

Nature of science progression in school year 1-9: An analysis of the Swedish curriculum and teachers' suggestions

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Abstract

Science education research on nature of science (NOS) has mostly focused students' and teachers' views of NOS, while less attention has been paid to the appropriateness of various NOS aspects at different levels in the educational system. Even more scarce is research focusing teachers' perspectives on these matters. The aim of this study is to: 1) analyze NOS progression in the Swedish national curriculum, and 2) investigate science teachers' perspectives on a NOS progression for year 1-9. Participants in the study are Swedish in-service science teachers (grades 1-9) who took part in a three-year research-project focusing NOS teaching. Throughout the project the teachers met in focus-group discussions. They also planned and implemented NOS lessons in their classrooms. Sources of data are: 1) curriculum material, and 2) two focus groups meetings about NOS progression (recorded and transcribed). The results show that many NOS aspects are, at least implicitly, part of the Swedish curriculum, but no specific progression is described. The teachers' suggestions for NOS progression are based on arguments concerning the level of abstractness. Theoretical approaches and unfamiliar contexts are considered abstract, while hands-on activities, everyday contexts, and historical cases are considered concrete approaches to NOS.

Keywords: *Nature of science, Curriculum, NOS progression, Teachers*

Introduction

National curricula and standards, as well as science education researchers, push for the inclusion of nature of science (NOS) in science teaching (Lederman, 2007; Matthews, 2012). Suggestions for what NOS to teach has been put forth from different perspectives: NOS tenets (Lederman, 2007), features of science (Matthews, 2012), and a family resemblance approach (Irzik & Nola, 2011; Erduran & Dagher, 2014; Van Dijk, 2011). However, regardless of perspective, science education researchers agree that an important task for science education is to change, challenge or broaden students' perspectives on NOS. This wish is due to investigations showing that students often seem to hold a simplistic picture of scientific knowledge as absolute facts deriving from observations automatically providing true answers about nature (Lederman, 1992). To be able to challenge these pictures science education needs to provide students with a wide variety of perspectives on different aspects of NOS, perspectives that should be broadened and deepened over the school years. Through curriculum studies, that have examined aspects

and dimensions of NOS emphasized at different times and in different countries¹, it becomes clear that NOS, in one way or another, has been part of curricula for a long period of time. This means that teachers in Sweden, as well as in other countries, have to handle curricula that explicitly and implicitly refer to NOS aspects. In policy frameworks such as *Benchmarks for Science Literacy* (AAAS, 1993/2009) or Next Generation Science Standards (NGSS Lead States, 2013) an explicit progression for NOS teaching at different school years is outlined. In the Swedish curriculum, however, no such explicit NOS progression is clearly presented – this is instead left for the teachers to develop.

There is a vast amount of research on how and what to teach about NOS. In this body of research there are sometimes comments and conclusions related to NOS progression, e.g. that subjective and sociocultural aspects of science are more difficult (than other NOS aspects) for young children to grasp (Akerson, Buck, Donnelly, Nargund-Joshi, & Weiland, 2011). Research directly focused on a progression for NOS at different educational stages is however, very scarce. One rare example is Abd-El-Khalick (2012), where a NOS progression (based on NOS tenets) with increasing levels of depth and complexity from elementary school to teacher education is briefly outlined. Another example is Erduran and Dagher (2014) who outline a NOS progression (based on a family resemblance approach) where NOS aspects (“FRA categories”) are linked to science teaching both horizontally (connected to science content) and vertically (connected to grade level). Thus, due to the limited amount on research on NOS progressions, there is a need for more studies dealing with what could be appropriate NOS content at different levels in the educational system (see also a call for papers for a special issue in *Science & Education*). Even rarer are studies on teachers’ perspectives on NOS progression. There is however one study (Deniz & Adibelli, 2014) showing that what the teachers’ consider to be developmentally appropriate concerning NOS plays an important role in the teachers’ choice of suitable NOS instruction. The developmental appropriateness was by the teachers in their study related to either teaching approach or the NOS aspect per se.

Research on teachers’ perspectives on, and experiences of varying NOS content for different school years can, together with other perspectives from science education research, contribute to the understanding of how a NOS progression for compulsory school can be built. It can also contribute to our knowledge about if/and how teachers’ perspectives (about both NOS and teaching approaches to NOS) needs to be challenged and/or broadened in pre-service and in-service teacher education.

Therefore the aim of this study is twofold: 1) to analyze the Swedish curriculum and the additional commentary material in respect of NOS content and aims for different school years, and 2) to shed light on in-service science teachers’ suggestions on a NOS progression for year 1-9 (compulsory school). In this paper we specifically focus on scientific knowledge as tentative or absolute.

¹ This has been investigated for English speaking countries by e.g. Hodson (2014) and Jenkins (2013), for Sweden by Johanson & Wickman (2012), and for the Nordic countries by Vesterinen (2009).

Methodology applied in the investigation

Study context

In Sweden, science is studied by all students throughout compulsory school². Although NOS has been a part of Swedish national curricula for the last couple of decades (Johansson and Wickman, 2012), the phrase “nature of science” (in Swedish “naturvetenskapernas karaktär”) is not mentioned in the current curriculum (Skolverket, 2011a). The national curriculum is divided in three main parts (see figure 1 for the structure of the curriculum). In addition to the curriculum an extensive Commentary material (Skolverket, 2011b) is provided to assist teachers in their interpretations of the curriculum.

Aim					
Basically the same text for all science subjects (physics, chemistry, biology) and for all students in year 1-9 (ages 7- 16)					
Core content					
Physics	Chemistry	biology	Physics	Chemistry	biology
Year 3			Year 6 and 9		
Shared content for all three subjects			Similar themes (e.g. physics/chemistry/biology and worldviews) but with specific physics, chemistry and biology content.		
Knowledge requirements					
Physics	Chemistry	biology	Physics	Chemistry	biology
Year 3			Year 6 and 9		
Shared requirements for all three subjects			Divided into three overarching abilities: 1) communicate and examine information, 2) carry out systematic studies, 3) use concepts, models and theories to explain.		

Figure 1. The science subjects in the Swedish national curriculum.

Data collection and participants

In this study two different sources of data were used: 1) curriculum material (aim, core content, knowledge requirements, and the additional commentary material), and 2) two focus-group meetings.

Six experienced science teachers (teaching year 1-9) participated in the study (each teacher took part in one of the two focus-group meetings). The focus-group meetings took place at the end of a three-year project in which the teachers have taken part in focus-group discussions about NOS and NOS teaching. In the course of the project the teachers have

² Compulsory school, year 1 (age 7) -9 (age 16). There are three stages in compulsory school, where each level has its own goals. Goals are set for year 3, year 6, and year 9.

also implemented jointly planned NOS lessons in their classrooms. During the two meetings in focus for this paper the teachers were gathered around the task of suggesting appropriate NOS-content for year 1-3, 4-6, and 7-9. A collection of NOS themes (see analysis below) served as a basis for the discussions. The focus-group meetings were audio recorded and fully transcribed.

Analysis

The curriculum analysis was based on an analytical framework, previously developed by the authors (Leden et al. submitted). The framework consists of six themes adapted and broadened from the tenets described by Lederman (2007). These themes include multiple perspectives (e.g. sociological, historical, philosophical perspectives). They deal with: 1) tentative/absolute science, 2) empirical/theoretical science (including scientific practices and methods), 3) subjectivity/objectivity in science, 4) creativity/rationality in science, 5) socioculturally embedded/universal science, and 6) models, theories and laws (for a description of the themes see Leden et al., submitted).

In a first step of the analysis the teachers' suggestions were sorted concerning NOS content and school year. In this step we used the analytical framework described above. In a second step we look for teachers' arguments for judging different content as appropriate at different educational levels. The analysis was carried out through repeated reading of the focus-group transcripts. First a tentative coding of the arguments was done, which was then followed by comparing and reorganizing the properties of each category of suggestions and arguments (Glaser and Strauss, 1967) until the categories became stable.

Results and discussion

The analysis shows that, in the Swedish curriculum, NOS aspects are mostly referred to in the overall aim which applies to all school years (year 1-9). All themes are represented (to varying extents) with one exception – *creativity/rationality* which is only present in the Commentary material (see table 1). Compared to AAAS and NGSS, which both have explicit statements about NOS, the NOS content in the Swedish curriculum is more implicit and without a distinct progression. Although the table shows that statements about e.g. tentative science are present in most parts of the curriculum this does not mean that notions of scientific knowledge as absolute are excluded in the curriculum. Absolute scientific knowledge is for example (implicitly) pictured through the extensive list of core content (facts) to be treated at each stage and for each subject.

Table 1. *Aspects of NOS that are present in some way in different parts of the curriculum.*

Aims	Core content	Knowledge requirements	Commentary material
	Year	Year	

		3	6	9	3	6	9	
tentative	x	x	x	x		x	x	x
empirical	x	x	x	x	x	x	x	x
subjective	x		x	x		x	x	x
creative								x
sociocultural	x	x	x	x	x	x	x	x
Models, theories and laws	x			x				x

Examples from the *tentative/absolute* theme is provided in table 2 where some statements from different parts of the curriculum are presented.

Table 2. *Aspects of NOS related to tentative/absolute science present in different parts of the curriculum*

Part of curriculum	School year	statement
Aims	1-9	Students should develop perspectives on changes in worldview
Core content	3	Man's use and development of different materials during the course of history
	6	Historical and contemporary discoveries...and their importance for people's /.../ views on nature
	9	Historical and contemporary discoveries and their importance for society /.../ and views of nature and science.
Knowledge requirements	3	-
	6	Pupils can talk about some scientific discoveries...
	9	Pupils can explain and generalize about some main scientific discoveries
Commentary material (commentary on how to	1-9	The purpose of the curriculum is to emphasize physics/chemistry/biology as a dynamic, /.../ subject, in constant development – in everyday contexts as well as in research.

interpret the aims)	Since theories have developed in a social and cultural context they are subject to change.
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As can be seen from table 2, in the statements for year 6 and year 9 (core content and knowledge requirements) there is a focus on *discoveries*. The difference in requirements for diverse school years lies in knowing more about issues that discoveries can have an impact on. The aim (and commentary material), however takes a broader approach by emphasizing science as dynamic and in interaction with society.

Studying the teachers' perspectives and suggestions we see that the teachers consider many NOS aspects eligible to teach throughout compulsory school. However, subjective and cultural aspects of science are regarded more difficult or even inappropriate to teach in the early years. The main feature for teachers' reasoning about NOS progression is suggestions about different approaches to NOS – from concrete ways for younger students to more abstract ways for the older. This is due to a concern for the students' abilities for abstract thinking. Theoretical approaches (e.g. general reasoning about uncertainty), as well as unfamiliar contexts (e.g. particle physics) are considered abstract, while hands-on activities and everyday contexts (e.g. cell-phones and pollution) as well as historical cases and myths are considered to be concrete approaches to NOS.

Continuing with, as previously, focusing on the *tentative/absolute* theme³, one suggestion from the teachers is that: 1) the younger students (year 1-3) learn about changes in the views and knowledge about the solar system (and the objects closest to earth) from an historical perspective (e.g. historical myths and narratives about the moon), 2) that students in year 4-6 learn about changes in the views and knowledge about the solar system (and the objects a bit further from earth e.g. Pluto not being considered a planet any more), and also how religion or culture can be an important part in shaping the views and knowledge about the solar system, and 3) the older students (year 7-9) should learn about contemporary ideas and uncertainty concerning the development of the universe e.g. expanding/non expanding (the entire universe and objects far away from earth). This could mean emphasizing the same aspects of tentative NOS throughout compulsory school (with no NOS progression) and instead only changing context from the closest objects (considered more familiar) to more distant objects in space (considered more abstract). However, the more abstract context could also mean that more room is provided for deeper discussions about tentativeness. Furthermore, from table 3 we can also see that the teachers connect argumentation to students learning about tentative science⁴. Still, again the teachers' change the focus and context for the argumentation connected to different school years, but do not necessarily make clear a progression neither for the argumentation skills nor for the understanding of tentativeness in science.

³ an overview of suggestions from the teachers for this theme is provided in table 3)

⁴ This has also been suggested in science education research by e.g. Khishfe (2012) and McDonald (2010)

Table 3. *Teachers' suggestions for NOS topics and progression related to tentative/absolute science*

Year 1-3	Year 4-6	Year 7-9
Historical cases about the universe e.g. myths about the moon and discussions of how this differs from today's knowledge.	Historical cases about the universe e.g. why do we not define Pluto as a planet any more.	Discussions about uncertainty concerning the development of the universe – infinite or not, expansion or not.
Students can create simple arguments for their own position.	Students can take position in uncertain questions (preferably learn to argue against their own position)	Students can produce texts where they argue (using both arguments and counterarguments) for a certain position in relation to science topics with much uncertainty
	Historical views on the atom connected to practical tasks (students participate in role play where they act like atoms)	Learning about the atom and about progression in science connected to learning about particles.
	Uncertainty in contemporary cases can be approached by using more present historical cases (e.g. environmental issues concerning for example the changed positions on using oil as a fuel)	Discussions about uncertainty concerning current topics (e.g. health/diets, radiation from cell phones) and frontline science.

Final considerations

As in Deniz and Adibelli (2014) the teachers in this study are also concerned about students' abilities and therefore chose approaches to NOS in accordance with their view of developmental appropriateness. For example they view subjective and sociocultural aspects as more appropriate for older students, since they view these aspects as too abstract for younger students. This is also in line with previous research (e.g. Akerson et al., 2011) where it has been reported that subjective and socio-cultural aspects are considered more difficult for young students than other NOS-aspects. In addition to this the teachers in this study, when trying to develop a NOS progression, discuss this mainly as a matter of the contexts for the NOS content (increasing levels of abstractness and more scientifically advanced contexts).

The teachers' suggestions are thus in line with the writings in the national curriculum which also emphasizes different contexts (through different scientific concepts and models) for

different school years while the overall aims of the teaching (see fig. 1) remains the same, or as in the example above add some issues related to the topic. One example of the latter is that students in year 6 should know about the impact of discoveries on our views on nature, while students in year nine should know about the impact of discoveries in relation to our views on both nature and science). However the different contexts (e.g. science content), described in the curriculum and suggested by the teachers as being what constitutes the progression of NOS, could make different NOS aspects more or less accessible to students and teachers. It could be that the contexts suggested for the older students open up more for more multifaceted NOS content than contexts suggested for younger students. However this have to be considered carefully to make sure that there is an actual progression also for NOS per se. In future articles we will look into the details of the teachers reasoning with respect to this.

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