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A science teacher's complex beliefs about nature of scientific inquiry

Abstract

One major concern relating to teaching scientific inquiry is that many teachers show epistemologically naive beliefs about nature of science (NOS). In this study, we use in-depth interviews to identify an upper secondary science teacher's beliefs about NOS and scientific inquiry in school. We found that what seemed to be a teacher's positivist position was embedded in broader concerns regarding pedagogical considerations and personal engagement relating to the students. This broader ecology of a teacher's beliefs enabled us to understand why positivist epistemology and related myths concerning NOS are seemingly robust in school versions of scientific inquiry. We suggest that implications for science teacher education and professional development are that teacher (students) need opportunities for guided reflections on personal experiences and commitments towards scientific inquiry to increase conscience with respect to how they might affect their situated practice.

Introduction

Reforms in science education all over the world advocate a view of teaching and learning science that emphasises inquiry to learn about nature of science (NOS) and increase interest in science (e.g., European Commission, 2007; Quinn, Schweingruber, & Keller, 2012). However, research reveals that practices of scientific inquiry in schools do not reflect a contemporary view of NOS (Capps & Crawford, 2012; Grandy & Duschl, 2008). One of the major concerns is that many science teachers show epistemological naïve views about NOS (Bryan, 2012; Hodson, 2009; Lederman & Lederman, 2012). Taking into consideration the key position teachers hold in shaping the teaching practice and students' learning environment, the desired change in school science depends heavily upon teachers' capacity to integrate the epistemology and practices of a reform with their beliefs and existing practices (Bryan, 2012). However, in an overview over teacher beliefs in science education, Wallace concludes that "*experienced science teachers have belief sets that are stable, closely held, and resistant to change*" (2014, s. 22). Thus, the wanted change put forward by curricula reforms, putting emphasis on scientific inquiry and NOS in school science might be difficult to effect in practice. There is a substantial body of literature relating to teachers' beliefs; however, these often tend to be studied in isolation (Rubie-Davies, Flint, & McDonald, 2012). We follow Jones and Leagon (2014) in that understanding how beliefs concerning NOS intersect with factors such as context, self-efficacy, or epistemic beliefs, we can better inform our approaches to reforming science education. Thus, in this article we seek to explore a science teacher's beliefs about NOS and how they connect with various beliefs concerning teaching and learning in a situated practice of scientific inquiry.

The point of departure for the present study was an action research project (Carr & Kemmis, 2003) where the authors collaborated with science teachers at an upper secondary school to learn from and develop a practice of open inquiry. The research project was initiated after the implementation of a Norwegian school curriculum reform in 2006 (Ministry of Education and Research, 2006) where the natural science subject revealed increased focus on scientific inquiry and NOS. We worked especially closely with an experienced teacher, Amir, which had implemented open inquiry for students to learn about scientific inquiry and NOS for several years. In the first cycle of the action research, we observed and analysed the open inquiry and found that it represented a simplified version of scientific inquiry, characterized by a step-by-step method and little use of theory to inform the students' inquiries (Bjønness & Kolstø, 2015). In the two next cycles of action research Amir decided to make chances towards a version of open inquiry reflecting a more contemporary view on scientific inquiry, but in the rough and tumble of practice, he fell back on the known practice. However, this "failed" attempt leads us to ask questions about why the wanted changes were not realized even though the teacher planned for and positively valued them. Even though there are likely other reasons why the desired changes did not occur, this motivated us to understand more about the teacher's complex beliefs about NOS and scientific inquiry in the situated school context.

The rationale for the case study is that in order to understand why beliefs about NOS and scientific inquiry are resistant to change, it is necessary to understand why they are important as they relate to classroom practice. We used in-depth semi-structured interviews and conversations with an experienced science teacher over the course of three years to identify the teacher's beliefs concerning NOS and scientific inquiry in a situated practice of open inquiry. The study is guided by two research questions:

1. What are the experienced science teacher's espoused beliefs concerning NOS and scientific inquiry in school?
2. How do these beliefs represent scope and force for the teacher in a situated context with low-achieving students performing open inquiry?

The following review provides background and theoretical framework for the article. We address relevant research concerning teacher beliefs about NOS and scientific inquiry, open inquiry as a context to learn about NOS and scientific inquiry, and teaching as a complex and uncertain enterprise.

Teachers' beliefs about NOS and scientific inquiry

Examining teachers' beliefs can provide insights into the types of experiences that teachers provide in their classrooms. In a review of teachers' beliefs and educational research, Pajares (1992) reported that beliefs are personal constructs that strongly affect individuals' behaviour and that the "*belief system has an adaptive function in helping individuals define and understand the world themselves*" (1992, p. 325).

Much research has investigated teachers' beliefs concerning NOS, and it appears that a positivist ideology is commonly held among science teachers (Bryan, 2012; Hodson, 2009; Lederman & Lederman, 2012). In short, this include ignorance of the theory-laden nature of observation and experiment, belief in a fixed algorithmic method of scientific inquiry, uncertainty about the status of scientific knowledge, a tendency to overlook the socio-cultural embededdness of scientific practice and the role of creativity and imagination (Hodson, 2009). Actually, a positivist view of NOS can take the shape of either naïve inductivism (that conclusions can be directly inferred from data if the correct method is used) or naïve deductivism (make observations-formulate a hypothesis-deduce consequences from the hypothesis-make observations to test the consequences-accept or reject the hypothesis) (Duschl & Grandy, 2008, p. 8). During the 80s and 90s the view referred to as the Standard Science Education, that anyone can develop scientific knowledge by applying certain intellectual and practical skills by the application of a stepwise method, became increasingly questioned (Hofstein & Kind, 2012).

There are research suggesting a congruency between teachers' beliefs about NOS and their instructional practice (e.g., Bencze, Bowen, & Alsop, 2006; Brickhouse, 1990), while other show no significant relationships between teachers' understanding of NOS and their classroom practice (Bartos & Lederman, 2014; Kang & Wallace, 2005). The latter seemed to be especially true for teachers holding sophisticated views of NOS, but who did not apply it in their teaching practice. Bartos and Lederman (2014) question whether standardised tests for assessing teachers' conceptions about NOS and scientific inquiry (e.g. Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) is effective to explain the documented disconnection between teachers' espoused views and classroom practice of NOS and scientific inquiry.

In a qualitative study of five teachers' conceptions and classroom practice of NOS and scientific inquiry, Bartos and Lederman (2014) found that even though the teachers had received instruction on NOS and scientific inquiry from the researchers in the project, and were aware of the intent of the study, the teachers' sophisticated views were not manifested in practice. The authors indicate that these teachers had not internalized the importance of teaching about NOS and scientific inquiry on par with traditional subject matter. Likewise, pre-service teachers' informed understanding of NOS does not necessarily lead to a sound practice at school. For example, in a three-year longitudinal study of five early career science teachers and their beliefs about teaching, Fletcher and Luft (2011) found that the new teachers' beliefs tended to move from a contemporary position while participating in their teacher training program toward more traditional beliefs about teaching through practice in school. They suggest that the shift can be caused by beginning teachers facing situations such as a static school culture, little support from school leaders for implementing reform-based strategies and the new teachers' feelings of being overwhelmed. However, some research reveals factors that seem important developing in-service and pre-service teachers' understanding of NOS; notably providing teachers with their own experiences of inquiry, as well as explicit opportunities for reflection about NOS (e.g., Bartos & Lederman, 2014; Ozgelen, Yilmaz-Tuzun, & Hanuscin, 2012; Schwartz, Lederman, & Crawford, 2004).

Open inquiry as a context for learning about NOS and scientific inquiry

Open-ended scientific inquiry projects has been suggested by numerous researchers to replace recipe-type experiments in order to enhance and enable more authentic science learning (Duschl & Grandy, 2008; Roth & Bowen, 1995; Wells, 1999). Moreover, open inquiry is supposed to provide the students with opportunities to learn about essential features of scientific inquiry and NOS through own experience (Asay & Orgill, 2010; Bencze, Bowen, & Alsop, 2006). The problem is that the open inquiry approaches presented in school science are mostly simplistic versions of the scientific method, and they obscure the complex methodological strategies found in real science (Windschitl, 2004; Grandy & Duschl, 2008).

The characteristics of NOS and scientific inquiry proposed for secondary school science (e.g. Lederman & Lederman, 2012) are not necessary easily translated into classroom practice. Many teachers will argue that it is a rather difficult undertaking. This may be one of the reasons why the practice of inquiry in school seems to be dominated by oversimplified versions of scientific inquiry that do not represent a contemporary understanding of NOS and scientific inquiry (Duschl & Grandy, 2008; Windschitl, 2004). Some of the difficulty is how to understand and implement progression in the teaching of NOS. Duschl and Grandy (2008) point to a transition from a sense-based science in early years of schooling to a model-based science in later years, where data are derived from theory-driven methods. How should this progression be operationalized? What can be said, is that naïve inductivism correspond better with sense based than with modelling practices of science. Furthermore, at what level of schooling should the tentativeness of scientific knowledge be introduced, and how? Some of the experts in the Delphi study of Osborne and colleagues (2003) were concerned that too much emphasis on the tentativeness would undermine a sufficiently clear idea about the purposes of science, or that a proper understanding of tentativeness demand a strong thematic understanding of the issue thus pushing teaching paradoxically into more transmissive modes. On the other hand, without recognizing that scientific knowledge is open to contestation and refinement, knowledge advancement as overall goal of science as a communal enterprise relying on argumentation cannot be grasped. In addition, a distinction between ready-made-science and science-in-the-making is important in education for citizenship focusing on socio-scientific issues (Kolstø, 2001). Indeed, when investigating socio-scientific issues, considering the embeddedness of scientific inquiry in communities of expertise that are part of society is essential (Karahan & Roehrig, 2016).

Teaching as a complex and uncertain enterprise

Barnett and Hodson (2001) suggest that development of the curriculum very often fails because education is looked upon in a decontextualized way. In contrast to this thinking, they propose that we must acknowledge teaching as a complex and uncertain enterprise.

> *To signify that what good science teachers know, do, and feel is largely about teaching, and is situated in the minutiae of everyday classroom life (...). The sources of this knowledge are both internal and external: internal sources include reflection on personal experiences of teaching, including feelings about the responses of students, parents, and other teachers to one's actions; external sources include subject matter knowledge, governmental regulations, school politics and the like. (p. 436)*

In accordance with this complex way of viewing teaching, a teacher may hold a specific epistemological position, not only because of his/her epistemological beliefs, but also because of needs such as instructional goals and classroom management (Kang & Wallace, 2005). Moreover, it is important to recognize that teachers invest themselves and their sense of identity in their work (Nias, 1996). Zembylas (2002) notes that there is a widespread belief that emotions are a central aspect of education and teaching, highlighting the importance of "*identifying how science teachers' emotions inform, expand or limit possibilities in their science teaching and how these emotions enable them to think and act differently*" (p. 97). Thus, it is can be argued that it is important to study beliefs about NOS from a wider perspective acknowledging that they can be moderated by experiences in school contexts and personal beliefs and emotions.

A complex understanding of teaching also takes account of the students' personal understandings. Cobern (1996) uses the concept of worldview to explain that every individual has a set of fundamental presuppositions and that his or her perception of reality is grounded on these. Cobern suggests that for school science to be meaningful, teaching must fit the students' sense of self, environment, personal goals and their understanding of how the world really is. A concept or belief has *force* if it is central in an individual's thinking rather than marginal, and it has *scope* if it has relevance for the individual over a wide range of contexts. To understand teachers' beliefs and their importance in guiding their practice, we draw a parallel to Cobern's idea of worldview and consider why certain beliefs have scope and force in a teacher's practice. In teacher professional development or teacher education, the teacher (student) may accept explicit instructions about NOS as a valid approach, but these instructions about NOS may still contradict deeply held commitments regarding NOS and what constitutes good and appropriate teaching practices.

Summing up, previous research has shown that teachers' inquiry practice are at odds with accepted NOS tenets. There seem to be two main reasons for this; it appears that a positivist ideology is commonly held among science teachers, and even if teachers held contemporary beliefs connected to NOS and scientific inquiry it does not necessarily inform their practice. Our study takes as point of departure that a science teacher's courses of actions are grounded in a web of belief structures, not necessarily consistent, related to important concerns regarding Nature, teaching, students, and learning. Specific beliefs, regarding for instance NOS, gain scope and force in this broader ecology of beliefs.

Method

The action research project was significant in two ways for the present case study: First, it enabled us to get acquainted with both the practices and the espoused beliefs of the teacher. Second, the lack of development in the teacher's practices stimulated our interest into understanding the scope and force of the beliefs articulated by the teacher. We chose semi-structured interviews (Kvale, 2008) as a means to let the teacher speak more freely about the complex subjects of NOS and scientific inquiry, and relate them to his own practice in the classroom. In this study we have focused on an experienced and particularly articulate teacher (Amir) that was able to express his views and intentions explicitly with respect to school science inquiry. The local culture of a classroom with low-achieving students is of interest, as it plays a significant role in the teacher's interpretation of inquiry practice.

The authors of the present paper have both been working as science teachers at the upper secondary level and are now working with science teacher education as well as research in science education. Our experiences have given us a deeper understanding of the important role of the teacher in improving school science inquiry. The analysis are presented in form of narratives and quotes representing the teacher's espoused beliefs (Connelly & Clandinin, 1990). The narratives are condensations of the data material written as first-person accounts that are thematically focused. We shared the narratives with the teacher in order to check their intentionality, and he supported our representation, as well as made some elaborations and clarifications that were taken into account.

Data collection

Data were collected from December 2007 to May 2010. It included four in-depth, semi-structured interviews with the teacher (eight hours) as primary sources. The interviews were performed by the first author at the school during and after the open inquiry project. The teacher spoke freely around some major themes concerning his experiences with open inquiry (possibilities and constrains, changing roles for students and teacher etc.), his motivation for undertaking open inquiry, his view about the students' learning about NOS from open inquiry, and his view concerning NOS. The secondary sources were classroom observations, meetings, informal conversations and site documents (e.g., assessment scheme, PowerPoint presentation, students' products) from the open inquiry project. Since we were in the field for a three year period, the tendency for the teacher to exhibit contrived behaviours for the benefit of the researchers was minimized. In addition, we were able to consider whether a given statement was typical or atypical, increasing the study's internal validity.

Data analysis

To analyse our case we have used an interpretive design that was derived from Erickson (2012). Firstly, we transcribed all semi-structured interviews and performed an open coding using the software ATLAS.ti for qualitative analysis, searching the data for interesting features relevant to our interest (ibid.). Secondly, we performed an analysis where the first step was collating codes into potential themes (e.g. Nature, science inquiry in school, teaching and learning science, NOS). Then, as part of refining the specifics of each theme, we made mind-maps, using the software www.text2mindmap.com, as a visual thinking tool to structure and explore the relationships between concepts related to each of the themes. Finally, scrutinizing the mind-maps in a collaborative effort, we found three emerging dimensions of the teacher's beliefs concerning NOS and the situated practice of open inquiry: (1) open inquiry as a way to motivate students and oppose rote learning, (2) nature as wonder as well as source of knowledge by individual observation and (3), scientific inquiry as a simple step-by-step method. The results of the analysis are presented in forms of narratives connected to each of the three dimensions to convey the belief that was implicit in the stories of the teacher. We also present discrepant statements concerning his beliefs. Finally, we have made a conceptual map (Miles & Huberman, 1994) to make explicit the teacher's beliefs as revealed through the narratives and to make visible the relationships between his beliefs (Figure 2).

Background context of the 12-week open inquiry project

The context of the study is a Norwegian upper secondary school located nearby the capital. It has mainly vocational education programmes, but offers a small section with programmes for general studies. The science teacher, Amir, has a master's degree in science and twelve year of experience as a science teacher. According to Amir, being consistent with our impressions from three years fieldwork, the students' typically displayed a shallow understanding of scientific concepts and processes and many had a history of defeats relating to the more academic subjects at the school. In such regard, the students in the present study can be seen as low-achieving students in academic subjects such as science. Research on school science in contexts with low-achieving students reveals that there is a tendency to concentrate teaching on achieving only basic factual science information based upon rote learning (Yerrick, Liuzzo & Brutt-Griffler, 2012). Amir's practice of open inquiry for these students struggling with school science stand in opposition to this view.

The overall goals, formulated by the teacher, were for the students to learn the scientific method by studying a natural phenomenon and to stimulate their creativity, curiosity and motivation for science. The school laboratory was well equipped, including data loggers with multiple sensors. Figure 1 shows a slide from Amir's PowerPoint presentation when he introduced the open inquiry, summing up what he called the "steps of the scientific method".

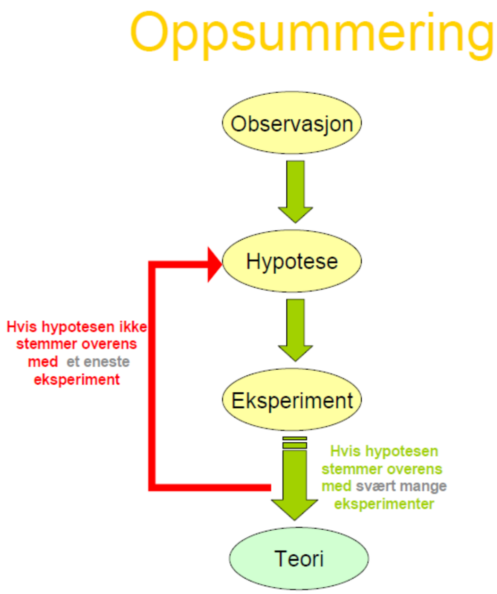


Figure 1. The teacher's PowerPoint summing up four main steps in the scientific method ('Observation → Hypothesis → Experiment → Theory'. Red arrow: 'If the hypothesis is not consistent with a single experiment').

After the introduction, the students worked independently in groups of 3-5 persons whilst being guided by the teacher. Their work followed roughly the phases: developing ideas, formulating research question and making a research design, experimenting and discussing, presenting of posters and writing of a report (for more details see Bjønness & Kolstø, 2015). The students' choices of research problems were often close to their interests or daily life, e.g.; Is the quality of bottled water better than the tap water at the school? How do the emissions of CO_2 change in cars produced in the period from 1980 and 2007?

Results

The following three dimensions were found through the analysis to account for Amir's espoused beliefs: (1) open inquiry as a way to motivate students and oppose rote learning, (2) nature as wonder as well as source of knowledge by individual observation and (3) scientific inquiry as a simple step-by-step method. We use narratives and excerpts from interviews with Amir to convey the beliefs that was implicit in the teacher's stories.

Open inquiry as a way to motivate students and oppose rote learning

The following narrative reveals how Amir perceives science is taught in Norwegian schools, and why he provides his students with the opportunity to do open inquiry.

> *Science education in our school system is mostly about rote learning and repeating facts. The teachers depend very much on the textbook and acts like a newscaster. The students know what to learn and they reproduce it on tests. They follow the rules because it is easy and secures good grades. The problem with this way of learning is that it puts a lid on students' natural curiosity and creativity, and the students' basic relationship to science is not altered. It is difficult for a teacher to discover the students' potential during teacher-directed activities. Open inquiry gives me a chance to discover, map and educate the 'little scientist' that is found in the students, and it gives students a chance to blossom in science education. I have faith in the students, and I want to be their co-researcher and discover a phenomenon of their interest together with them. I do not force the students, I place myself shoulder-to-shoulder with them and we learn things together. I have experienced that students become more self-confident in school science through working with open inquiry. For instance, at oral examination, they show better reasoning abilities than other students do. In addition, they reveal a more balanced view on how knowledge is built in science. I believe it is caused by their direct involvement in the processes of scientific inquiry.*

Amir reveals a concern related to school science as focusing on memorizing facts. In his opinion, this way of teaching alienates the students' relationship with nature and science. As a contrast to this, he highlights the open inquiry project as a chance for students to engage personally in a phenomenon of their own interest. The following narrative reveals that his own experiences as a child seem to be important for his epistemological belief and a driving force for how he frames the open inquiry project.

> *I have a great interest in science. It started when I was a child. I had a small notebook, which I named the "book of everything", where I made notes of observations and other interesting things, and I tried to set up possible explanations. I did not have a clue about hypothesis or observations, but I was just interested. I actually did a lot of experimenting as well with simple means. For me, the open inquiry project is first and foremost about upbringing and education, it gives students a chance to blossom by letting them do research on something of their own interest. It motivates me as well. My idea is to give the project as a gift to the students.*

Amir's personal experience as a "little scientist" seems to be of importance for his teaching practice. He wants his students to experience that science is relevant and meaningful. They have experienced failure in academic subjects at school, and the open inquiry may represent a path for them into the world of science. It becomes clear that Amir sees open inquiry as an alternative form of teaching and learning that can create interest for science. Moreover, it motivates him in his work as a teacher.

Nature as source of wonder as well as knowledge by individual observation

The following narrative reveals Amir's positive emotions regarding nature, and his believes in science is for all.

> *I see nature as holy. It provides pleasure and wonder. Nature is a source of knowledge, and it is essential for us. In my opinion, natural phenomena are everything that exists and happens in nature. It can be everything from ice crystals to cancer cells. Scientific inquiry gives us the possibility to study how things are connected in nature. We need to understand humans' relationship to nature, how we are influenced by nature and how we can influence it. Nature is a reference for everyone; no one has actual authority. So, we do not have problems with authorities that prevent creativity and restrain growth. I believe science is for all. It is democratic and gives freedom and possibilities.*

The narrative reflects the teacher's positive emotions relating to nature in his use of words such as "pleasure" and "wonder". He believes that nature is the only true authority and that this makes science democratic; as expressed by him, "everyone is on equal footing". Access to nature opposes a repressive school science culture, and this represents force in Amir's beliefs. The framing of the school project reflects his thinking in the way that it encourages the students to connect with natural phenomena more than to textbooks. The following narrative reveals how Amir emphasizes the importance of observations.

> *I would like the students to experience joy in relation with nature and science. They will observe a natural phenomenon that they are interested in, and they use logic and creativity to build a bridge between themselves and nature. The students will start with clean sheets. Our senses are the first approach towards a natural phenomenon; it can be described by using an analogue, a radio transmitter, in the way it plays a role in the reaction and signals that emerge. In my opinion, observation is an ability that can be trained, and I find that it is meditational and brings pleasure. When the students observe and use tools in order to explore their hypothesis, I can see that they enjoy it, and that they soon take ownership for what they are doing.*

The narrative reflects Amir's belief that observations provide an opportunity for the students to actively involve themselves in the inquiry process, and thus create positive experiences towards science. However, the following excerpt from an interview with Amir reveals what seems to be a positivistic position regarding the role of observations in scientific inquiry.

> *I am going to draw parallels from the medieval considerations of true and false, and science in its nature is such that no one really has the authority, if I am poor or rich (...) from Africa or Japan. If I have found that water boils at 100 degrees at sea level, it does not matter whom we are. We are just basing it on the experiment, at a very objective level; therefore, in this field, all human are set equal. (Amir, December 2007)*

Amir is framing the project as individual thinking and learning, where students connect with a phenomenon using their own senses and logic.

Scientific inquiry as a simple step-by-step method

The following narrative reveals Amir's beliefs in scientific inquiry designed as a simple step-by-step method to support low-achieving students.

> *Scientific inquiry is very complex, and the students will only get a small taste of it. I simplify it by presenting it as a step-by-step method, almost like a recipe you can follow. These students will lose interest and motivation if you push them too much. You need to be careful not to present too much theory and conceptual framework for what they are going to do. If you do this, they will retreat. Most of them have a history of defeats in the academic subjects. In this project, we have a focus on the experimental side of science. During the inquiry, the students will experience that the method is more complicated than first expected, and they often need to make new hypotheses and designs when the first one fails. They learn to be critical towards their own work, they understand there are many things that they did not have time to explore and they do not think they have "found the truth".*

Amir's espoused beliefs are in accordance with ignoring the theory-laden nature of observation and experiment, and belief in a fixed algorithmic method of scientific inquiry to support low-achieving students during open inquiry (cf. Figure 1). He is focusing on knowledge advancement as an individual enterprise by framing the project as individual thinking and learning, where students connect with a phenomenon using their own senses and logic. Thus, he is framing scientific methods as an individualist, simplified hypothetical-deductive method when talking about his students and teaching practices. However, in the following quote from an interview, Amir reveals a more elaborated epistemological view concerning scientific inquiry.

> *I have told them (the students) (…) that the scientific method is actually an ideal recipe. (…). Many great scientists do not necessarily follow this method. Many of them have a very critical attitude to the method; the whole logic of the scientific method is not something on which they have agreed. (…) It is not necessarily the only method. (Amir, December 2007)*

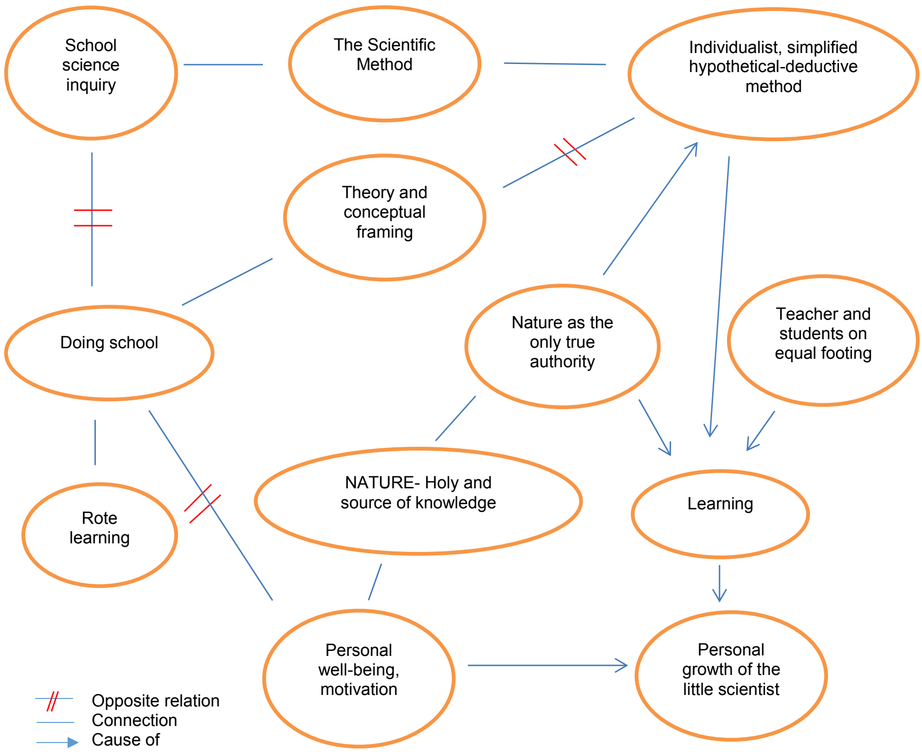
His espoused belief in a simplified scientific method for these students struggling with science is discrepant to his more sophisticated view on authentic scientific inquiry; suggesting that he distinguishes between the school version and authentic versions. In a note written after Amir had read our representation of his beliefs concerning NOS and scientific inquiry in the situated school context, he elaborated the following point of view.

> *In a way, students 'realize' themselves by working with 'the scientific method', that they actually construct knowledge about the natural phenomenon. Thus, they look at scientific knowledge as something that is formed by their personal/psychological/social norms in addition to the natural phenomenon itself and experiments. (Amir, June 2012)*

The statement reflects that he believes that students will implicitly by engaging in scientific inquiry appreciate the social and personal nature of science. Amir's framing of scientific inquiry as an individual approach represents scope and force for him as a means to empower students by erasing boundaries between them and science. To bring in the social community as a central part of the nature of science may stand in opposition to the teacher's idea of connecting students with a phenomenon without too much complexity that could disturb the students' personal experiences. The gap between the teacher's epistemological beliefs about NOS and his views related to the classroom practice of NOS and scientific inquiry can be understood by his pedagogical concerns related to the group of students.

We have summarized the main findings in a conceptual map (Figure 2) depicting the relationships between central concepts of Amir's various beliefs revealed through the narratives. The map illustrates that his conceptualization of the "the scientific method" as school science inquiry is considered as opposed to rote learning of the usual "doing school" practices, which inhibits students' motivation for science and their personal well-being. His ambition is to foster students' personal growth by enabling learning experiences guided by the scientific method where nature is the only authority to knowledge by a simplified hypothetical-deductive method. With this method in hand, students and teacher can explore Nature on equal footing. Figure 2 shows that specific beliefs, concerning for instance NOS, are interconnected with beliefs regarding the students' personal well-being and motivation. This indicates that what gain scope and force for Amir in his practice of school science inquiry relates to a web of beliefs.

Figure 2. Conceptual map depicting the relationships between central concepts of Amir's various beliefs concerning NOS and scientific inquiry in school.



Discussion

It is well known that teachers may hold beliefs about NOS and scientific inquiry that are at odds with tenets found in the research literature, and that although these beliefs are important they may not be consistent with what is observed in teachers' practices. Our contribution is to show through our analysis of an experienced science teacher that beliefs about NOS, even if problematic in light of science educational research, gain scope and force by their connections to other beliefs structures also important to schooling. In the following, we will discuss the experienced science teacher's beliefs concerning NOS and practice of scientific inquiry, as well as further discuss how these beliefs represent scope and force for the teacher in a situated context with low-achieving students. This is our answer to the research questions. Finally, some implications for science teacher education and teacher professional development will be suggested.

The first research question was: What are the experienced science teacher's espoused beliefs concerning NOS and scientific inquiry in school? To sum up the results, the current study has shown that Amir combines elements from "naive inductivism" as well as naïve deductivism (Duschl & Grandy, 2008). The deductive aspect opens for a creative side of theory formation, which is an important part of the teacher's goal of fostering the "little scientist". Students can inquire about just anything using the scientific method; nature will correct their understanding if it is not correct. However, as there is little emphasis on theoretical understanding, the inductivist part becomes most important; students learn from inferences based on observations. The problematic tenet of inductivism is that theory-independent evidence is obtainable. However, it follows that his beliefs about NOS and inquiry is differentiated between authentic and school science. Our findings is an indication that teachers' views of the nature of science need to be considered as situated, coloured by several elements that compose a view of what constitutes "good teaching".

The second research question was: How do these beliefs represent scope and force for the teacher in a situated context with low-achieving students performing open inquiry? We found that what give Amir's beliefs scope and force are not formal epistemological principles from the philosophy of science, but his educational agenda, which is his ambition for the personal growth of his students. By the scientific method students are provided a tool connecting them with natural phenomena. They can learn from nature by this method driven by their curiosity. Previous failures as learners can be left behind and uninteresting and passive rote learning are replaced by active inquiry. In this sense, the scientific method "rescues" students from what Amir's sees as a harmful school culture, the norms of "*doing schooling*" (Schleppegrell, 2002). The learning process becomes a matter of a relationship between the student, nature and the teacher as co-researcher, freed from social background of the students, earlier experiences of defeat and the context of formal education. Furthermore, there is much complexity involved in the teaching of a more authentic nature of science; and his portrayal of the scientific method aligns well with his concern for avoiding too much complexity that could disturb the students' personal experiences.

This implies an empowerment of the individual over tradition that has a historical parallel in the history of science. According to Shapin (1996), what the 17th century natural philosophers considered their most profound task was to identify methods that could ensure reliable knowledge. Such knowledge would need to be strong enough to refute the authority of classical literature. A cornerstone in this struggle was to seek knowledge in 'the book of nature' instead of the authorities of ancient tradition (most notably, Aristotle). This refutation of classical authority has been interpreted by Shapin (ibid.) as a part of reactions against a natural philosophy that had proved itself helpless when confronted with practical, everyday problems and was seriously hampered by academic quarrels and petty rivalry. It was necessary to tune down the social dimension and address nature more directly, seeking "the method". However, the devaluation of both the social dimension and the authority of the classics were implemented in the sense that knowledge was now to be sought inductively from conscientious documentation of singular experience (Knain & Flyum, 2003). This empowerment of individual experience of nature over classical authority parallels Amir's ambition to empower his students to prevail over a repressive school culture by the scientific method. This also implies profound changes in his role as teacher. With the scientific method in hand, he can step out of a traditional teacher role and become a co-investigator and motivator in the joint adventure of exploring natural phenomena. In this sense, Amir too, not only his students, steps out of a repressive school culture. Thus, his simplified scientific method that may be criticized on philosophical and social grounds is motivated by pedagogical concerns and driven by care for his students. However, these concerns come with a prize: that the development from sense-based to model-based conceptions of data becomes more difficult (cf. the opposition towards theory in Figure 2).

The development of a science curriculum must be looked upon in a contextual way, taking into account the situated school contexts and the teachers' knowledge and beliefs (Barnett & Hodson, 2001).

Thus, the pedagogical considerations espoused by Amir must be understood in situated practice with students that have low sense of mastery in science, finding it alienating and not relevant in their lives. Open inquiry may provide opportunities for these students to engage in activities to which they are committed (Wells, 1999). Moreover, real issues, where students do not know the answer, could be a way to oppose the impression that science is not related to everyday life (Hodson, 2009). Furthermore, it makes sense for a teacher not to present more of the same traditional teaching that made these students feel powerless and alien to the culture of school science. In the case of Amir, he focuses on the affective value of the individual students' pleasures when they explore a natural phenomenon of own interest. This can be well understood in light of Amir's own positive experiences as "a little scientist". His role as a teacher was to create a safe learning environment and to work closely with the students, discovering and enjoying their "research" together with them. This teacher role represented a strong force in Amir's motivation of being a teacher.

Implications for Science Teacher Education and Professional Development

The present study reveals how a teacher's personal beliefs can be construed as a web of context-dependent considerations that are vital components in framing a practice of scientific inquiry in school. Problematic and sound beliefs, from the perspective of educational research, may coexist and bring flexibility to the beliefs structures. This may be a reason why research on teachers' professional growth reveals that the personal beliefs and images the teacher students bring to teacher education normally remain inflexible (Kagan, 1992). According to Kagan, students tend to use educational coursework to confirm rather than confront and correct pre-existing beliefs.

It follows from the results of this article that it is necessary for teachers (students) to become aware of the strengths of their beliefs to build further development on the one hand, and to become aware of limitation of their beliefs for the development of future practices on the other. Essential for this development is to consider beliefs about NOS and inquiry in school science as differentiated according to the specific concerns of teaching practices. Thus, we suggest that in order for teacher (students) to prepare for and develop their practice of inquiry in school, they need opportunities for guided reflection on personal experiences and emotions towards scientific inquiry, as well as how they may affect their situated practice. This emphasises the value of teachers (students) spending time on a productive inward journey in the developmental process of their professional identity (Beijaard, Meijer, & Verloop, 2004; Nias, 1996). Teachers (students) may then identify the relevant aspects of their beliefs and concerns that need to be considered for a change in teaching practice of scientific inquiry to occur. The reason why simplified versions of scientific inquiry continue to rule in school science may be that in addition to beliefs concerning NOS, the strong educational and personal sides to teachers' framing of their practice is not considered a part of both the problem and the solution.

References

Asay, L. D., & Orgill, M. (2010). Analysis of essential features of inquiry found in articles published in The Science Teacher, 1998–2007. *Journal of Science Teacher Education, 21*(1), 57-79.

Barnett, J., & Hodson, D. (2001). Pedagogical context knowledge: Toward a fuller understanding of what good science teachers know. *Science Education, 85*(4), 426-453. doi:10.1002/sce.1017

Bartos, S. A., & Lederman, N. G. (2014). Teachers' knowledge structures for nature of science and scientific inquiry: Conceptions and classroom practice. *Journal of Research in Science Teaching, 51*(9), 1150-1184. doi: 10.1002/tea.21125

Beijaard, D., Meijer, P. C., & Verloop, N. (2004). Reconsidering research on teachers' professional identity. *Teaching and Teacher Education, 20*(2), 107-128. doi:10.1016/j.tate.2003.07.001

Bencze, J. L., Bowen, G. M., & Alsop, S. (2006). Teachers' tendencies to promote student-led science projects: Associations with their views about science. *Science Education, 90*(3), 400-419. doi: 10.1002/sce.20124

Bjønness, B., & Kolstø, S. D. (2015). Scaffolding open inquiry: How a teacher provides students with structure and space. *Nordic Studies in Science Education, 11*(3), 223-237.

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41*(3), 53-62.

Bryan, L. (2012). Research on science teacher beliefs. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 477-495). Netherlands: Springer.

Capps, D. K., & Crawford, B. A. (2012). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education*, 1-30.

Carr, W., & Kemmis, S. (2003). *Becoming critical: education knowledge and action research*. London: Routledge.

Cobern, W. W. (1996). Worldview theory and conceptual change in science education. *Science Education, 80*(5), 579-610.

Connelly, F. M., & Clandinin, J. (1990). Stories of experience and narrative inquiry. *Educational Researcher*, 19(5), 2-14.

Duschl, R. A., & Grandy, R. E. (2008). Reconsidering the character and role of inquiry in school science: Framing the debates. In Duschl, R. A., & Grandy, R. E. (Eds.) *Teaching scientific inquiry: Recommendations for research and implementation* (pp. 1-37). Rotterdam: Sense Publishers.

Erickson, F. (2012). Qualitative research methods for science education. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 1451-1469). Netherlands: Springer. doi: 10.1007/978-1-4020-9041-7_93

European Commission (2007). *Science education now: A renewed pedagogy for the future of Europe*. Brussels: European Commission, Directorate-General for Research.

Fletcher, S. S., & Luft, J. A. (2011). Early career secondary science teachers: A longitudinal study of beliefs in relation to field experiences. *Science Education, 95*(6), 1124-1146. doi:10.1002/sce.20450

Grandy, R., & Duschl, R. (2008). Consensus: Expanding the scientific method and school science. In R. Duschl, & R. Grandy (Eds.), *Teaching scientific inquiry: Recommendations for research and implementation* (pp. 304-325). Netherlands: Sense Publishers.

Hodson, D. (2009). *Teaching and learning about science: Language, theories, methods, history, traditions and values*. Netherland: Sense Publishers.

Hofstein, A., & Kind, P. M. (2012). Learning In and From Science Laboratories. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (Vol. 1, pp. 189-207). Dortrecht: Springer.

Jones, M. G., & Leagon, M. (2014). Science Teacher Attitudes and Beliefs. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education* (Vol. 2, pp. 830-847): Routledge.

Kagan, D. M. (1992). Implication of research on teacher belief. *Educational psychologist, 27*(1), 65-90.

Kang, N. H., & Wallace, C. S. (2005). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education, 89*(1), 140-165. doi: 10.1002/sce.20013

Karahan, E., & Roehrig, G. (2016). Secondary School Students' Understanding of Science and Their Socioscientific Reasoning. *Research in Science Education*, 1-28. doi: 10.1007/s11165-016-9527-9

Knain, E., & Flyum, K. H. (2003). Genre as a resource for Science education: The history of the development of the experimental report. *Academic discourse. Multidisciplinary approaches*, 181-205.

Kolstø, S. D. (2001). Scientific Literacy for Citizenship: Tools for Dealing with the Science Dimension of Controversial Socioscientific Issues. *Science Education, 85*, 291-310. doi. 10.1002/sce.1011

Kvale, S. (2008). *Doing interviews*. London: Sage Publications

Lederman, N., & Lederman, J. (2012). Nature of scientific knowledge and scientific inquiry: Building instructional capacity through professional development. In B. J. Fraser, K.

Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 335-359). Netherlands: Springer.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521. doi: 10.1002/tea.10034

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage Publications, Incorporated.

Ministry of Education and Research (2006). *Knowledge Promotion*. Retrieved October 16, 2016, from www.udir.no/kl06/NAT1-03?lplang=eng

Nias, J. (1996). Thinking about feeling: The emotions in teaching. *Cambridge Journal of Education, 26*(3), 293-306.

Osborne, J.F., Ratcliffe, M., Collins, S., Millar, R., & Dusch, R. (2003). What "Ideas-about- science" Should Be Taught in School Science? A Delphi Study of the Expert Community. Journal of Research in Science Teaching, 40(7), 692-720

Ozgelen, S., Yilmaz-Tuzun, O., & Hanuscin, D. L. (2012). Exploring the Development of Preservice Science Teachers' Views on the Nature of Science in Inquiry-Based Laboratory Instruction. *Research in Science Education*, 1-20.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332.

Quinn, H., Schweingruber, H., & Keller, T. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*: National Academies Press

Roth, W.-M., & Bowen, G. M. (1995). Knowing and interacting: A study of culture, practices, and resources in a grade 8 open-inquiry science classroom guided by a cognitive apprenticeship metaphor. *Cognition and Instruction, 13*(1), 73-128.

Rubie-Davies, C. M., Flint, A., & McDonald, L. G. (2012). Teacher beliefs, teacher characteristics, and school contextual factors: What are the relationships? *British Journal of Educational Psychology, 82*(2), 270-288. doi: 0.1111/j.2044-8279.2011.02025.x

Schleppegrell, M. J. (2002). Linguistic features of the language of schooling. *Linguistics and education*, *12*(4), 431-459.

Schwartz, R., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*(4), 610-645. doi: 10.1002/sce.10128

Shapin, S. (1996). *The scientific revolution*. Chicago: University of Chicago Press.

Wallace, C. S. (2014). Overview of the Role of Teacher Beliefs in Science Education. In R. Evans, J. Luft, C. Czerniak, & C. Pea (Eds.), *The Role of Science Teachers' Beliefs in International Classrooms* (pp. 17-31). Rotterdam: Sense publishers.

Wells, G. (1999). *Dialogic inquiry: Towards a socio-cultural practice and theory of education*: Cambridge University Press.

Windschitl, M. (2004). Folk theories of "inquiry": How preservice teachers reproduce the discourse and practices of an atheoretical scientific method. *Journal of Research in Science Teaching, 41*(5). doi: 10.1002/tea.20010

Yerrick, R., Liuzzo, A., & Brutt-Griffler, J. (2012). Building common language, experiences, and learning spaces with lower-track science students. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 1419-1434). Netherlands: Springer. doi: 10.1007/978-1-4020-9041-7_91

Zembylas, M. (2002). Constructing genealogies of teachers' emotions in science teaching. *Journal of Research in Science Teaching, 39*(1), 79-103. doi: 10.1002/tea.10010