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Chapter 5

Depicting physics to secondary students: A small-scale explorative interview study on physics teachers' beliefs and intentions

ABSTRACT

This chapter reports on a small-scale explorative interview study (N=3) on the content and structure of physics teachers' beliefs about 1) the nature of physics and science and 2) teaching and learning physics. In addition, the study included an investigation of relations between these beliefs and the intentions teachers expressed in a lesson plan of an introductory physics lesson. Data were analyzed by an interpretivist approach. With regard to the former beliefs, differences were found concerning a) the aim of scientific inquiry, b) the purposes of physics as a research field, c) the tentativeness of scientific theories, and d) the difference between scientific 'theories' and 'laws'. With respect to the latter beliefs, teachers had different priorities concerning what knowledge, skills, and attitudes were important to teach. Moreover, they differed in their beliefs about adaptive teaching and the purposes of practical work and inquiry activities. The exploration of relations between beliefs and intentions showed, amongst other things, that beliefs about inquiry were especially reflected in teachers' intentions. The discussion of these findings focuses on teachers' rationale behind beliefs and priorities and the extent to which teachers' beliefs about the nature of physics and science are biased by perceptions of the nature of school physics.

5.1 INTRODUCTION

For many teachers, teaching the content of their subject is often accompanied by sharing their passion for the subject with students. In this respect, the image of the subject that is presented to students is not only influenced by a teacher's content knowledge but also by his or her personal beliefs about the nature of the subject (Pajares, 1992; Richardson, 1996; Stipek, et al., 2001). Suppose, for instance, that a student asks a science teacher what science is all about. In answering that question, it is reasonable to expect that most teachers would refer to aspects of inquiry and the process of constructing scientific theories, principles and laws aiming to describe, explain, and predict natural phenomena (cf. Lederman, 2007). Some would probably refer to the adoption of scientific attitudes (e.g., critical thinking, questioning, and a perseverance in searching for empirical evidence to underpin knowledge claims) or positive attitudes towards science, such as an enjoyment in inquiry activities or an interest in science as a profession (cf. Osborne, Simon, et al., 2003). Others might point to the development of problem-solving skills, such as analyzing a problem by removing redundant information or finding a solution in a systematic and step-wise way (cf. Talisayon, 2008; Wallace & Kang, 2004). Thus, in describing a subject to students, teachers might emphasize different aspects of its content.

Besides an emphasis on different content aspects, teachers could hold different beliefs about the nature of the subject itself and instructional strategies for teaching and learning specific content. In the domain of science education, research on teachers' beliefs indicates that teachers may differ in their beliefs about 1) aspects of the *nature of science* (NOS) and 2) *the goals and pedagogy of teaching and learning science*. First, the literature on NOS beliefs suggests differences in beliefs about the tentativeness of scientific knowledge, the role of creativity and imagination in inquiry, whether there is a distinction between 'observations' and 'inferences' or between scientific 'theories' and 'laws', and to what extent scientific knowledge is socially and culturally embedded (Abd-El-Khalick, 2005; Abd-El-Khalick & Lederman, 2000; Lederman, 2007). In this respect, our large-scale survey study on physics teachers' beliefs about NOS revealed differences in beliefs about the *status* and *utility* of scientific theories, principles, and laws (see chapter 4). Second, teachers could also differ in their beliefs about the goals and pedagogy of teaching and learning science. For example, they could have different curriculum emphases (cf. Van Driel, et al., 2008) or hold different beliefs about learning and the regulation of students' learning processes (cf. Meirink, et al., 2009). In this respect, our explorative interview study showed that some teachers' beliefs reflected only two types of regulation (i.e., teacher-regulated learning and regulation by both teacher and students) whereas the beliefs of others reflected three types of regulation including student-regulated learning (see chapter 2). However, our survey study on teachers' beliefs about the goals of education in general and their domain-specific curriculum emphases showed no well-defined belief patterns or significant differences (see chapter 3).

In the present study, we were interested in whether teachers' beliefs about 1) the nature of physics and science and 2) the goals and pedagogy of teaching and learning physics were reflected in teachers' intentions concerning the introduction of the school subject to students. We interviewed three physics teachers working at secondary schools (students aged 12-18) in the Netherlands. The purpose of the study was to investigate the content of these beliefs as well as relations between these beliefs and teachers' intentions regarding an introductory physics lesson.

5.2 THEORETICAL FRAMEWORK

5.2.1 Depicting the nature of physics at school

In the practice of teaching, teachers make choices concerning what ideas about physics should be taught to their students (cf. Osborne, Collins, et al., 2003). We expect that these ideas are possibly related to teachers' beliefs about the nature of physics and NOS as well as to their beliefs about the goals and pedagogy of teaching and learning physics. In the next paragraphs we use two imaginary examples to present the theory that was used to formulate these expectations.

Imagine, for instance, that a teacher paints a picture for his or her students that physics is about 'the critical testing of hypotheses by conducting repeated measurements, using various scientific methods, and/or analyzing and interpreting data'. This teacher's own beliefs about the nature of physics might be that a) physics knowledge is empirically based and theory driven, b) there is no one scientific method, and c) there is a distinction between observations and inferences (cf. Lederman, et al., 2002). In addition, this teacher's beliefs about teaching and learning physics might include a) teaching students a sense of what physics and/or scientific methods are, b) students should have an understanding of the testability and reliability of physics knowledge, and c) that students should be aware of the significance of theory in scientific inquiry (cf. Barrett & Nieswandt, 2010; Wong & Hodson, 2009). Moreover, there is a possibility that this teacher has the opinion that a) student learning should involve higher level thinking and critical thinking, such as students asking themselves a lot of questions and searching for relations between observations and b) physics is best learned by hands-on activities and authentic inquiry projects (cf. Crawford, 2007; Friedrichsen, Van Driel, & Abell, 2011; Lotter, Harwood, & Bonner, 2007; Loughran, Mulhall, & Berry, 2008).

Or, to give another example, a teacher who would primarily depict physics as 'understanding natural phenomena by a theoretical framework of physics concepts that are empirically proven' (cf. Osborne, Collins, et al., 2003; Osborne, Simon, et al., 2003; Sadler, et al., 2010) might believe that the tentativeness of scientific knowledge is explained by the improvement of scientific methods over time (i.e., belief about *the nature of physics and NOS*) (cf. Abd-El-Khalick & Lederman, 2000; Lederman, 2007), that students should be prepared for the next level of schooling, and that physics is best learned when teachers transmit knowledge to students in order to cover all curricular topics (i.e., *beliefs about the goals and pedagogy of teaching and learning physics*) (cf. Barrett & Nieswandt, 2010; Bybee & DeBoer, 1994; Lotter, et al., 2007).

5.2.2 Beliefs and teaching behavior

Teacher beliefs and the practice of teaching

The relationship between teacher beliefs and the practice of teaching is not straightforward (Feucht & Bendixen, 2010; Thompson, 1992). In the domain of science education, some studies found coherent relationships between beliefs and the practice of teaching, especially in studies of experienced science teachers (e.g., Brickhouse, 1990) whereas other studies reported discrepancies (e.g., Briscoe, 1991). Various factors may account for these consistencies or inconsistencies between teachers' beliefs and actual teaching behavior (Fang, 1996; Mathijsen, 2006). For example, teacher beliefs are organized into larger belief systems and these systems do not necessarily form a cohesive unit. In addition, some beliefs are prioritized over others and other beliefs are tacit (Hashweh, 1996; Hofer & Pintrich, 1997; Jones & Carter, 2007; Maggioni & Parkinson, 2008; Pajares, 1992; Tsai, 2006). Furthermore, the more abstract or general the beliefs, the more likely that discrepancies with practice will be found (Richardson, 1996; Stipek, et al., 2001). Moreover, teachers are often confronted with practical constraints such as a lack of time, mandated curriculum materials, large classroom sizes, and students' preparation for the final exams. These constraints may impact how teachers' beliefs are manifested in teaching behavior (Clark & Peterson, 1986; Jones & Carter, 2007; Lombaerts, et al., 2009; Tillema, 2000; Wallace & Kang, 2004). Finally, teacher characteristics such as teaching experience (in various contexts), previous training (in content as well as pedagogy), and limited knowledge and skills may also play an important role (Jones & Carter, 2007; Lederman, 1999; Schwartz & Lederman, 2002).

Beliefs and intentions

In many of the studies mentioned above, the underlying assumption is that teacher beliefs manifest themselves, to a greater or lesser extent, in teaching behaviors. However, as Fishbein and Ajzen already noted in their *Theory of Reasoned Action* (1975) as did Ajzen in his *Theory of Planned Behavior* (1991), the role of attitudes and intentions must not be overlooked. Despite various critiques on these theories, for example, regarding the individualistic bias, the linearity of the model, and constraints on action (Kippax & Crawford, 1993) or the difficulty of finding significant correlations between behavior and all the other cognitive constructs mentioned in these models (e.g., Courneya & McAuley, 1995), it is still a valid assumption that the relationship between beliefs and teaching behaviors (at least) is mediated by *intentions* to perform particular behaviors (Ajzen & Fishbein, 2005; Van der Schaaf, Stokking, & Verloop, 2008).

In the domain of science education, some studies explored the relationship between teachers' beliefs and intentions to implement, for example, particular curriculum innovations, educational technology, ICT applications, and instructional methods (e.g., Crawley & Salyer, 1995; Kriek & Stols, 2010; Zacharia, 2003). For instance, Lumpe and colleagues (1998) investigated science teachers' beliefs and intentions to implement Science-Technology-Society (STS) in the classroom and found both weak and moderately positive relations between beliefs and intentions. Kilic et al. (2011) conducted a survey study and found strong positive relations between pre-service teachers' beliefs, attitudes, and behavioral intentions toward laboratory applications in science teaching. Crawford (2007) examined the knowledge, beliefs, and efforts of five pre-service teachers to enact teaching science as inquiry. She found that teachers' abilities and intentions to teach science as inquiry were highly influenced by the teachers' complex belief system about teaching science. So far, however, little is known about how particular teacher beliefs about the nature of a subject as well as beliefs about the goals and pedagogy of teaching and learning specific content are reflected in teaching intentions.

5.3 RESEARCH QUESTIONS

The purpose of the present study was not to investigate the complete relationship between teacher beliefs and teaching behavior. We aimed to take the next step in our research on teacher beliefs by conducting an in-depth explorative study of the relations between beliefs and intentions. In other words, we explored not only the content and structure of teachers' belief systems but also whether these beliefs were reflected in particular teaching intentions. We chose to focus on the intentions that were expressed in a teacher's lesson plan of an introductory physics lesson, because we expected that this particular lesson plan would reflect not only a teacher's beliefs about teaching and learning physics (including beliefs about the goals of physics education), but also his or her beliefs about the nature of physics and NOS.

The study was guided by the following two research questions:

1. What are the content and structure of these three physics teachers' beliefs about a) the *nature of physics and NOS* and b) *teaching and learning physics* (including the goals of secondary physics education)?
2. To what extent are the beliefs mentioned in 1 reflected in a teacher's intentions expressed in a lesson plan of an introductory physics lesson?

5.4 METHOD

We conducted a small-scale structured interview study among three physics teachers working at three different secondary schools (students aged 12-18) in the Netherlands.

5.4.1 Data collection

Sample and procedure

We selected three physics teachers by purposeful sampling; we aimed at interviewing three representatives of the belief patterns identified in the large-scale survey study on teacher beliefs about NOS (i.e., *absolutist* (cluster A), *relativist* (cluster B), and *pragmatist* (cluster C); see chapter 4). To select one teacher from each of these three clusters, we used the following two guidelines: 1) the difference between a teacher's individual mean scale scores and the cluster mean scale scores falls within the range of $0 \leq d \leq 1$, and 2) the pattern of a teacher's individual mean scale scores over the three questionnaire scales is similar to that of the cluster mean scale scores. From now, we refer to the teachers of clusters A, B, and C by using the names Ann, Brandon, and Chris, respectively. Table 5.1 presents the cluster means and the individual means (of the three selected teachers) on the questionnaire scales of the survey study on beliefs about NOS (i.e., study 3, chapter 4).

In January 2011, we invited by phone the selected teachers to participate in the interview study. All three teachers were willing to cooperate and the interviews were conducted (by the author) in the second and third week of February 2011. The set-up of the interviews was structured, with a duration of 40, 49, and 60 minutes. All interviews were audio taped and fully transcribed.

With regard to general teacher characteristics, both Ann (female) and Brandon (male) were older than fifty years and they had more than ten and twenty years of teaching experience, respectively. Chris (male) was in his twenties and had five years of teaching experience.

Table 5.1. *Cluster means and teachers' individual means on the questionnaire scales*

Beliefs about the nature of science (NOS)	***Cluster A*** *'Absolutist'*		***Cluster B*** *'Relativist'*		***Cluster C*** *'Pragmatist'*	
	Cluster A (N=71)	***Teacher Ann***	*Cluster B (N=112)*	***Teacher Brandon***	*Cluster C (N=116)*	***Teacher Chris***
Scientific theories, laws, and principles are empirically proven, absolute and objective (*Status*)	3.50	**4.17**	2.53	**2.83**	3.05	**3.17**
Scientific theories, laws, and principles aim to provide a correct description, explanation, and prediction of natural phenomena (*Purpose*)	3.69	**4.25**	3.55	**4.38**	4.07	**4.50**
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*)	2.87	**3.00**	2.96	**2.67**	3.70	**4.50**

All three teachers were teaching physics at Dutch secondary schools. Ann was teaching upper secondary students (aged 16-18), Brandon taught both lower and upper secondary students (aged 12-18), and Chris taught physics to lower secondary students (aged 12-15).

Instrument

We developed an interview format with a series of questions to measure a teacher's beliefs about a) the *nature of physics and NOS* and b) *teaching and learning physics*. Teachers' *intentions* were measured by an assignment, namely to design a lesson plan of an introductory physics lesson (see Appendix 4).

First, to investigate beliefs about the nature of physics and NOS, we asked the teachers to give a brief definition of the nature of physics; that is, we asked them to describe in their own words what physics is all about. In this description, we stimulated the teachers to make explicit what, in their opinion, is the essence of physics as well as what physicists are aiming to achieve (Appendix 4, part A). Furthermore, we used a shortened version of the *Views about Nature of Science* (*VNOS*) questionnaire, Form B (Lederman, et al., 2002) with questions about the tentativeness of theories, the content and status of atomic models, the difference between scientific theories and laws, the role of creativity and imagination in scientific inquiry, and different scientific statements about the universe (i.e., VNOS-Form B, questions 1, 2, 3, 5, and 7) (Appendix 4, part B).

Second, teachers' beliefs about teaching and learning physics were measured by a series of questions about what aspects of the content are emphasized by the teacher in the daily practice of teaching physics, what teaching and learning activities are frequently conducted, and what image of the nature of physics a teacher would like to convey to students in lower and upper secondary education. In all these questions, we specifically asked the teacher to explain why he or she thinks this is important as well as what his or her objectives are in order to gain more information about the underlying beliefs.

Finally, to explore a teacher's intentions, we developed an assignment in which the teacher was asked to design a 50-minute lesson to introduce physics to secondary students (aged 12-14). We chose to focus on an introductory physics lesson because we assumed that this lesson would be an excellent opportunity for teachers to portray a specific image of physics to their students as well as to pay attention to the nature of physics and NOS.

Since teaching is a multifaceted activity and teachers' concerns might be influenced by practical constraints such as a lack of resources, facilities, and supplies available in the school context (Doyle, 1990, 2006; Kennedy, 2006), we were aware that the lesson plan might merely reflect teachers' anticipation of practical constraints. Therefore, we told the teachers that they should treat this case as an ideal situation without any practical constraints; i.e., if needed, facilities, supplies and technical assistance would be at their disposal. We stimulated the teachers to explicate and explain their intentions and beliefs in relation to the lesson plan of this introductory physics lesson (Appendix 4, part C and D).

5.4.2 Data analysis

The process of data analysis was characterized by four phases and an interpretivist approach (Miles & Huberman, 1994). First, we decided to treat the whole interview as a unit of analysis because teachers' beliefs often became more explicit in the course of the conversation. For instance, sometimes the teachers referred to statements that they expressed earlier in the interview to stress particular beliefs or to add some aspects that they considered to be important. Second, after thorough readings of the complete transcripts, the author paraphrased each transcript and deleted redundant information (Miles & Huberman, 1994, p. 11). Next, the paraphrased transcripts were checked by a second researcher and, after approval, used for further analysis. Fourth, an in-depth analysis of the content of these paraphrased transcripts started by categorizing teachers' responses. In this respect, teachers' responses revealing beliefs about the *nature of physics and science* were categorized with the following labels: 'scientific inquiry', 'testing of hypotheses', 'creativity and imagination', 'human reasoning', 'tentativeness of theories', 'definition of axioms', and 'distinction between theories and laws'. Teachers' beliefs about *teaching and learning physics* were categorized under the themes 'teaching a specific way of thinking', 'conducting inquiry, hands-on activities and experiments', 'models in physics knowledge', and 'a teacher's personal teaching goals and interests'. Finally, the *intentions* of the three teachers were categorized by making a distinction between 'lesson objectives', 'image of physics to be portrayed to students', and 'teaching and learning activities'. This fourth and final phase of data analysis was characterized by an iterative process: the author started with thorough readings of the paraphrased transcripts followed by categorizing the teachers' responses; next, similarities and differences in teachers' beliefs and intentions regarding the various labels and themes were discussed with the second researcher until understanding and consensus was reached.

5.5 RESULTS

5.5.1 Beliefs about the nature of physics and science

The interview questions related to the nature of physics and NOS revealed that the three teachers in our sample found it difficult to distinguish between physics as a research field and the school subject physics. For example, the questions of part A and B of the interview format focused on the nature of the broader domain of physics. However, many times the three teachers started by answering the question in relation to the school context, for example by explaining what they would typically tell their students about this topic. In such a situation, the interviewer interrupted the teacher by stressing that the question was not focused on the school subject physics but on the nature of the broader domain of physics and science.

Table 5.2. *Teacher beliefs about the nature of physics and NOS*

Themes	Ann	Brandon	Chris
Aim of scientific inquiry	- Testing and verifying theories	- Constructing theories	- Testing and verifying theories
Tentativeness of scientific theories	- Theories are tentative - Methods and measurements have improved - Advancing science	- Theories are tentative - Insights and methodological rules have changed - Reduction of axioms	- Theories are tentative - Methods and measurements have improved - Small adaptations, some 'old' theories are still valid in daily life
Difference between scientific 'theories' and 'laws'	- Difference between laws and theories - Laws are beyond question - Theories are work in progress, they eventually become laws	- Difference between laws and theories - Laws are the mathematical relations between variables - Theories tell how these variables are related to each other	- Laws and theories are synonyms - Laws and theories refer to scientific concepts or ideas that explain natural phenomena
Purposes of physics as a research field	- Knowing to know, discovering new things - Verifying theories and models with experiments - Applying knowledge in technology and devices	- Explaining essential processes within nature by an interaction between theory and experiments - Process of knowledge development is characterized by different methodological phases	- Explaining essential processes within nature by an interaction between theory and experiments - Process of knowledge development is characterized by both inductive and deductive approaches

The analysis of teachers' beliefs about the nature of physics and NOS revealed differences in their beliefs about 1) *the aim of scientific inquiry*, 2) *the tentativeness of scientific theories*, 3) *the difference between scientific 'theories' and 'laws'*, and 4) the *purposes of physics as a research field*. We summarized these findings in Table 5.2.

Beliefs about the aim of scientific inquiry

With regard to the aim of scientific inquiry, both Ann and Chris expressed the belief that physicists conduct experiments to *test and verify theories*. In other words, they aim to find empirical evidence that supports a particular theory. In this respect, Ann indicated that it is not possible to confirm hypotheses; at best you cannot falsify them. When asked about how physicists deal with unexpected data and/or phenomena, Ann and Chris explained that most physicists refer to measurement inaccuracies and errors. However, Chris thought that real 'creative' persons are triggered by such unexpected results and, in an attempt to explain these data by 'out-of-the-box-thinking', they try to discover something new. In contrast to Ann and Chris, Brandon expressed the belief that physicists conduct experiments to *construct theories*. They observe and explore qualitative relations between natural phenomena and then try to quantify these relations into mathematical ones. Thus, Brandon thought that scientific inquiry aims at increasing one's understanding of the world around us. In this process of knowledge development, physicists are concerned with fundamental questions, such as 'When is an observation valid?' and 'What are important steps in proving the validity of your observations?'

Beliefs about the tentativeness of scientific theories

All three teachers thought that scientific theories are tentative and they provided examples of theories that have been adapted and changed in the course of time. However, the teachers differed in explaining why scientific theories are tentative. Ann indicated that scientific *methods and measurements have been improved* over time, leading to an increased reliability and validity of empirical evidence and the advancement of existing theories. Chris shared this belief to a large extent, but reported that *some 'old' theories are still valid in daily life*. For instance, "Einstein proposed some improvements of Newton's law resulting in the theory of relativity," Chris said, "but when you insert normal values for the variables of velocity and mass, that old law of Newton is still applicable." So Chris emphasized that, instead of world-shattering changes, most existing theories have been slightly adapted. Brandon explained the tentativeness of theories by referring to *a change of scientific insights and methodological rules*. As a consequence, questions about the establishment of empirical evidence and the validity of observations and knowledge claims have become more central, often calling for a reconsideration of existing theories. Moreover, Brandon indicated that physicists sometimes succeeded in *combining and linking existing theories* leading to a shift and/or reduction of axioms.

Beliefs about the difference between scientific 'theories' and 'laws'

While Ann and Brandon thought there was a difference between scientific 'theories' and 'laws', Chris indicated that they were the same. Chris regarded 'theories' and 'laws' as synonyms; they refer to scientific concepts or ideas being used to explain natural phenomena. In contrast, Ann and Brandon differentiated between 'theories' and 'laws'. According to Ann, *'theories' are work in progress, they eventually become 'laws'*. Thus, she said, "laws are beyond question, they are true in 99.999% of all situations." Moreover, Ann expected that discussions about the truth of scientific statements would be inevitable, but that they would eventually converge into one law. Brandon said that *'laws' are the mathematical relations between variables*, for instance 'force = mass * acceleration'. *'Theories' are the stories behind that law, they tell how the variables are related to each other*. Brandon compared it with the human body: "Laws are what you'd call the skeleton, theories are the flesh on the bones."

Beliefs about the purposes of physics as a research field

Finally, the three teachers in this study differed in their beliefs about the purposes of physics as a research field. Ann said that physicists differ in what they are trying to achieve. Their purposes are related to the various sub disciplines within physics, namely 1) *knowing to know, discovering new things, and investigating the origin of mass* (i.e., theoretical physics; physicists are concerned with the origin of mass and their inquiry is more related to mathematics), 2) *verifying theories and models with experiments* (i.e., experimental physics), and 3) *applying scientific knowledge in technology and devices* (i.e., technology). Both Brandon and Chris thought that the purpose of physics is to *explain the essential processes within nature by an interaction of theories and* *experiments*. However, they stressed different aspects. In this respect, Brandon emphasized that *the process of theory construction and knowledge development is characterized by various methodological phases*, such as systematic observations, attempts at finding relations and regularities between observations, the act of quantifying qualitative relations, and the reduction of axioms. Chris indicated that *the interaction between theory and experiments is characterized by both deductive and inductive approaches*, namely 1) physicists construct theories and then try to verify these by experiments and 2) they conduct experiments and try to explain the results afterwards by theory. Moreover, Chris added that the ultimate goal of physics is to *create a kind of 'blueprint' that tells you how nature works*. The search for this 'blueprint' is inspired by the old philosophical questions, such as 'Are we the only creatures that live in this universe?' and 'Where are we from, what is our origin?'

5.5.2 Beliefs about teaching and learning physics

Teacher beliefs about teaching and learning physics could be divided into beliefs about the *goals of physics education* and beliefs about *the pedagogy of teaching and learning physics*.

Beliefs about the goals of physics education

Teacher beliefs about the goals of secondary physics education revealed that teachers had *different priorities* concerning what *knowledge* and *skills* should be taught to students and what *attitudes* were important to adopt. These priorities are summarized in Table 5.3. The analysis of these priorities revealed that the three teachers primarily indicated *what* knowledge, skills, and attitudes were important to focus on in secondary physics education. However, the rationale behind these priorities often remained to a greater or lesser extent tacit. In other words, they did not clearly explain why they thought it was important to focus on this particular knowledge and these specific skills and attitudes.

First, with regard to teaching physics knowledge, both Ann and Brandon emphasized that they taught content in accordance with the *examination syllabus*. Ann explained that she strictly taught the concepts that were necessary for the final exams because their students needed a degree after all. Brandon reported that it was important for students to understand the basic theories because they needed to know what physics is all about. In addition, he stressed the importance of teaching students about the *nature of scientific knowledge development*. In his opinion, students need to understand how scientific theories have been constructed, that the quality of scientific knowledge claims is influenced by the extent to which observations and measurements are accurate, that inquiry methods and observation facilities have been improved over time, and that students themselves might contribute to this ongoing process of theory construction. In this respect, Brandon thought it was a pity that the examination syllabus was very limited; roughly speaking, it covers physics knowledge till the beginning of the 20th century, leaving all 'modern' and current scientific insights out of scope. Compared to Ann and Brandon, Chris had a more general approach. He thought that it was enough when

Table 5.3. *Teacher beliefs about the goals of physics education*

Goals	Ann	Brandon	Chris
Knowledge	- Examination syllabus - Strictly content and concepts that are needed for a degree	- Examination syllabus - Basic theories that are needed to understand what physics is all about	- General approach - Underlying basic ideas of physics
Skills	- *Problem-solving:* solving problems in an analytical, systematic, and step-wise way - *Inquiry:* conducting experiments and handling devices - *Studying:* memorizing content and other homework assignments	- *Problem-solving:* applying theories and mathematical manipulation of formulas - *Inquiry:* conducting experiments and inquiry on their own, writing a scientifically sound inquiry report	- *Problem-solving:* making predictions in advance and removing redundant information
Attitudes	- Willingness to discover new things by observing and conducting experiments - Positive attitudes towards physics as a research field and profession - Personal development: perseverance	- Thinking about what methodological steps are needed in order to underpin and justify knowledge claims - Personal development: nature of knowledge development	- Questioning and a willingness to explain natural phenomena with theory and experiments

students would understand the *underlying basic ideas of physics*. In other words, they need not to understand the whole conceptual framework or every existing formula. In this respect, Chris indicated that when students understand a particular concept, it offers you, as a teacher, new opportunities to take them to the next level by stimulating to explain the working of natural phenomena.

Second, all three teachers indicated that it is an important goal of physics education to teach students *problem-solving skills*, for example by recurrently making various assignments. Ann stressed that it is important for students to learn how to solve problems in an analytical and systematic way, for instance by following a step-wise method. Chris emphasized that students should learn to make predictions in advance and make the problem solvable by removing redundant information. Brandon stressed that students should learn how to apply theories while solving problems as well as how to mathematically manipulate formulas. Furthermore, both Ann and Brandon emphasized that students should learn *inquiry skills* in order to conduct a practical and various experiments on their own. Ann basically referred to practical skills, such as how to conduct an experiment and how to use various devices. Brandon expressed the belief that students should eventually be able to conduct scientific inquiry on their own, including the writing of a scientifically sound inquiry report. He focused on questions such as: 'How to formulate a good research question?''What are the necessary steps for answering your research question?' and 'What is needed to get valid measurements and/or observations?' In contrast, Chris did not mention inquiry skills at all. Moreover, Ann stressed the importance of *studying skills*. For instance, she thought it was important to give homework assignments such as memorizing content and making a summary of a textbook section. Ann said that she applied sanctions for not finishing homework.

Third, all three teachers in this study expressed the belief that it was important for students to adopt *scientific attitudes*. For example, Chris strived for attitudes such as questioning and a willingness to explain natural phenomena with the help of scientific theories and experiments whereas Brandon emphasized that students should think about what steps are needed to underpin and justify scientific knowledge claims. Ann promoted attitudes such as a willingness to discover new things by observing and conducting experiments. In addition, she pointed at the possibility to tell upper secondary students about physics as a research field and profession, for example by focusing on the different sub discipline-related purposes of physicists (e.g., verifying theories and applying knowledge in technologies). While Chris only mentioned scientific attitudes, both Ann and Brandon stressed that physics education could make a contribution to students' personal development by focusing on more *general attitudes*. For instance, Ann explicated that physics is a challenging subject, in the sense that problem-solving activities, conducting experiments, and analyzing data often cost students a lot of time and effort. She thought, however, that getting one's teeth into a problem, not giving up too easily, and eventually finding a solution is very joyful and rewarding. Brandon in particular aimed at broadening students' horizons by showing them that physics is more than just another school subject you need to pass. Again, he emphasized the value of learning more about the nature of knowledge development.

Beliefs about the pedagogy of teaching and learning physics

When it comes to the pedagogy of teaching and learning physics, the teachers in this study mainly expressed beliefs about *adaptive teaching* and the *purpose of practical work and inquiry activities*. A summary of these beliefs is provided in Table 5.4.

First, all three teachers stressed the importance of adaptive teaching. Given students' ages and levels, both Ann and Brandon differentiated in the *selection of lesson content* whereas Chris differentiated in the *selection of appropriate examples* to explain lesson content. For instance, Ann indicated that she pays attention to more 'advanced' topics in upper secondary education such as the close relationship between physics and mathematics or the tentativeness of scientific theories. Brandon stated that in lower secondary education, learning activities are more practically-oriented whereas in upper secondary education lesson content is more focused on understanding theoretical concepts because of the final exams. Furthermore, Brandon talked about a shifting function of inquiry activities in lower and upper secondary education. For instance, he expected 2nd grade students (aged 13-14) to gain experience in making precise observations, 3rd grade students (aged 14-15) to be stimulated to investigate topics of own choice in an attempt to increase their engagement, and in upper secondary education (students aged 16-18) students were trained how to conduct inquiry on their own as well as how to construct theoretical knowledge (e.g., formulating research questions, conducting repeated

Table 5.4. *Beliefs about the pedagogy of teaching and learning physics*

Pedagogy	Ann	Brandon	Chris
Adaptive teaching	- Selection of lesson content: Basic versus advanced physics topics	- Selection of lesson content: Practically versus theoretically oriented learning activities - Shifting function of inquiry activities	- Selection of appropriate examples: Students' ages and reasoning are taken as a point of departure - Focus on relevancy of conceptual knowledge
Purpose of inquiry activities	- Understanding physics concepts and verifying theories - Training problem-solving skills	- Learning and training inquiry skills - Conducting inquiry on your own	- Understanding physics concepts and verifying theories

measurements, and writing scientifically sound and theoretically embedded inquiry reports). Finally, Chris stated that he took students' ages and reasoning as a point of departure. In this respect, he emphasized that it was important not to lose yourself (as a teacher) in trying to explain every minor detail of physics theory. He stressed the importance of widening the scope by discussing the relevance of particular conceptual knowledge; otherwise students would get disconnected from the lesson content and consequently give up trying to understand what the teacher is talking about.

Second, with regard to the purpose of practical work and/or inquiry activities, both Ann and Chris shared the belief that experiments and lab experiences aimed at *students' understanding of physics concepts* whereas Brandon thought inquiry activities primarily aimed at *learning and training inquiry skills*. Thus, Ann and Chris stimulated students to apply and verify physics concepts and theories when they were conducting experiments and inquiry activities. Moreover, Ann stressed the importance of a particular sequence of learning activities, namely first introducing a new physics concept to students followed by an experiment to process and apply this conceptual knowledge. Otherwise students would not know how to conduct such an experiment on their own. In addition, Ann thought that practical work and inquiry activities were excellent options for *training problem-solving skills*, because students had to apply different formulas and make calculations based on their data. In contrast to Ann and Chris, Brandon expressed the belief that inquiry activities should focus on learning and training practical and inquiry skills. For instance, he thought it was important to teach students the essentials of the process of scientific knowledge development such as various methods of data gathering, the principle of repeated measuring, how to represent data in tables and graphs, the identification of mathematical relations between observed data (e.g., straight line, parabola), and how to write a scientifically sound inquiry report (i.e., writing it down in such a way that it enables the verification of your experiment as well as makes a contribution to existing physics theory). Furthermore, Brandon was eager to stimulate his students to *conduct inquiry on their own*, both during physics lessons and at home. For example, he tried to trigger their curiosity by means of various questions and showed them that it is far from complicated to use regular household materials for setting up a new experiment. By doing so, he indicated, students would hopefully get the idea that physics is a vivid subject.

5.5.3 Relations between teachers' beliefs

In this section we discuss the relations that we identified between particular teacher beliefs about the nature of physics and NOS and beliefs about teaching and learning physics (i.e., beliefs about the goals of physics education and the pedagogy of teaching and learning physics).

Relations between particular beliefs about the nature of physics and NOS

We explored the structure of teachers' beliefs about the nature of physics and NOS and found relations between teachers' beliefs about the *aim of scientific inquiry* and the *purposes of physics as a research field*. For instance, Ann primarily stressed that scientific inquiry aims at testing and verifying theories and models. In her opinion, the verification of theories and models by experiments was also one of the main purposes of physics as a research field. Chris shared Ann's belief that the aim of scientific inquiry is to test and verify theories and models. He explained that physicists tried to verify scientific theories in order to explain and predict how nature works. Brandon thought that the aim of scientific inquiry was to construct theories. With regard to the purposes of physics as a research field, he referred to the explanation of natural phenomena, particularly by stressing the nature of knowledge development and the various methodological steps needed in the process of constructing scientific theories and justifying knowledge claims.

Relations between particular beliefs about teaching and learning physics

Our analysis of teacher beliefs about teaching and learning physics made clear that beliefs about the *purpose of practical work and inquiry activities* were especially related to teachers' priorities concerning what *knowledge* and *skills* should be taught and what *attitudes* were important for students to adopt. For example, Ann said that inquiry activities were a useful means for fostering students' understanding about physics concepts, training students to verify theories, and training problem-solving and inquiry skills. In this respect, Brandon focused especially on the learning and training of inquiry skills and students' ability to conduct inquiry on their own (including the writing of a scientifically sound inquiry report). He emphasized that inquiry activities should aim at the acquisition of knowledge about methods of inquiry and justification of knowledge claims so that students would know how to construct theories. Chris thought that inquiry activities should be conducted to verify theories in order to enhance students' understanding of physics concepts. In addition, students should be challenged to ask questions about natural phenomena and encouraged to explain and predict how nature works.

Relations between beliefs about the nature of physics and NOS and beliefs about teaching and learning physics

In our exploration of the relations between teacher beliefs about the nature of physics and NOS and their beliefs about teaching and learning physics, we found the following two patterns: 1) beliefs about the *aim of scientific inquiry* were related to beliefs about the *purpose of practical work and inquiry activities* and 2) beliefs about the *purposes of physics as a research field* were related to beliefs about the *goals of physics education*. First, both Ann and Chris thought that the aim of scientific inquiry was to test and verify theories; they also considered this as an important purpose of inquiry activities in physics education. Brandon referred to the construction of theories as the aim of scientific inquiry, and he thought that students should learn to construct their own theories by inquiry activities in the classroom. Second, the beliefs of all three teachers about the purposes of physics as a research field were, to a greater or lesser extent, related to priorities concerning what *knowledge*, *skills*, and *attitudes* were important to focus on. For instance, Ann talked about the adoption of positive attitudes towards physics as a research field and profession. In this respect, she referred to what she called "key activities of physicists", such as discovering new things and a willingness to know, the act of verifying theories, and applying scientific knowledge in technology and devices. Brandon talked about the importance of knowing more about the nature of scientific knowledge development. He provided examples, such as knowledge about the reduction of axioms, the methods of underpinning and justifying knowledge claims, and the various methodological steps of scientific inquiry. Chris primarily focused on the adoption of the attitude of a willingness to explain natural phenomena by theory and experiments. In this respect, he referred to the interaction between theory and experiment in the research field of physics.

5.5.4 Teachers' intentions expressed in a lesson plan of an introductory physics lesson

We asked all three teachers to design an introductory physics lesson without taking into account any practical constraints. In this section, we discuss teachers' intentions by focusing on their *lesson objectives* (including what image of physics they wanted to portray to their students) and the *teaching and learning activities* they considered to be important for such a lesson. An overview of all three lesson plans is included in Appendix 5.

Intentions with regard to lesson objectives

The three teachers clarified their lesson plan by making the lesson objectives explicit. Both Brandon and Chris explained that they intended to use the introductory physics lesson for giving students an *impression of the various topics and/or concepts that are covered by the domain of physics*. Thus, they preferred to center the teaching and learning activities around multiple topics, such as 'light', 'electricity', 'gravity', and 'magnetism'. In addition, both Brandon and Chris aimed at *arousing students' curiosity, wonder, or even astonishment about natural phenomena*. Because Brandon intended to tell his students that physics is about 'conducting inquiry and trying to find answers for one's own questions about nature', he would stimulate students to ask questions about what they observe. Chris aimed at depicting physics as a subject that concerns 'explaining how nature works'. Therefore, he strived for a surprise act, an unexpected event, that triggered students to think about possible explanations. Ann's main lesson objective was to *increase students' awareness of the existing link between theory and experiments*. For this reason, she intended to use a systematic, step-wise approach and designed an introductory lesson with one topic, namely 'sound'. Furthermore, she would like to show her students that physics is 'interesting, challenging, and fun'.

Intentions with regard to specific teaching and learning activities

The teachers continued their explanation of the lesson plan by expressing their intentions with regard to specific teaching and learning activities. All three teachers said that they would start with an *introduction including specific questions* both to activate student thinking and to focus the lesson. Ann intended to start with the (scientific) statement "Sound is a vibration" followed by the question "How can you prove that?" whereas Brandon would ask his students "What happens when light rays go through different types of materials?" Chris would start with a guided experiment: he intended to show his students two tennis balls and tell them that he would drop them. Next, he aimed to have a whole-class discussion prompted by questions such as "What will happen?" "What causes the balls to fall down on the floor?" and "Can we predict that these balls will reach the floor at the same time?" After a couple of student responses, Chris would drop the balls, the students would observe that the balls reach the floor at the same time, and he would continue the discussion by asking "Why did this happen?" and "Why wouldn't one ball fall faster than the other?" Chris expected that some of his students would say that the balls are equally heavy. Then, he would throw the balls into the classroom and the students would find out that one ball is heavier than the other (because Chris has injected water into it). The whole-class discussion would end by questions such as "How come a ball that is twice as heavy as the other still falls equally fast?" and "How to explain this?"

After the introduction, all three teachers would conduct a particular *sequence of teaching and learning activities*. Ann intended to have a chain of teaching and learning activities (e.g., demonstrations, whole-class discussions, and experiments) with a tuning fork and one or two ping-pong balls. This *chain of activities* was characterized by the following systematic step-wise approach: 1) observing, 2) thinking, 3) drawing conclusions, 4) linking to existing physics theory, and 5) constructing personal theoretical concepts (i.e., students would be asked to explain why the ping-pong ball vibrated). Ann would end the lesson by giving the students a homework assignment. In contrast, Brandon intended to discuss various topics that covered physics content. Furthermore, the students would conduct several inquiry activities that were related to the question he posed at the beginning of the lesson. In this respect, Brandon would give his students a *sequence of assignments* with a light box and multiple prisms. This sequence would start with an open assignment (e.g., "create a beautiful pattern with the light rays and the prism") followed by more focused assignments, such as "create a straight light ray on your paper" or "explore the reflection of the light ray with different prisms". In addition, the assignments would include a *range of teacher-initiated questions* that stimulated students to make precise observations, to find regularities and differences between these observations, and to explain what they observed. Brandon intended to end the lesson by discussing various questions, such as "Why are some fabrics transparent and others are not?" and "Explain why something is or is not reflecting light?" Finally, Chris indicated that he intended to conduct a *chain of teaching and learning activities* that was characterized by the following five steps: 1) arousing students' wonder and curiosity, 2) stimulating them to ask questions about how nature works, 3) active student thinking, 4) trying to explain how nature works by constructing personal theories, and 5) verifying these personal theories by conducting an experiment. For this reason, Chris would start the lesson with the guided experiment mentioned above, followed by a discussion of various topics related to physics content, and inquiry activities with a light box and a prism.

Besides the intentions with regard to the lesson objectives and the teaching and learning activities, all three teachers made some remarks in relation to the content of the introductory lesson. These remarks concerned *student engagement*, *student comprehension*, and *students' active involvement*. First, Ann emphasized that the lesson content should be related to students' daily life whereas Brandon reported that he would conduct experiments that would be impressive for students (thus no dull experiments, such as measuring the time of oscillation). Second, Ann intended to conduct experiments that were illustrative examples of theoretical physics concepts and Chris stressed the importance of making precise observations in order to explain the working of nature. He said that the inquiry activities were an excellent opportunity to stimulate students in making precise observations (e.g., drawing and discussing the position of the prism and the light box to create a colorful spectrum). Finally, Brandon emphasized that he strived for students' active involvement, for instance by conducting hands-on activities and experiments. Likewise, Chris said that students should conduct an experiment on their own (including tidying up the classroom afterwards).

5.5.5 Manifestations of teachers' beliefs in teaching intentions

In the present study, we were interested in whether teachers' beliefs about the nature of physics and science as well as beliefs about teaching and learning physics were reflected in their teaching intentions. All three teachers said that they planned to devote a large part of the 50-minute lesson time to *inquiry*, because they thought inquiry was an important aspect of physics. With regard to teachers' beliefs about the nature of physics and NOS, we found that their beliefs about *the aim of scientific inquiry* and *the purposes of physics as a research field* were especially reflected in their intentions. Remarkably, these beliefs were mainly expressed in teachers' own definition of the nature of physics (i.e., interview format, Appendix 4, part A). Furthermore, we found that teachers' *priorities concerning* what *knowledge, skills, and attitudes* were important to focus on and beliefs about the *purpose of practical work and inquiry activities* were reflected in their lesson objectives and specific teaching and learning activities. However, the teachers were not accustomed to making the rationale explicit. In the next paragraphs, we illustrate the relations between beliefs and intentions that we identified.

Relations between Ann's beliefs and intentions

Ann expressed the beliefs that 1) scientific inquiry aims at testing and verifying theories, 2) one of the purposes of physics as a research field is to discover new things, 3) an important goal of secondary physics education is that students are willing to discover new things by observing and conducting experiments, and 4) inquiry activities are conducted in order to verify theories and to understand physics concepts. Ann's main lesson objective was that students would become aware of the link between theory and experiments. Therefore she would conduct experiments that functioned as illustrative examples of physics concepts (e.g., the vibration of ping-pong balls by a tuning fork to illustrate that sound is a vibration). Ann intended to start the lesson by asking her students how they can prove that sound is a vibration. After discussing this question, she would conduct various experiments that were all focused on testing and verifying Ann's scientific statement. While conducting these experiments, Ann would stimulate her students to link their actual observations (e.g., the vibration of ping-pong balls by a tuning fork or the vibration of students' vocal cords) as well as their possible explanations for these observations (e.g., "the ping-pong balls are vibrating by the sound of the tuning fork" or "we feel our vocal cords because we are producing sound") to existing theory about sound and the principle of resonance. Besides that, Ann also expressed as a lesson objective that students would obtain the image of physics as an interesting, challenging and fun subject. In this respect, she emphasized the importance of students making their own observations and conducting experiments on their own in order to find answers to their questions and discover something new.

Relations between Brandon's beliefs and intentions

Brandon's beliefs were that 1) the aim of scientific inquiry is to construct theories, 2) physics as a research field aims at explaining the essential processes within nature by an interaction between theory and experiments (this process of knowledge development is characterized by different methodological phases), 3) important goals of physics education are that a) students learn to conduct experiments and inquiry on their own, b) students think about what steps are needed in order to underpin and justify their knowledge claims, and c) students are willing to develop their own knowledge, and 4) inquiry activities serve the learning and training of students' inquiry skills. With regard to Brandon's teaching intentions, he reported that one of the lesson objectives was to show students that physics is about conducting inquiry and trying to find answers for their own questions about nature. Therefore, he intended to start by asking students what happens when light rays go through different types of materials (i.e., he asked a question about one of the essential processes in nature). In answering this question, Brandon would stimulate his students to construct their own hypotheses and to think about what experiments were needed to test these hypotheses. In addition, Brandon intended to teach his students a variety of inquiry skills, such as making precise observations, finding the regularities and differences between these observations, and to explain what has been observed. Thus he planned a chain of open and closed inquiry assignments with a light box and different prisms that were focused on these skills. Furthermore, Brandon said that another lesson objective was to arouse students' curiosity and to stimulate them to ask questions about what they observed. He believed that these were important aspects of students' personal knowledge development.

Relations between Chris's beliefs and intentions

Finally, Chris thought that 1) scientific inquiry is conducted to test and verify theories, 2) the purpose of physics as a research field is to explain essential processes within nature by an interaction between theory and experiments (this interaction is characterized by both inductive and deductive approaches), 3) important goals of physics education are that a) students learn to solve problems by making predictions in advance as well as removing redundant information and b) students have the willingness to explain natural phenomena with theory and experiments (e.g., asking questions and trying to find answers), and 4) the purpose of inquiry activities is that students understand physics concepts and verify theories. According to Chris, students' willingness to explain natural phenomena was very important, because this could be seen as an intrinsic motivation to conduct inquiry. For this reason, he formulated as lesson objectives that he intended to arouse students' wonder, surprise, and curiosity. Moreover, he would like to show students that physics is about explaining how nature works. Because Chris saw curiosity and wonder as prerequisites for conducting inquiry, he intended to start the lesson with an experiment (i.e., two tennis balls are dropped and reach the floor at the same time) that would challenge students' own predictions, expectations, and explanations (e.g., they would find out that one of the tennis balls is twice as heavy as the other). Chris said that he would stimulate his students to construct 'personal theories' about the phenomenon both by making predictions in advance (e.g., "when you drop the tennis balls, they will fall because of gravity") and by explaining their observations afterwards (e.g., "the tennis balls reached the floor at the same time because they are equally heavy"). In addition, he would ask his students to test and verify these 'personal theories' by conducting an experiment (e.g., dropping the tennis balls and observing what will happen and checking whether the balls are equally heavy).

5.6 CONCLUSIONS AND DISCUSSION

5.6.1 Main conclusions

Content and structure of teachers' belief systems

The present study was guided by two research questions. The first question focused on the content and structure of teachers' beliefs about the nature of physics and NOS and beliefs about teaching and learning physics. With regard to the content of teachers' beliefs about the nature of physics and NOS, we conclude that the three teachers in our sample differed in their beliefs about a) the aim of scientific inquiry, b) the tentativeness of scientific theories, c) the difference between scientific theories and laws, and d) the purposes of physics as a research field. With reference to teachers' beliefs about teaching and learning physics, we conclude that the teachers had different priorities concerning what knowledge, skills, and attitudes should be focused on in the context of secondary physics education. However, the rationale behind teachers' priorities often remained to a greater or lesser extent tacit. Furthermore, the teachers expressed different beliefs about the pedagogy of teaching and learning physics, namely about adaptive teaching and the purposes of practical work and inquiry activities.

With regard to the structure of teachers' beliefs, we conclude that the following relations could be identified: 1) teachers' beliefs about the aim of scientific inquiry were related to their beliefs about the purposes of physics as a research field, 2) beliefs about the purpose of practical work and inquiry activities (in the classroom) were related to priorities concerning what knowledge, skills and attitudes should be taught, 3) beliefs about the aim of scientific inquiry were related to beliefs about the purpose of practical work and inquiry activities, and 4) beliefs about the purposes of physics as a research field were related to priorities concerning what knowledge, skills, and attitudes were important to teach.

Manifestations of teachers' beliefs in their intentions

The second research question of the present study focused on whether the beliefs we investigated would be reflected in teachers' intentions regarding an introductory physics lesson. All three teachers intended to devote a large part of the 50-minute lesson time to inquiry, because they thought inquiry was an important aspect of physics. In this respect, we found that the beliefs that were related to inquiry were especially reflected in these intentions. More specifically, we found that teachers' beliefs about the aim of scientific inquiry, the purposes of physics as a research field, the purpose of practical work and inquiry activities, and priorities concerning knowledge, skills, and attitudes that should be taught in secondary physics education were reflected in the lesson objectives and the teaching and learning activities expressed in the lesson plan. The former two beliefs (about the nature of physics and NOS) were primarily expressed in teachers' own definition of the nature of the physics domain (i.e., interview format, Appendix 4, part A).

5.6.2 Discussion

Manifestation of beliefs in teaching intentions

The present study showed that all three teachers intended to pay explicit attention to inquiry in their introductory lesson. In this respect, we found that beliefs about scientific inquiry and the purposes of inquiry activities were particularly reflected in teachers' intentions. However, although the teachers sometimes shared the same belief (e.g., "scientific inquiry aims to test and verify theories" or "the purpose of physics as a research field is to explain the essential processes within nature by an interaction between theory and experiments") they emphasized different aspects of inquiry, such as 'testing and verifying a theory by searching for empirical evidence' (Ann), 'asking questions, observing nature, and finding regularities between observations to construct a theory' (Brandon), and 'formulating predictions about natural phenomena and verifying these to explain how nature works' (Chris). Thus, we found that similar beliefs manifested themselves in different lesson objectives as well as different teaching and learning activities. Furthermore, although the three teachers explained clearly *what* particular lesson objectives and teaching and learning activities were important, the rationale behind these priorities often remained to a greater or lesser extent tacit. One explanation could be that teachers are not accustomed to expressing this rationale, another explanation could be that this rationale is tacit or absent (cf. Zanting, Verloop, & Vermunt, 2003).

Teachers' beliefs about the nature of physics and NOS

With regard to teachers' beliefs about the nature of physics and NOS, we noticed that in particular teachers' responses to the questions of the *VNOS* (Lederman, et al., 2002) were not clearly related to their intentions. The relations that we found between these beliefs and teaching intentions were mainly derived from teachers' own definitions of the nature of physics and science and their answers to questions about the aim of scientific inquiry and what physicists are trying to achieve (Appendix 4, part A). In addition, the teachers in this study indicated that it was difficult to respond to the questions of the *VNOS* (i.e., Appendix 4, part B), because they hardly ever thought about such topics. A possible explanation is that teachers' beliefs about the nature of physics and NOS are biased by perceptions of the content of the *school subject* physics. Most teachers have been confronted with physics and science only in the context of their own education. In addition, many in-service professional development programs are mainly focused on aspects of physics and science *teaching*. As a consequence, there is a possibility that teachers have developed a 'second nature' in talking about the nature of physics and NOS. In other words, their responses could be *colored* and *biased* by the actual school context (cf. Guerra-Ramos, 2012; Southerland, Johnston, & Sowell, 2006).

Limitations of the present study

Since the sample of the present study consisted of three teachers, no generalizations can be made based on the relations that were identified between teachers' beliefs about the nature of physics and NOS, their beliefs about teaching and learning physics, and particular intentions expressed regarding an introductory physics lesson. In addition, although the interview included an assignment that was closely related to teachers' daily practice of teaching, the intentions that were expressed were based on an ideal teaching situation (i.e., without taking practical constraints into account). However, the results of this explorative study do provide some implications for practice and suggestions for further research.

Implications and future research

When talking about physics and science the teachers did not clearly distinguish terms such as 'inquiry' and 'experiment' from 'practical' and 'lab work'. Often they used these terms interchangeably to indicate a range of teaching strategies that were characterized by practical and hands-on activities. This implies that teachers' *language*, at least in this study, might be typified as 'educational language', i.e., mainly related to the context of education. Thus, even when the teachers in this study used words derived from the scientific jargon, there is a reasonable chance that they either were not fully aware of the precise scientific definitions and meanings or created their own definitions in an attempt to clarify these terms and concepts to students (cf. Gyllenpalm, Wickman, & Holmgren, 2010). In this respect, more research is needed to investigate the extent to which teachers' beliefs and language about NOS are biased by or 'translated' to the school context and what the consequences for students' images of NOS are.

When we asked the three teachers about what image of physics they would portray to their students, we noticed that these teachers *differentiated* between students' age (i.e., lower/upper secondary education) and level (i.e., senior general secondary education and pre-university secondary education). In addition, when explaining their intentions concerning the teaching and learning activities of the introductory physics lesson, these teachers referred to the specific nature of this lesson and its related lesson objectives as well as to particular student characteristics (e.g., "lower secondary students that are confronted with physics for the first time", "this lesson should trigger their curiosity and interest", and "the students are 12-13 years old"). Thus, when talking about their beliefs and intentions, the teachers in this study differentiated by taking into account specific contextual variables, such as student characteristics and lesson objectives. This implies the possibility that what teachers consider important is, to a greater or lesser extent, *context specific*. In other words, a teacher's priorities may (slightly) differ per context (cf. Borko, et al., 2000; Borko, Mayfield, Marion, Flexer, & Cumbo, 1997; Guerra-Ramos, Ryder, & Leach, 2010). More research is needed to investigate to what extent and, if so, in what way the manifestation of teachers' beliefs in teaching intentions differs when specific student characteristics, particular content topics, and/or specific lesson objectives are taken into account.