroom practice. In other articles (Authors 2015; in press) we have reported on, and argued that, teachers' perspectives constitute an important part in the attempt to understand and examine this gap further. In this study, we continue our exploration of teachers' perspectives. The present article contributes with longitudinal research on teachers' suggestions of what issues, within the scope of sociocultural and subjective aspects, could be considered meaningful and possible to teach in compulsory school. Furthermore, the article adds to previous research by providing an in-depth report on teachers' perspectives on both opportunities and challenges that follow from teaching the suggested issues. Moreover, the longitudinal approach contributes with insights into how perspectives and suggestions can change over time through taking part in reflective discussions about NOS and NOS teaching. These results are useful in the development of NOS courses for teacher education and professional development.

4.1 Longitudinal exploration of issues, opportunities and challenges

Despite earlier reports on difficulties connected to teaching about sociocultural and subjective aspects (Akerson et al. 2011; Authors 2015) the present study reports on an increasing number of issues that were suggested by the teachers as possible and meaningful to address in compulsory school science teaching. From the number of issues presented in table 3 it is clear that many of the sociocultural and subjective issues that have been suggested by *researchers* in previous studies (e.g. Abd-El-Khalick 2012; Allchin 2011, Erduran and Dagher 2014; Hodson and Wong 2014; Lederman 2007) also were suggested by the *teachers* in the present study. Many issues were suggested already during year one. However, from the increase in issues during years two and three we argue that teachers' reflective discussions as well as the connection to concrete teaching situations are of great relevance. This is due to the fact that, after year one, the moderator only provided material that could be regarded as teaching examples which did not include explicit references to NOS (see overview of material for focus groups in Appendix A).

During the project years the way that the issues were talked about changed character and they became more concrete in relation to scientific processes and contexts. This could be the result of the teachers' work with trying to find ways for how to include the issues in their own teaching. The practical connection to teaching resulted in suggestions that, to an increasing extent, connected the suggested issues to socio-scientific or science-practice contexts. Especially the connection to scientific practices became more pronounced after the first year –

issues were suggested that could create a deeper understanding of how all parts of the research process, are affected by sociocultural and subjective aspects. Thus, the sociocultural and subjective issues presented in this study constitute an important example of teachers' suggestions of how a more nuanced picture of science and its processes, results, and applications can be presented to their students.

Similarly, to the suggested issues, opportunities and challenges increased over the years and became more concretely connected to the teaching situations. However, opportunities and challenges that were discussed at the beginning of the project continued to be part of the discussions till the end of the project. Many of the discussed challenges are recognizable from earlier studies on NOS such as students' abilities for abstract thinking (Abd-El-Khalick et al. 1998; Aikenhead 2006; Brickhouse and Bodner 1992; Hodson 1993; Lederman 1995; Author 2015) and NOS stealing time from the teaching of science concepts (Abd-El-Khalick et al. 1998; Clough and Olson 2012, Höttecke and Silva). Thus, prevailing, as well as added, challenges and opportunities existed in parallel throughout the project (see table 4).

However, teachers' awareness of opportunities, or "utility values" is imperative if NOS teaching is to become a reality in the science classrooms (Herman et al. 2015). When studying the opportunities that are discussed by the teachers in the present study (table 4), it could be said that a large part deals with the teaching of sociocultural and subjective aspects as a means to: (a) reach other, more overarching, goals of science teaching such as the development of critical scientific literacy through, for example, developing the ability to evaluate trustworthiness and critically examine investigations described in media; and (b), which implicitly follows from the above, to foster a confidence in students to endure and handle complex and nuanced questions with lack of exact answers. In table 4 this can be seen as opportunities related to students' understanding of nuances, development of critical thinking, reflexivity, ability to take part in discussions, and to deal with science in media, which means that the teachers, even though perceived challenging, considered sociocultural and subjective issues as part of a critical or functional scientific literacy that can be useful in everyday life as suggested in Allchin (2011), Hodson and Wong (2014), and Feinstein (2011). Thus, the goals of teaching sociocultural and subjective aspects do not seem to be so much about enhancing the understanding of NOS for its own sake, but rather NOS as a means to reach other, more far-reaching goals.

4.2 Tensions and parallel tracks

Both the challenges and the opportunities that are described in the results section bear witness of NOS teaching as something that is perceived as different from traditional science teaching. To teach about sociocultural and subjective aspects of NOS, at least through the issues that these teachers suggest, means to challenge that tradition for better or worse. A common part of the school-science tradition, as described both in the research literature (e.g. Allchin 2003; Feinstein et al. 2013; McComas 1998; Rudolph 2005; Ruhrig and Höttecke 2015; Zacharia and Barton 2004) and by the teachers in this study, is the focus on concepts. These concepts, which are often presented as indisputable facts, constitute an important part of what is referred to as black and white science in the present study. The emphasis on black and white science runs like a silver thread throughout the project through, for example, the continuous concerns for not having enough time to teach all the facts/concepts in the overcrowded curriculum. Meanwhile, grey scales run on parallel tracks, constantly challenging and blurring the black and white images. These parallel tracks create interesting tensions in the teachers' discussions

of challenges and opportunities connected to the teaching of sociocultural and subjective aspects of science.

One of the tensions in the material is the ongoing implicit discussion of what science teaching is supposed to be, and lead to, and how goals can be reached. Can the desired knowledge be obtained through learning “hard facts” or should it be learned through taking part in discussions about scientific practices or socio-scientific issues debated in media; or is a combination the best solution (c.f. Feinstein et al. 2013)? This eventually comes down to discussions about the goals of the science curriculum and the possibilities of meeting all goals. Another tension, which is in part intertwined with the above, is the time factor. The teaching of sociocultural and subjective aspects takes, and should according to the teachers take, a great deal of time in order to become meaningful. It takes time to plan and implement it in the classroom, and all this expenditure of time reduces the time spent on facts. It is possible that the way teachers, to an increasing extent, connect the suggested issues to science practices during the project (see Fig. 1), not only is a result of becoming more concrete in their suggestions, but also is a way to try to solve this tension. That is, the tighter the specific issues become connected to science the more science-like the teaching can become. Furthermore, through connecting the sociocultural and subjective issues to science content, the feeling that the facts are put on hold might be reduced. This could also create more possibilities for the teachers to get used to teaching about sociocultural and subjective aspects, as well as about other NOS aspects, on the spur of the moment in connection to whatever science content that is the topic of the lesson. Developing the abilities for teaching NOS on the spur of the moment is thought to be an important factor in making a more nuanced science part of everyday teaching practices (Herman et al. 2013; Author 2016).

As previously mentioned, the challenges discussed by the teachers at the beginning of the project prevail, and more are added; however, this trend applies also to the opportunities. The discussed opportunities could become very important keys in scaffolding the efforts of changing traditional science teaching. As teachers experience the engagement and participation of their students in combination with the satisfaction of developing their own practice, and the possibilities to reach more overarching goals, it might just become worth the effort.

4.3 Implications and concluding remarks

It is fairly possible that the challenges of teaching complex topics, such as the ones discussed in this article, through complex teaching approaches, like discussions and argumentation, might never disappear – after all, teaching in compulsory school is in itself a very complex task where teachers meet different student groups with different backgrounds, abilities, values and wishes. However, teacher education has to be aware of, and take these challenges seriously. The present article shows how immensely important it is that teachers get the opportunity to plan and implement new teaching approaches. This way, vague ideas about topics, issues, and approaches necessarily turn into concrete, and hopefully, teachable issues and practical plans. Through implementing the activities, teachers get first hand experiences of challenges and opportunities, which makes it possible to deal with these through reflections and collaboration with other teachers, teacher students, and science educators. The experiences could also lead to the challenging of teachers’ own preconceptions of, for example, students’ abilities for handling abstract topics. As, we saw in this study many

students took an active part in the discussions, also students that the teachers had not expected to take part.

Moreover, in combination with first-hand experiences there ought to be a never ending discussion on what and whom compulsory school science is for, and how meaningful teaching can be accomplished for the intended group. The discussions that the teachers in this study took part in, connected both to anticipated and experienced challenges. The dynamics of the group discussions brought tensions and diverging meanings out in the open. Such discussions can create an urge and curiosity to take on the challenges. Another way to create a notion that it might be worth taking on the challenge, is to take advantage of the opportunities, as the ones presented in this article as well as “success stories” (Authors forthcoming), and use them as examples in teacher education and professional development courses. This provides insight into opportunities through practicing teachers own voices and can be combined with ideas for how to meet the challenges. Furthermore, first-hand experiences of NOS teaching in combination with teaching examples (e.g. from “success stories” or from the rich source of instructional material c.f. Allchin 2012; Clough 2011; Henke and Höttecke 2015) could constitute the basis of a broader and more solid teaching repertoire.

This article has followed a line of research in which teachers’ voices are listened to and taken seriously. The results add to the understanding of how the actual planning and implementation of NOS activities in combination with reflective discussions, can become important catalysts in making discussions of NOS teaching, in this case the teaching of sociocultural and subjective aspects of science, more concrete both as regards the suggestion of relevant issues, and the discussion of opportunities and challenges. As teachers are important keys to what takes place in the classroom, their perspectives provide important information that has to be taken into consideration both in teacher education and in future science education research. Without insights into their perspectives on what is possible and valuable to do in the science classroom the gap between the aspirations from science education research and the everyday teaching practice is not likely to be bridged.

An important lesson from this study is that no matter how willing the teachers are to teach indisputable facts from time to time, NOS is seldom suggested as facts for its own sake, but rather as issues for discussion. Hence, when they suggest teaching about nuances of science (sociocultural and subjective aspects) it is by no means intended as a way to teach facts about these nuances, but instead the nuances are welcomed as a means to reach other, overarching, goals of science education. Thus, based on the results from this study, teacher education courses set on teaching NOS to future teachers, should consider to contextualize much of the NOS teaching in situations both outside and within science, and above all, discussions should be initiated regarding how NOS can become a fruitful element in teaching towards scientific literacy for all.

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Appendix A description focus group activities and material

Meeting (year:group)	Summary description and distributed material
1:1	<p>Introduction</p> <ul style="list-style-type: none"> • Participant presentation • Reflections on pre-distributed text • Participants explore the national curriculum for references to NOS (NOS references are marked and debated). Discussion on how the marked passages become visible in teaching <p>Distributed Material:</p> <ul style="list-style-type: none"> • Pre-distributed text (introduction to NOS)* • Overview of goals in national curriculum
1:2	<p>Tentative, empirical, subjective aspects of science</p> <ul style="list-style-type: none"> • Participants' reflections on pre-distributed text with regards to both NOS in general and NOS teaching (what, how, when, for whom?) • Discussion about NOS teaching that can be appropriate for different school years • Participants take part in a card game (Coburn and Loving 1998) where they are prompted to take position regarding statements about science. Each person gets three envelopes marked with "agree", "disagree", and "uncertain". One card at a time is distributed. Participants discuss and debate the statement on the card – consensus is not the goal. Each participant place the card in the envelope of their choice. The envelopes are collected after the meeting. <p>Distributed Material:</p> <ul style="list-style-type: none"> • Pre-distributed text with questions and examples from tentative, empirical, and subjective aspects of science • Table with school years and themes for participants' documentation • 20 cards (adapted from Coburn and Loving 1998).
1:3	<p>Creativity, socio-cultural contexts in science, observation /inferences, theories/laws/models</p> <ul style="list-style-type: none"> • Same approach as in meeting 1:2 directed towards new themes • Joint planning of second year of the project. <p>Distributed Material:</p> <ul style="list-style-type: none"> • Pre-distributed text with questions and examples dealing with creativity, socio-cultural contexts in science, observation /inferences, theories/laws/models • 16 cards (adapted from Coburn and Loving 1998).
2:1	<p>Teaching examples</p> <ul style="list-style-type: none"> • Summary of discussions from year 1; • 3 examples of NOS activities are distributed and demonstrated by the moderator: • Participants discuss for each example: a) what aspects of NOS are visible in the examples, b) which aspects could be made visible in the science classroom, c) how?/for whom? • Participants discuss what NOS could be made visible in a common lab activity

	<ul style="list-style-type: none"> • Short discussion of what kind of activities and NOS aspects the teachers would like to try in their own classrooms. <p>Distributed Material:</p> <ul style="list-style-type: none"> • Excerpts from descriptions of classroom activities: <ul style="list-style-type: none"> ◦ Excerpt from Black-box activity “the bucket” (Wickman & Persson 2009), ◦ Excerpt from SSI-approach “Can cell phones cause illness?” (Ekborg et al. 2012), + Newspaper articles about cell phones ◦ Translated excerpt of historical case study “the battle over the electron” (Kolstø 2008).
2:2	<p>Planning of NOS teaching</p> <ul style="list-style-type: none"> • Participants make up joint plans for NOS teaching: choose key NOS aspects and issues, connect to curriculum; decide on possibilities for assessment; • The group is divided in two (year 1-6 and year 7-9 teachers) where detailed lesson plans are made. The groups present their thought to each other by the end of the meeting. • Practical plans for dates and classroom observations are made. <p>Distributed Material:</p> <ul style="list-style-type: none"> • List of formerly discussed aspects and issues
2:3	<p>Reflection on implementation</p> <ul style="list-style-type: none"> • Each member shares their experiences from the implementation: details of the group, details from the activity, what NOS issues were targeted and how they were included, problems and achievements; • Teachers read 2 short descriptions of critical incidents** and discuss them from a NOS perspective; • Teachers get a task to prepare for the next meeting: to search for critical incidents in their own science lessons. <p>Distributed Material:</p> <ul style="list-style-type: none"> • 2 Written descriptions (translated) of critical incidents “Cells” and “Lamps” (Nott and Wellington 1998)
2:4	<p>Critical incidents, teaching examples</p> <ul style="list-style-type: none"> • Participants describe and discuss their collected critical incidents**; • Discussion of 5 more critical incidents adjusted from Nott and Wellington (1998) • 3 new examples of NOS activities are distributed and demonstrated by the moderator (due to earlier request from the teachers). Followed by teachers’ discussion about NOS and NOS teaching connected to the examples. • Joint plans for next year: how do we proceed? Suggestions of trying a black-box activity at the beginning of the semester. <p>Distributed Material:</p> <ul style="list-style-type: none"> • 5 written descriptions (translated) of critical incidents “The magnesium incident”, “Rats”, “Contraception”, “Chemists”, and “Predictions” (Nott and Wellington 1998) • Excerpts from descriptions of classroom activities: “Mystery tube” (Lederman & Abd-El-Khalick 1998), “The scrambled sentence” (http://www.sciencelearn.org.nz/Nature-of-Science/); Card game: “Which are scientific questions?” (created by the second author of this article and described in Author forthcoming)
3:1	<p>Planning of NOS teaching</p> <ul style="list-style-type: none"> • Participants make detailed plans for teaching a black-box activity “the bucket” (Wickman & Persson 2009) that have been demonstrated to them earlier. Discussion of NOS aspects and connection to the curriculum. • Practical plans for dates and classroom observations are made.

	<p>Distributed Material: none</p> <p>Reflection on implementation</p> <ul style="list-style-type: none"> • Short round of sharing of experiences from implementation of the black-box activity. • Reflections and comparisons between the black-box activity and the previously implemented NOS teaching session (year 2). • (Contrary to the other meetings, in this focus group meeting the moderator was prepared with a battery of detailed questions about the activities. Thus the participants were not the owners of the discussion to the same extent as in former meetings). <p>Distributed Material: none</p>
3:2	<p>NOS progression for compulsory school</p> <ul style="list-style-type: none"> • Participants get the task to, from the basis in their gained experiences, discuss what and how specific NOS issues are appropriate to teach at different educational stages (in a year 1- 9 perspective). Notes are taken by one of the participants. <p>Distributed Material:</p> <ul style="list-style-type: none"> • Table with school years and themes for participants' documentation
3:3	<p>Loose ends</p> <ul style="list-style-type: none"> • Discussions of teachers' ideas that have been recurrent in interviews, and informal discussions, but that have not been shared or thoroughly discussed in the focus group (e.g. washing powder lab, inquiry with many degrees of freedom). • Revisiting progression: teachers discuss the researcher's preliminary analysis of their discussion from last time, make adjustments and put forward new suggestions. <p>Distributed Material:</p> <ul style="list-style-type: none"> • Excerpt from transcript of follow up-interview where John describes a teaching activity "the washing powder lab" • Table over preliminary analysis
3:4	<p>Summing up evaluations</p> <ul style="list-style-type: none"> • Written prompts and diagrams for teachers to answer/fill in providing their thoughts on their individual journeys through the project. (Example: how was your attitude and confidence in relation to your teaching affected by different parts of the project on a scale from zero to five.) • Short discussion and sharing of evaluations. <p>Distributed Material:</p> <ul style="list-style-type: none"> • Written prompts and diagrams for evaluation
3:5	<p>*An agreement was met that pre-distributed material never should exceed 3 pages</p> <p>**A critical incident is defined as:</p> <p>...an event which makes a teacher decide on a course of action which involves some kind of explanation of the scientific enterprise. It may be an event like some practical work going wrong or it may be an event which raises moral and ethical issues about scientific knowledge or the conduct of scientists. These events are often stimulated by pupils saying and doing things, but they may also arise through the action of the teacher, particularly when a demonstration goes wrong. (Nott & Wellington, 1998 p.581)</p>

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What is the purpose of school science and whom is it for? What happens with the answers to these questions if new elements are included in a science teaching that traditionally has emphasized science concepts and lab-work? This thesis longitudinally explores teachers' perspectives regarding the inclusion of "nature of science" (NOS) in science teaching. The thesis shows how teachers' construction of NOS practice is negotiated in relation to policies and traditions of science teaching. The analysis is based on results from four included articles, illuminating different facets of what NOS to be taught at different educational levels; how NOS can be approached; rationales for teaching NOS; challenges and opportunities related to student expectations, teacher roles, and goals of science teaching. Thus, the thesis contributes with teachers' perspectives on what, how, why, and for whom NOS should be taught.

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