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Chapter 4

The use of contrasting philosophical positions to explore teacher beliefs about the nature of science: A large-scale survey study[3]

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The use of contrasting philosophical positions to explore teacher beliefs about the nature of science: A large-scale survey study

ABSTRACT

This chapter reports on a large-scale survey study on physics teachers' beliefs about the nature of science (NOS). We developed a questionnaire containing 24 Likert-type statements that were based on ideal types of contrasting philosophical positions concerning the nature and status of scientific knowledge claims. In this respect, three NOS dimensions were used (i.e., intentional, epistemic, and methodological). The piloted questionnaire was administered to a sample of physics teachers working at secondary schools (students aged 12-18) in the Netherlands; the useful response was N=299 (17.9%). Explorative factor analysis resulted in the extraction of three factors that were interpreted as teachers' beliefs about the *status*, *purpose*, and *utility* of scientific knowledge. On average, physics teachers in this sample thought that 'scientific theories, laws, and principles aim to provide a correct description, explanation, and prediction of natural phenomena' (i.e., descriptivist belief about the purpose of scientific knowledge). However, they differed in their beliefs about the status and utility of scientific knowledge. Hierarchical cluster analysis resulted in the identification of three clusters of teachers that we labeled 'absolutist' (N=71), 'relativist' (N=112), and 'pragmatist' (N=116). On the basis of our findings, we argue that the description and categorization of beliefs about NOS is served by a more refined terminology than the often used dichotomy between 'naïve' versus 'sophisticated' beliefs.

4.1 INTRODUCTION

Both teachers and students of science are confronted with the complex web of science concepts and their evolving nature. According to Matthews (1994), science education serves two professional purposes. First, it is concerned with teaching and acquiring knowledge *of* science, in other words introducing students to "the conceptual and procedural realms of science" (i.e., knowledge of the *products*, such as scientific laws, theories, and principles, as well as knowledge of the *processes* of science, namely "the technical and intellectual ways in which science develops and tests its knowledge claims" (pp. 3, 81)). Second, science education involves teaching and acquiring knowledge *about* science: "its changing methods, its forms of organization, its methods of proof, its interrelationships with the rest of culture and so forth." (Matthews, 1994, p. 81). This purpose is linked to "the values and beliefs inherent to scientific knowledge and its development" (Lederman, 2007, p. 833). As will be argued in the next sections, teaching and learning *about* science is an initiation into "a peculiar way of thinking about, and investigating, the world" (Matthews, 1994, p. 28), a way of thinking which is 'unnatural' (Hodson, 1992).

The values and epistemological assumptions underlying scientific processes (i.e., activities related to collecting and interpreting data, and deriving conclusions) are in the literature about science and science education generally referred to by the term *nature of science* (NOS) (Lederman, 2007). Stated differently, in the words of Abd-El-Khalick (2012), NOS refers to "the epistemology of science, which in essence is a *normative* undertaking that 'deals with issues relating to the justification of claims to scientific knowledge' (Papineau, 1996, p. 290)" (p. 367). When it comes to NOS, many science curricula as well as international educational reform and policy documents contain a section discussing explicit NOS aspects that should be taught in contemporary science education (Feldman, Galosy, & Mitchener, 2008; Lederman, 2007; Rudolph, 2000). According to Abd-El-Khalick (2012), these target aspects are often formulated in a pragmatic way: they focus on those NOS aspects on which there is consensus (i.e., they are practically uncontroversial), and which are relevant to school science curricula: the tentativeness of scientific knowledge, the distinction between observations/inferences and scientific theories/laws, the role of creativity and imagination in inquiry, and that scientific knowledge is socially and culturally embedded (cf. Akerson, Cullen, & Hanson, 2009; Lederman, 2007; Lederman, et al., 2002; Liang et al., 2009; McDonald, 2010; Morrison, Raab, & Ingram, 2009; Niaz, 2009).

In the daily practice of science education, however, there is no guarantee that these target NOS aspects are taught in accordance with the descriptions in science curricula and policy documents (Abd-El-Khalick, 2012; Lederman, 2007). Apart from misrepresentations of NOS in some school science textbooks (Abd-El-Khalick & Akerson, 2009), science teachers themselves hold personal beliefs about NOS. These personal teacher beliefs will be either explicitly conveyed to classes, or may implicitly inform teachers' "decision-making about texts, curriculum, lesson preparation, assessment and other pedagogic matters" (Matthews, 1994, p. 204). For this reason, particularly over the past two decades an entire subdivision of research on science education has been devoted to assessing teachers' beliefs about NOS (e.g., Abd-El-Khalick, 2005; Akerson, et al., 2009; Bell, Matkins, & Gansneder, 2011; Dogan & Abd-El-Khalick, 2008; Liang, et al., 2009; Liu & Lederman, 2007; McDonald, 2010; Morrison, et al., 2009; Murphy, Kilfeather, & Murphy, 2007; Niaz, 2009).

Despite the many publications and researchers' consensus about the common aspects of NOS mentioned above, research on teachers' beliefs about NOS is far from straightforward. First, beliefs about NOS are often tacit and scholars differ in their ideas about appropriate *instruments* and *methods* by which to measure and investigate these beliefs. For instance, many researchers value qualitative instruments and methods (such as open-ended questionnaires and semi-structured interviews) over quantitative ones (such as surveys) because these lead to more nuanced, comprehensive, and contextualized results (Lederman, 2007; Lederman, et al., 2002; Maggioni & Parkinson, 2008; Tsai, 2002). A side effect, however, is that many of these studies are limited in scale. Second, researchers use different *labels* and *categorizations* to describe teachers' NOS beliefs. For example, Tsai (2002) categorizes NOS beliefs into '*traditional*', '*process*', and '*constructivist*' beliefs, whereas many others make use of the distinction between '*naïve*' versus '*informed/sophisticated*' beliefs (e.g., Lederman, 1992, 1999; 2002). Finally, scholars are often *not explicit* about their underlying philosophical assumptions regarding scientific knowledge claims (cf. Niessen, 2007) and remain silent about significant controversies about NOS when investigating science curricula, NOS instruction, and teachers' NOS beliefs (Abd-El-Khalick, 2012).

The purpose of this study is twofold. First, in order to obtain a more generalized picture of the content and structure of teachers' personal NOS beliefs, we investigated these beliefs at a large scale. Second, since Abd-El-Khalick (2012) argues that the field of research on NOS should be advanced further by including not only consensus NOS aspects but also paying more explicit attention to "contested aspects of how scientific knowledge is produced and validated" (p. 359), we used contrasting ideal types derived from the philosophy of science in our investigation. Our sample consisted of in-service secondary physics teachers in the Netherlands.

4.2 LITERATURE REVIEW

In order to provide a theoretical context for our investigation of teacher beliefs about NOS we will in the next sections briefly discuss: 1) research on teacher beliefs, 2) research on teacher beliefs about NOS, and 3) controversial NOS issues.

4.2.1 Research on teacher beliefs

Research on teacher beliefs shows that these are organized into larger belief systems that include self-efficacy, epistemologies, attitudes and expectations (Jones & Carter, 2007; Pajares, 1992). According to Pajares (1992), "the filtering effect of belief structures ultimately screens, redefines, distorts, or reshapes subsequent thinking and information processing" and "beliefs are prioritized according to their connections or relationship to other beliefs" (p. 325). Thus, some beliefs function as core beliefs or priorities, whereas others are more peripheral (Brownlee, et al., 2002; Hofer & Pintrich, 1997). In the literature teacher beliefs are sometimes distinguished from teacher knowledge (e.g., Den Brok, 2001). However, this distinction remains somewhat arbitrary because in the mind of a teacher beliefs and knowledge are intertwined (Meijer & Van Driel, 1999; Pajares, 1992; Verloop, et al., 2001).

In the present study we used the following basic assumptions about the *stability, organization,* and *functionality* of beliefs, respectively (cf. Niessen, 2007): Beliefs are relatively stable, they are organized into larger multidimensional systems, and they play an important role in the interpretation of knowledge and information because they act like perceptual filters (Calderhead, 1996; Jones & Carter, 2007; Pajares, 1992; Richardson, 1996).

4.2.2 Research on teachers' beliefs about NOS

As mentioned earlier, in the literature different categorizations are used to describe teacher beliefs about NOS, for instance the widely used distinction between '*naïve*' and '*informed/sophisticated*' beliefs of the open-ended '*Views of Nature of Science* (VNOS) questionnaire' (Lederman, et al., 2002). 'Naïve' beliefs are here associated with the idea that scientific knowledge provides a correct and objective description of natural phenomena. 'Informed/sophisticated' beliefs indicate a 'better' understanding of NOS aspects, such as the tentativeness of scientific knowledge, the distinction between observations/inferences and scientific theories/laws, the role of creativity and imagination in inquiry, and that scientific knowledge is socially and culturally embedded (e.g., Abd-El-Khalick & Lederman, 2000; Akerson, et al., 2009; Lederman, 2007; Lederman, et al., 2002; Liang, et al., 2009; McDonald, 2010; Morrison, et al., 2009; Niaz, 2009).

The distinction between 'naïve' versus 'informed/sophisticated' beliefs is often limited to a specified number of target NOS aspects which are stressed in international reform documents and science curricula (e.g., Abd-El-Khalick & Akerson, 2009; Dogan & Abd-El-Khalick, 2008; Khishfe & Abd-El-Khalick, 2002; Liu & Lederman, 2007). According to Abd-El-Khalick (2012), these documents and curricula usually do not adopt any of the different philosophical stances on NOS, such as constructive empiricism, sophisticated falsificationism, radical relativism or scientific realism, and neither do they "take a stand on continuing debates between empiricists (e.g., van Fraassen, 1998) and realists (e.g., Musgrave, 1998) as to the ontological status of entities postulated by scientific theories" (p. 359). Thus, research on teachers' NOS beliefs usually focuses on beliefs about consensus NOS aspects; teachers' beliefs about controversial NOS issues usually fall beyond the scope of the investigation. It is, however, conceivable that these ongoing philosophical debates impact teachers' beliefs about NOS. Therefore, we will here discuss some controversial NOS issues that have been the center of the discourse of the philosophy of science.

4.2.3 Controversial NOS issues

We do not claim that the following discussion of controversial NOS issues is comprehensive and all-inclusive. For this section we selected those issues that are extensively debated in the history and philosophy of science, and which might have influenced teachers' NOS beliefs. It is our aim here to present ideal types of philosophical positions concerning the nature and status of scientific knowledge claims, positions distinctive enough to serve as reference points in measuring teachers' NOS beliefs.

Philosophical debates about objectivity and truth

Characterizing and describing NOS inevitably means dealing with questions such as: "What is science? What typifies scientific method? What are the characteristic tests for truth claims? What is the relevant role of observation and reason in the conduct of science? What is the role of authority in science?" and so on (Matthews, 1994, p. 204). Needless to say, everyone would agree on the fact that scientific theories, principles, and laws are the result of human reasoning. However, the question is to what extent scientific knowledge depends on personal ideas, time, place, individual experiences, research communities and/or cultures. Thus, the question is to what extent scientific knowledge is *objective* or *intersubjective*. According to Niiniluoto (2002), scientific inquiry and theorizing, including generating and evaluating scientific ideas, is always based upon some 'background knowledge' and existing assumptions. Scientists propose hypotheses and construct theories, and investigate the limits of the correctness of these theories and hypotheses through controlled observation and experimentation. The reports about these studies are then critically discussed and evaluated by other scientists. But what are the criteria for acceptability and justification? (e.g., Devitt, 2011; Greene, Azevedo, & Torney-Purta, 2008; Greene, Torney-Purta, & Azevedo, 2010; Kivinen & Piiroinen, 2006; Kukla, 1994; Thomasson, 2003) It is the answers to these questions that underpin people's personal beliefs about NOS.

Throughout history philosophers of science have debated the role of logic within science, as well as the question whether scientific statements should be viewed as claims with truth values (Niiniluoto, 2002). Suppose, for instance, that a physicist is conducting an experiment to investigate the pendulum motion. The philosophy of science focuses on the question whether the theorized, schematic object, together with the physicist's scientific reasoning, corresponds with the concrete object, namely the pendulum that is manipulated, and the actual processes regulating this phenomenon (cf. Matthews, 1994). In general, these philosophical debates focus on two fundamental questions: 1) Does science primarily aim at a true and correct description of all natural phenomena and their related processes (*descriptivism),* or is the goal to construct functional, usually mathematical, models that sufficiently explain the real world and its processes (*instrumentalism*)? and 2) Do scientific theories, laws, principles, and statements have a truth value? In other words, does scientific knowledge have an *absolute* or *relative* status compared to other forms of knowledge (e.g., common sense reasoning and personal experiences and opinions)? Often, a third question arises from these discussions, namely 3) What are the best methods for pursuing knowledge? (cf. Niiniluoto, 2002). For instance, are scientific theories primarily derived from generalizing findings based on unique, individual observations and experiments (*inductivism*) or is scientific knowledge constructed by testing hypotheses through experiments (*deductivism*)? Answers to these three issues can be placed on one of the following dimensions: *intentional*, *epistemic*, and *methodological*, respectively. In the next section we will elaborate a little more on each of these three dimensions.

Intentional, epistemic, and methodological dimension of NOS

The *intentional* dimension of NOS refers to the aims and goals of the scientific enterprise. Two different positions on this dimension, namely *descriptivism* and *instrumentalism*, represent contrasting beliefs about the ultimate aims of scientific investigation and the nature of scientific theories, laws, and principles. *Descriptivist* beliefs reflect the idea that science is about revealing and correctly describing all real entities and causal mechanisms that generate the realm of experience, in order to explain observable phenomena. *Instrumentalist* beliefs represent the idea that science aims to produce functional theories and models, which serve as a tool for problem-solving and explaining natural phenomena (cf. Matthews, 1994; Niiniluoto, 2002).

The *epistemic* dimension is associated with the nature and status of scientific knowledge (Greene, et al., 2008; Greene, et al., 2010; Kwak, 2001). In general, there are two approaches to defining the nature and status of scientific knowledge (Wong, 2002). In the first approach the boundaries between science and 'non-science' are demarcated by attaching an *absolutist* status to scientific knowledge claims, as opposed to the second approach, in which the boundaries between science and 'non-science' are blurred by a *relativist* status of scientific knowledge. *Absolutist* beliefs in this context refer to the idea that the principles of scientific knowledge are objectively true because they have been proven (cf. Agassi, 1992). In this respect, people holding absolutist beliefs assume a clear relationship between empirical evidence and scientific knowledge claims, and also emphasize the central role of logical reasoning in order to make justifiable decisions and determine truth (Wong, 2002). In contrast, people with *relativist* beliefs do not "distinguish science as a unique and privileged way of knowing" (Wong, 2002, p. 389). They argue that "no claim to objective and privileged observation is possible" because "all observation is inevitably theory-ladened [theory-laden]" (Wong, 2002, p. 389). In other words, scientific experiments, theories, and scientific knowledge claims are influenced by individual norms and opinions within a specific research community, and are consequently socially and culturally embedded. Thus, a relativist "renders the uncontested truth local and establishes in this way tolerance between different truth claims by recognizing each as valid within its territory and no further" (Agassi, 1992, p. 301).

The *methodological* dimension refers to the nature of scientific inquiry. Contrasting beliefs on this dimension represent the idea that science progresses through either 1) *inductive* generalization from unique observations, or 2) the generation and testing of relevant hypotheses and theories (*deductive*) (Lawson, 2010). Thus, people with *inductivist* beliefs hold that it is a scientist's job to interrogate nature. Universal laws are discovered by making generalizations based on many unique observations and experiments. *Deductivist* beliefs reflect the idea that scientific conceptualizations start with the formulation of hypotheses based on either empirical evidence or imagination. Theories and laws are then constructed by testing these hypotheses through repeated measuring (Nott & Wellington, 1993). Again, we would like to emphasize that these contrasting positions should be treated as ideal types. In real life it is plausible for people to hold beliefs that to a greater or lesser extent correspond with both ends of the dimensions mentioned here.

4.3 FOCUS OF THE STUDY AND RESEARCH QUESTION

In this study we attempted to obtain a more comprehensive overview of the content and structure of teachers' beliefs about NOS by investigating these beliefs at a large scale. We used the contrasting positions on the intentional, epistemic, and methodological NOS dimensions mentioned above as starting points for developing an instrument. Our study was guided by the following research question:

What are the content and structure of secondary physics teachers' beliefs about the nature of science (NOS)?

4.4 METHOD

We explored the content and structure of teachers' beliefs about NOS at a large scale by conducting a survey study among physics teachers in secondary schools (students aged 12-18) in the Netherlands.

4.4.1 Data collection

Sample and procedure

As a starting point for sampling we used the directory of the Dutch *Digischool* online educational community network. In this directory, 2432 members were registered in the 'Community of Physics' in spring 2010. On the basis of their personal profiles, 1667 (68.5%) members were identified as physics teachers working at secondary schools in the Netherlands. In March 2010 we emailed these teachers a personalized invitation letter, containing a link to an online version of a questionnaire measuring beliefs about NOS. A total of 461 persons (27.7%) responded to our invitation; the useful response was 299 (17.9%). General characteristics of the respondents are summarized in Table 4.1.

Table 4.1. *General characteristics of the physics teachers in the survey study (N=301)*

Variable	Categories	Frequency	Percentage
Gender	Male	250	83.1
	Female	51	16.9
Age	19-25 years	6	2.0
	26-35 years	46	15.3
	36-50 years	117	38.9
	51-65 years	129	42.8
	> 65 years	3	1.0
Years of teaching experience	0-2 years	18	6.0
	3-5 years	27	9.0
	6-10 years	77	25.6
	11-20 years	71	23.6
	> 20 years	108	35.8
Previous education of teacher	Category 1: Teacher education physics - *Higher vocational education*	130	43.2
	Category 2: Teacher education physics – *University Master's degree*	79	26.2
	Category 3: No teacher education physics – *Physics University Master's degree and/or other previous education*	87	28.9
	Category 4: Unknown	5	1.7

Instrument

We developed a questionnaire containing a series of statements representing beliefs about NOS. First, we made a distinction between items measuring a) *beliefs about the nature of scientific theories, laws, and principles*, and b) *beliefs about the nature of scientific processes* (cf. Lederman, et al., 2002). Second, with regard to beliefs about the nature of scientific theories, laws, and principles we formulated items measuring 1) beliefs about the extent to which scientific knowledge corresponds with reality (i.e., *intentional dimension*), using statements representing *descriptivist* versus *instrumentalist* beliefs, and 2) beliefs about the status of scientific knowledge (i.e., *epistemic dimension*), using statements representing *absolutist* versus *relativist* beliefs (cf. Greene, et al., 2008; Greene, et al., 2010; Kwak, 2001; Wong, 2002). Regarding beliefs about the nature of scientific processes (i.e., *methodological dimension*), we differentiated between items measuring *inductivist*, and those measuring *deductivist* beliefs about scientific inquiry (cf. Nott & Wellington, 1993). As a starting point for formulating the items we used existing questionnaires about NOS (e.g., Aldridge, Taylor, & Chen, 1997; Lederman, et al., 2002; Nott & Wellington, 1993; Tsai, 2006).

The initial version of the questionnaire was sent to a group of six expert physics teacher educators, who were asked to give feedback on the content and phrasing of the items. Their response was used to make changes in the questionnaire and a revised version was piloted in a sample of pre- and in-service physics teachers (N=48). The final version of the questionnaire consisted of 41 items covering topics divided between beliefs about NOS (24 items), and background variables (17 items) such as gender, age, teaching experience, and previous education. All items measuring beliefs about NOS had to be scored on a five-point Likert scale, ranging from 1 'totally disagree', through 3 'neither agree, nor disagree', to 5 'totally agree'. Some examples of these items, translated from the Dutch, are presented in Appendix 3.

4.4.2 Data analysis

We developed an instrument based on the three dimensions of NOS (i.e., intentional, epistemic, and methodological dimension). Since we did not know whether and how these NOS dimensions would manifest themselves in teachers' beliefs, we were interested in the underlying factor structure. Therefore, data were explored by conducting Principal Axis Factoring on these items. As a rotation method we used Varimax with Kaiser Normalization in order to determine the factor structure at item level. Oblique rotation resulted in the same factor structure at item level. For this reason, further analyses were conducted on the basis of an orthogonal factor structure. In addition, Bartlett's test of sphericity and the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) showed satisfactory results. Items that did not fit (i.e., items with round factor loadings of less than .30) or ambiguous items (i.e., items with similar factor loadings on multiple scales, i.e., differences between factor loadings of <.05) were excluded from further analyses. Four items were excluded for these reasons. Next, we created scales based on the factor structure found and conducted a reliability analysis on each of the scales by computing Cronbach's alpha coefficient scores. After mean scores had been computed for each of the identified scales, two-way ANOVAs were conducted to compare means among different groups of respondents; background variables such as age, years of teaching experience, and previous education, were here used as grouping factors. Finally, we investigated the relations between teachers' beliefs about NOS by conducting the following analyses: 1) computation of bivariate Pearson correlations between mean scale scores and 2) hierarchical cluster analysis in order to investigate distinctive patterns.

4.5 RESULTS

4.5.1 Statistical analyses

The underlying factor structure of teachers' beliefs about the nature of science

Explorative factor analysis of teachers' beliefs about NOS resulted in the extraction of three factors explaining 23.62% of the total variance; four items were excluded from further analyses. We called the first factor '*Status* of scientific knowledge: Scientific theories, laws, and principles are empirically proven, absolute and objective' (Status – NOS 1, 6 items, α=.66, N=294). The second factor was labeled '*Purpose* of scientific knowledge: Scientific theories, laws, and principles aim to provide a correct description, explanation, and prediction of natural phenomena' (Purpose – NOS 2, 8 items, α=.65, N=286) and the third '*Utility* of scientific knowledge: The value of scientific theories, laws, and principles depends on the extent to which they function as adequate means for problem-solving and inquiry activities' (Utility – NOS 3, 6 items, α=.60, N=294). The accompanying rotated factor matrix is shown in Table 4.2. The first column contains the scale items that we eventually used in further analyses, the second column presents the original characterization of these items (i.e., the contrasting positions on the three NOS dimensions used during the development of the questionnaire), and the other columns show the factor loadings of each item per factor.

Table 4.2. *Rotated Factor Matrix (rotation converged in five iterations): Beliefs about the nature of science (N=301)*

Scale	***Original***		***Factor***	
Items	*Characterization*	*1*	*2*	*3*
Status 1	Intentional – descriptivist	.572		
Status 2	Epistemic – relativist	- .549		
Status 3	Epistemic – relativist	- .507		
Status 4	Epistemic – relativist	- .476		
Status 5	Epistemic – relativist	- .445		.315
Status 6	Epistemic – absolutist	.424		
Purpose 1	Intentional – descriptivist		.563	
Purpose 2	Intentional – descriptivist		.495	
Purpose 3	Intentional – instrumentalist		.434	
Purpose 4	Intentional – descriptivist	.307	.407	
Purpose 5	Methodological – inductivist		.385	
Purpose 6	Methodological – deductivist		.361	
Purpose 7	Methodological – deductivist		.357	
Purpose 8	Methodological – inductivist		.324	

Table 4.2. *Rotated Factor Matrix (rotation converged in five iterations): Beliefs about the nature of science (N=301)* (continued)

Scale	***Original***	***Factor***		
Items	*Characterization*	*1*	*2*	*3*
Utility 1	Intentional – instrumentalist			.529
Utility 2	Epistemic – absolutist			.529
Utility 3	Intentional – instrumentalist			.427
Utility 4	Methodological – deductivist			.416
Utility 5	Intentional – instrumentalist			.389
Utility 6	Methodological – inductivist			.296

Means and standard deviations of the questionnaire scales

Table 4.3 shows the descriptive statistics of the questionnaire scales. All items were scored on a five-point Likert scale ranging from 1 'totally disagree' to 5 'totally agree'. The physics teachers in our sample on average neither agreed nor disagreed with the absolute and objective status of scientific theories and laws ($M_{\text{Status – NOS 1}}$=2.96, *SD*=.60). In addition, they on average thought that scientific theories and laws aim to correctly describe, explain and predict natural phenomena ($M_{\text{Purpose – NOS 2}}$=3.78, *SD*=.43). Furthermore, they agreed to some extent with items representing the idea that the value of a scientific theory and/or law depends on the extent to which it functions as an adequate means for problem-solving and inquiry ($M_{\text{Utility – NOS 3}}$=3.23, *SD*=.57).

Mean differences of scale scores were investigated by conducting a series of two-way ANOVAs. We used background variables such as age, years of teaching experience, and teachers' previous education as grouping factors. The effect of the variable gender was investigated by a *t*-test. No significant main effects were found for the variables *gender* and *age*. The main effects of the variables *years of teaching experience* and *teachers' previous education* were significant, but post hoc comparisons did not result in meaningful differences.

Table 4.3. *Means and standard deviations of the scales measuring beliefs about the nature of science (NOS)*

Scale description **Beliefs about NOS**	**n items**	**Cronbach's alpha**	**N**	**M**	**SD**
1. Scientific theories, laws, and principles are empirically proven, absolute and objective (*Status – NOS 1*)	6	.66	300	2.96	.60
2. Scientific theories, laws, and principles aim to provide a correct description, explanation, and prediction of natural phenomena (*Purpose – NOS 2*)	8	.65	299	3.78	.43
3. The value of scientific theories, laws, and principles depends on the extent to which they function as adequate means for problem-solving and inquiry activities (*Utility – NOS 3*)	6	.60	299	3.23	.57

Bivariate Pearson correlations between mean scale scores

We investigated relations between physics teachers' beliefs about NOS by computing bivariate Pearson correlations between teachers' scale scores (see Table 4.4). We decided upon the strength of a correlation as follows: < .30 indicated 'weak' correlations, correlations ≥ .30 and < .50 were called 'moderate', and ≥ .50 were considered as 'strong' correlations (Weinberg & Knapp Abramowitz, 2002). We found significant weak relations (.258 and .271) between the scale 'Purpose – NOS 2' on the one hand and 'Status – NOS 1' and 'Utility – NOS 3', respectively, on the other. This means that teachers who thought that 'the purpose of formulating scientific theories, laws, and principles is to correctly describe, explain and predict natural phenomena,' also tended to express the belief that 'scientific knowledge is empirically proven, absolute and objective,' as well as that 'scientific theories, laws, and principles should be adequate means for problem-solving and inquiry activities'.

Table 4.4. *Bivariate Pearson correlation matrix between mean scale scores (N=299)*

		Status NOS 1	Purpose NOS 2	Utility NOS 3
	Scientific theories, laws, and principles are empirically proven, absolute and objective (*Status, NOS 1*)	1		
Beliefs about NOS	Scientific theories, laws, and principles aim to provide a correct description, explanation, and prediction of natural phenomena (*Purpose, NOS 2*)	.258**	1	
	The value of scientific theories, laws, and principles depends on the extent to which they function as adequate means for problem-solving and inquiry activities (*Utility, NOS 3*)	-.037	.271**	1

** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)

4.5.2 Identifying belief patterns

We conducted hierarchical cluster analysis on teachers' scale scores (i.e., Status – NOS 1, Purpose – NOS 2, and Utility – NOS 3) to identify distinctive belief patterns. We used Ward's cluster method because the standard deviations of the questionnaire scales were relatively small (Norusis, 2010). Inspecting the dendrogram led us to create three different clusters. Table 4.5 presents an overview of the cluster means on the three questionnaire scales.

Teachers from cluster A on average thought that the status of scientific theories, laws, and principles is absolute and objective (M=3.50), whereas teachers in cluster B on average thought the opposite (M=2.53). Teachers in cluster C neither agreed nor disagreed with items reflecting beliefs about the absolute and objective status of scientific knowledge (M=3.05). Furthermore, all three clusters on average thought that scientific theories, laws, and principles

Table 4.5. *Cluster means on questionnaire scales (N=299)*

Beliefs about NOS	***Cluster A (N=71)*** ***Absolutist***	***Cluster B (N=112)*** ***Relativist***	***Cluster C (N=116)*** ***Pragmatist***
Scientific theories, laws, and principles are empirically proven, absolute and objective (*Status – NOS 1*)	3.50	2.53	3.05
Scientific theories, laws, and principles aim to provide a correct description, explanation, and prediction of natural phenomena (*Purpose – NOS 2*)	3.69	3.55	4.07
The value of scientific theories, laws, and principles depends on the extent to which they function as adequate means for problem-solving and inquiry activities (*Utility – NOS 3*)	2.87	2.96	3.70

aim to describe, explain, and predict natural phenomena in a correct way. However, teachers in cluster C showed stronger agreement with items that represented this idea (M=4.07) than teachers in the other two clusters. With regard to the practical utility of scientific knowledge, teachers in cluster C on average thought that the value of scientific theories, laws, and principles depends on the extent to which they function as adequate means for problem-solving and inquiry (M=3.70). Teachers in clusters A and B on average neither agreed nor disagreed with this statement (M=2.87 and M=2.96, respectively).

The beliefs of teachers in all three clusters could be characterized as 'descriptivist', in the sense that on average all teachers thought that 'scientific theories, laws, and principles aim at giving a correct description, explanation and/or prediction of natural phenomena' (Purpose – NOS 2). However, we noticed that the belief patterns of teachers in cluster A differed from those in cluster B primarily in beliefs about the *status* of scientific knowledge (Status – NOS 1). In addition, the belief pattern of teachers in cluster C could be distinguished from the other two clusters by their beliefs about the *utility* of scientific theories, laws, and principles (Utility – NOS 3).

We used labels related to contrasting positions on the epistemic NOS dimension to characterize cluster A and B. Since teachers in cluster A on average expressed beliefs about the absolute and objective status of scientific knowledge, we labeled this belief pattern 'absolutist'. We called the belief pattern of cluster B teachers 'relativist', since these teachers on average agreed with statements about the relativist status of scientific knowledge. Finally, we labeled the belief pattern of teachers in cluster C 'pragmatist' because these teachers on average expressed the belief that the value of scientific theories, laws, and principles depends on their practical utility in problem-solving and inquiry.

4.6 CONCLUSIONS AND DISCUSSION

In this chapter we investigated teachers' beliefs about the nature of science (NOS) by taking into account different philosophical positions regarding the aim and status of scientific knowledge claims.

4.6.1 Conclusions

One of our main conclusions was that physics teachers' beliefs about NOS comprised beliefs about the *status*, *purpose,* and *utility* of scientific knowledge. The teachers in our sample on average held 'descriptivist' beliefs about the purposes of scientific knowledge, in the sense that they thought that science aims to correctly describe, explain, and predict natural phenomena (cf. Mulhall & Gunstone, 2008). Another conclusion was that we found three clusters of teachers that we labeled 'absolutist', 'relativist', and 'pragmatist'. These clusters differed primarily in their beliefs about the *status* and *utility* of scientific theories, laws, and principles. In the next sections we will focus on 1) the content and structure of teachers' beliefs about NOS and 2) the categorization and labeling of teachers' beliefs about NOS.

4.6.2 Discussion

The content and structure of teachers' beliefs about the nature of science

Explorative factor analysis of teachers' NOS beliefs (Table 4.2) showed that the *epistemic* dimension of NOS, including its contrasting positions (i.e., 'absolutist' versus 'relativist'), was reflected in beliefs about the *status* of scientific theories, laws, and principles. In addition, contrasting positions on the *intentional* NOS dimension (i.e., 'descriptivist' and 'instrumentalist') manifested themselves in two distinct factors associated with teachers' beliefs about the *purpose* and the *utility* of scientific knowledge, respectively. Furthermore, contrasting positions on the *methodological* dimension (i.e., 'inductivist' and 'deductivist') were, in this study, not reflected in teachers' NOS beliefs. The latter finding might be an indication that physics teachers in our sample did not think that there is 'one' fixed scientific method, but that science comprises generating and testing hypotheses as well as constructing theories based on the generalization of unique observations.

With respect to the structure of teachers' NOS beliefs, we found that teachers' 'descriptivist' beliefs (Purpose – NOS 2) had weak, positive correlations with both 'absolutist' beliefs about the status (Status – NOS 1) and 'pragmatist' beliefs about the utility (Utility – NOS 3) of scientific knowledge. A possible explanation could be that the physics teachers in our sample associated the correctness of scientific descriptions, explanations, and predictions (Purpose – NOS 2) with not only an absolute status of scientific knowledge because of objective empirical evidence (Status – NOS 1), but also with the adequacy for problem-solving and scientific inquiry (Utility – NOS 3). In other words, the more correct a scientific statement, the more absolute its status and the more adequate it functions as a tool for problem-solving and inquiry. Another explanation could be that much scientific knowledge, particularly that which is taught in school science, is well-established and beyond reasonable doubt (cf. Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

Cluster analysis showed that distinctions between teachers' NOS belief patterns could be made on the basis of an emphasis on either an 'absolute' (cluster A, N=71) or 'relative' status (cluster B, N=112), and the utility (cluster C, N=116) of scientific theories, laws, and principles. Thus, teachers' beliefs about the purpose of science were not very distinctive: on average, all teachers thought that science aims to correctly describe, explain, and predict natural phenomena (cf. Mulhall & Gunstone, 2008). This is in itself not a very remarkable result. What is the function and value of a scientific statement about reality if it is not sufficient to explain and predict phenomena? However, the differences in beliefs about the status and utility of scientific knowledge (cf. Hodson, 1992) could manifest themselves in an emphasis on different aspects of science. For example, cluster A teachers with 'absolutist' beliefs might stress that science is about finding a unifying theory that describes and explains all natural phenomena, that science is about the ultimate search for truth. Cluster B teachers with 'relativist' beliefs may emphasize that science is a discourse with specific rules and criteria for accountability and/or justifying observations, claims, and statements. Finally, teachers in cluster C, holding 'pragmatist' beliefs, could characterize science as the act of constructing models and tools for problem-solving and explaining or predicting phenomena.

The categorization and characterization of teachers' beliefs about NOS

Our findings suggest that teachers' beliefs about NOS are characterized by multiple dimensions. However, in the literature on teachers' NOS beliefs often just one distinction is used: that between 'naïve' and 'informed/sophisticated' beliefs (Abd-El-Khalick & Lederman, 2000; Lederman, 2007; Lederman, et al., 2002). Although the beliefs of cluster A teachers could be characterized as 'naïve' since these teachers held 'absolutist' and 'descriptivist' beliefs about science, the belief pattern of cluster B is not easily accommodated in this categorization. For instance, how to combine 'descriptivist' beliefs, often labeled 'naïve', with 'relativist' beliefs, often labeled 'informed/sophisticated'? And what about the belief pattern of cluster C teachers? Should neither agreement nor disagreement with the absolute and relative status of scientific knowledge, together with 'pragmatist' beliefs about the utility of scientific theories, laws, and principles, be labeled 'naïve' or 'informed/sophisticated' beliefs? It seems that the terminology and categorization of 'naïve' and 'informed/sophisticated' fails to characterize two of the three NOS belief patterns that we found in this study. Therefore, we argue that research on beliefs about NOS is served by a more refined terminology and categorization in order to do justice to the complexity of teachers' NOS beliefs.

Limitations and future research

This study should be seen as an attempt to explore teachers' NOS beliefs at a large scale and at the same time pay more explicit attention to contested aspects of how scientific knowledge is produced and validated. First, we have no intention to claim that the content and structure of teachers' NOS beliefs is conclusively described and explained by the three clusters we found, because the response rate and percentage of total variance explained was relatively low. Second, we used philosophical ideal types derived from controversial NOS issues as a starting point for developing a questionnaire. One of the main dilemmas we struggled with was that we needed items that were distinctive enough to measure specific beliefs, whereas we knew that beliefs about NOS are often nuanced and contextualized (Lederman, 2007; Lederman, et al., 2002). Perhaps the validity of the instrument would be enhanced by allowing teachers to add clarifications or exemplifications when they feel the need to do so. Another possibility would be to include in the questionnaire descriptions of some controversial NOS issues or philosophical debates, and to ask teachers what arguments they think the most convincing. For instance, teachers could rank or score a list of arguments derived from the issues or debates presented. Another option would be for them to write down and explain what arguments were overlooked or should be emphasized in the debate.

However, our findings do indicate that the physics teachers in our sample differ in their beliefs about the *status* and *utility* of scientific knowledge. Moreover, the study shows that teachers' beliefs about NOS should be seen as a complex and multidimensional construct. More research is needed in order to gain knowledge of and insight into 1) whether and, if so, to what extent the complexity of NOS is manifested in teacher beliefs about NOS, and 2) whether differences in NOS belief patterns lead to an emphasis on different aspects of science or a different image of science in the context of science education. This knowledge will contribute to a more refined and nuanced terminology by which to describe and categorize teachers' beliefs about NOS.

Implications

Research on teachers' NOS beliefs often entails many suggestions for developing 'adequate' NOS views. For example, in the literature it is suggested that 'informed/sophisticated' beliefs about NOS are enhanced by 1) *explicit* and *reflective* instruction (e.g., reflective journal writing and seminars), focusing on the depth of NOS understanding as well as relations between NOS and science content knowledge, and 2) a *specific context* for reflection (e.g., a science research component) (e.g., Abd-El-Khalick, 2005, 2012; Abd-El-Khalick & Lederman, 2000; Akerson, Buzzelli, & Donnelly, 2008; Akerson & Hanuscin, 2007; Schwartz & Lederman, 2002; Schwartz, Lederman, & Crawford, 2004). We argue that research on teachers' NOS beliefs benefits from 1) making explicit what paradigmatic assumptions underlie research designs and instruments, and 2) gaining more insight into how controversial NOS issues manifest themselves in teachers' NOS beliefs. These insights could help to identify misrepresentations in descriptions of target

NOS aspects in contemporary science curricula and reform/policy documents. Moreover, they can provide guidelines for both a nuanced categorization of teachers' NOS beliefs and research on the role of teachers' NOS beliefs in actual teaching behavior. Finally, these insights can be used to improve professional development programs focused on the enhancement of teachers' NOS understandings and teaching NOS to students.