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ICLON

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Engaging students in the study of physics

An investigation of physics teachers' belief systems about teaching and learning physics

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Chapter 1

General introduction

1.1 INTRODUCTION

Good education is characterized by high quality learning opportunities for students. In this respect, "the teacher is the most important factor for student learning" (Abell, 2007, p. 1105). Effective teachers are competent in building positive social relationships with individual students, establishing a positive classroom climate by effective classroom management, and teaching content by a variety of instructional methods and strategies (Den Brok, Brekelmans, & Wubbels, 2004; Doyle, 2006; Nordenbo, Larsen, Wendt, & Østergaard, 2008; Shulman, 1986). Therefore, efforts to improve education are served by efforts to improve teachers' teaching competences, for instance by providing high quality learning opportunities for teachers in the context of teacher education and professional development programs. Recently, Van Veen, Zwart, Meirink, and Verloop (2010) conducted a review on the characteristics of effective teacher professional development interventions. One of their main conclusions was that the interventions proved to be effective when the content was related to the daily practice of teaching, especially when it paid attention to subject-related problems regarding *content*, *pedagogy*, and *students' learning processes*. These findings support the notion of Borko and colleagues (2010) that the content of high-quality professional development "should be situated in practice and should be focused (at least in part) on students' learning" (p. 549). In designing these professional development programs, one of the major challenges is to scaffold teacher learning in such a way that it is immediately relevant to practice. Moreover, these programs should build on a more generalized *knowledge base* for the teaching profession (Borko, et al., 2010; cf. Hiebert, Gallimore, & Stigler, 2002).

1.2 THEORETICAL FRAMEWORK AND PURPOSE OF THE RESEARCH

1.2.1 The knowledge base of teaching

This dissertation aims to contribute to the knowledge base of teaching; the work of Verloop, Van Driel, and Meijer (2001) is used as a point of departure for studying *teachers' practical knowledge*. In this work, the complexity and interdependency of teacher behavior is acknowledged by the basic assumption that there is an interaction between teaching behavior, on the one hand, and teacher cognitions and beliefs, on the other (cf. Kansanen et al., 2000). In other words, in line with Schön's (1983, 1987) principle of *reflection-in-action*, in the act of teaching, a teacher's thinking is in "a continuing dialogue with the permanently changing situation" (Verloop, et al., 2001, p. 442). Thus, a teacher's knowledge and beliefs regarding each educational process are seen as a central feature of teacher professionalism. In this respect, Verloop and colleagues adopt a comprehensive conception of knowledge by defining the knowledge base of teaching as "all profession-related insights that are potentially relevant to the teacher's activities" (p. 443). As a result, the knowledge base of teaching includes not only *formal theoretical knowledge* (e.g., classical theories from research on teaching and learning) but also *teachers' practical knowledge* (e.g., insights, beliefs, and practical arguments that constitute teachers' routines and day-to-day activities).

According to Verloop et al. (2001), research on the knowledge base of teaching, specifically research on teachers' practical knowledge, is important for the following three reasons. First, although it is reasonable to expect that particular elements of teachers' personal knowledge bases can be shared by larger groups of teachers or even by all teachers, "*there is no a priori assumption that it is possible to detect such general features*" (p. 447). The basic assumption underlying teachers' practical knowledge (as part of the overall knowledge base of teaching) is that this knowledge originates partly from teaching practice. Besides, the insights that guide an individual teacher's behavior (i.e., a teacher's personal knowledge base) are highly 'colored' by a teacher's individual beliefs, experiences, subject matter knowledge, personality variables, personal learning processes, and so on. Thus, the content of teachers' practical knowledge is complex and not self-evident (cf. Abell, 2007; Meijer, 1999; Meirink, Meijer, Verloop, & Bergen, 2009; Van Veen, Sleegers, Bergen, & Klaassen, 2001). Therefore, one of the aims of research on teachers' practical knowledge is to explore whether such general features can be identified. Second, research on teachers' practical knowledge aims "*to enhance teachers' awareness of and, subsequently, their options for action*" (Verloop, et al., 2001, p. 448) in an attempt to bridge the often perceived 'gap' between theory and practice. The process of combining, exchanging, and integrating formal theoretical knowledge and teachers' practical knowledge is very complex, partly because it is not an easy job for practicing teachers to explicate their personal knowledge, let alone to confront this knowledge with formal theoretical knowledge. Thus, the conditions under which teachers' practical knowledge can become a more substantial component of the overall knowledge base, as in the context of teacher learning and professional development programs, are complex (cf. Borko, Davinroy, Bliem, & Cumbo, 2000; Imants & Van Veen, 2010; Loughran, 2007; Meijer, Zanting, & Verloop, 2002; Putnam & Borko, 2000; Wongsopawiro, 2012). In this respect, teacher education and professional development programs are challenged by the question of how to make teachers' practical knowledge accessible to prospective teachers. Third and finally, *teachers' practical knowledge is relevant in the context of implementing educational innovations* (cf. De Vos, 2010; Ertmer & Ottenbreit-Leftwich, 2010; Henze, Van Driel, & Verloop, 2007; Oolbekkink-Marchand, 2006). In the past, many educational innovations failed because teachers experienced a mismatch between the innovation, their personal routines, and perceptions of the domain or the existing school culture. Therefore, in order for innovations to succeed, teachers' practical knowledge should be taken into account. For instance, designers and implementers of educational innovations could start by investigating teachers' personal beliefs about the fundamental ideas of an innovation and their (possibly negative) attitudes towards implementing particular teaching behaviors.

1.2.2 Purpose of the dissertation

The purpose of this dissertation is to gain more insight into the content of teachers' practical knowledge, particularly the content and structure of teachers' *beliefs*. Because teachers' practical knowledge is embedded in the personal context of teachers, in which various domain-specific and student-related factors play a significant role (Verloop, et al., 2001), the studies of this dissertation focus on the domain of science education, more specifically, on secondary physics education (students aged 12-18). Thus, the research aims to contribute particularly to the knowledge base of science teaching (cf. Corrigan, Dillon, & Gunstone, 2011).

1.3 LITERATURE REVIEW

1.3.1 Research on teacher beliefs

The problem of defining teacher 'beliefs'

Research on teacher beliefs is complicated due to a lack of consensus about how to define the construct of 'beliefs' (Jones & Carter, 2007). In his famous review, Pajares (1992) noticed that the literature provides many different definitions of 'beliefs' – opinions, conceptions, attitudes, perceptions, judgments, perspectives, dispositions, practical principles, axioms, internal mental processes, repertoires of understanding, rules of practice, conceptual systems, personal theories, action theories, and so on. In an attempt to "clean up the messy construct", Pajares synthesized the findings on beliefs so far in sixteen fundamental assumptions; however, a clear definition of the construct of 'beliefs' was not formulated.

Ever since, although many scholars have based their own research on Pajares' assumptions about beliefs, still various labels have been used to describe beliefs. For instance, Jones and Carter (2007) reviewed the literature on teacher beliefs in the domain of science education and found such definitions as 'subjective, private opinions', 'propositions considered to be true by the individual', 'personal constructs', 'psychologically held understandings, premises, or propositions about the world that are felt to be true', 'individuals' thoughts', 'espoused theories of action', and so on. In an attempt to synthesize their findings, Jones and Carter proposed the "sociocultural model of embedded belief systems" (2007, p. 1074). In this model, beliefs about *science*, *science teaching*, and *science learning* (cf. Keys, 2003; Kwak, 2001) are related to knowledge, skills, motivation, attitudes, perceptions of efficacy, social norms, and environmental constraints (cf. Ajzen, 1991; Ajzen & Fishbein, 2005). The model suggests that all these different constructs are reciprocally related to each other and to the sociocultural context. Jones and Carter composed this model as a basis for framing research on teacher beliefs, but they did not provide a clear definition of beliefs.

Fundamental assumptions about 'teacher beliefs'

Despite the lack of a clear definition of 'beliefs', research on teacher beliefs provides ample evidence about the nature of beliefs. By combining the assumptions formulated in the reviews of Pajares (1992) and Jones and Carter (2007) with the work of Richardson (1996) and Calderhead (1996), it is possible to formulate fundamental assumptions that represent what the majority of scholars agree on. These assumptions refer to the *stability*, *organization*, and *functionality* of teacher beliefs.

Stability

- Beliefs are relatively stable because they tend to self-perpetuate, sometimes persevering against contradictions caused by reason, time, schooling or experience. In other words, after being confronted with scientifically correct explanations, individuals might hold on to beliefs based on incomplete or incorrect knowledge.
- Some beliefs are more changeable than others. The earlier a belief is formed, the more difficult it is to alter. In contrast, beliefs that are recently acquired are most vulnerable to change.
- Once beliefs have changed, the stability of this belief change is influenced by sociocultural and contextual factors.

Organization

- Beliefs are organized into larger multidimensional belief systems.
- Beliefs are related to other cognitive and affective structures, such as self-efficacy, attitudes, values, expectations, and so on.
- Within the belief system, beliefs are prioritized according to their connections to other beliefs, knowledge, and attitudes. As a result, belief systems contain core beliefs and peripheral beliefs. Thus, apparent inconsistencies in beliefs may be explained by exploring the centrality and functional connections of the different beliefs.

Functionality

- Beliefs strongly influence perception; they act like filters. The filtering effect of belief structures ultimately screens, distorts, redefines, and reshapes information processing and subsequent thinking. In other words, beliefs play a critical role in organizing knowledge and information.
- The belief system has an adaptive function in helping individuals define and understand themselves, the behavior of other individuals, and the world around them.
- Beliefs affect an individual's own behavior, because they are instrumental in defining tasks and selecting the cognitive tools with which to plan, interpret, and make decisions regarding such tasks. However, beliefs can be an unreliable guide to the nature of reality.

Measuring teacher beliefs

The investigation of teacher beliefs is complicated because beliefs are often tacit (Pajares, 1992; Thompson, 1992). Moreover, some beliefs are more tacit than others. In other words, some beliefs are more directly accessible, as, for example, by explicit reflection and discussion, than others. Thus, in selecting what methods are appropriate for investigating teacher beliefs, scholars should take the accessibility of beliefs into account. For example, some beliefs lend themselves to being measured by questionnaires and interviews, whereas other more tacit beliefs should be elicited by triangulating both quantitative and qualitative methods (which is in many cases complex and time consuming). Overall, research on teacher beliefs often necessitates inferences based on a combination of what teachers say, intend, and actually do (Kagan, 1990; Lombaerts, De Backer, Engels, Van Braak, & Athanasou, 2009).

The relationship between knowledge and beliefs

According to Jones and Carter (2007), the literature on teacher beliefs comprises multiple perspectives on the relationship between knowledge and beliefs. For instance, some scholars treat knowledge and beliefs as separate constructs with reciprocal impact, while others view knowledge and beliefs as inseparable or assume that beliefs are an integral part of the overarching knowledge construct. In this dissertation we treat teacher beliefs as part of teachers' practical knowledge. Roughly speaking, beliefs refer to personal values, attitudes, and ideologies whereas knowledge refers to teachers' more factual propositions (Verloop, et al., 2001). However, this distinction remains somewhat arbitrary because in the mind of a teacher knowledge and beliefs are inextricably intertwined (Meijer & Van Driel, 1999; Pajares, 1992; Verloop, et al., 2001).

The relationship between beliefs and the practice of teaching

The relationship between teachers' beliefs and the practice of teaching is not straightforward (Feucht & Bendixen, 2010; Thompson, 1992). In the domain of science education, some studies found highly 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 consistencies or inconsistencies between teachers' expressed beliefs and actual teaching behaviour (Fang, 1996; Mathijsen, 2006), such as 1) the *nature of beliefs* which are studied, and their 'conceptual distance' to observed teaching behaviour, 2) the *content and structure* of a teacher's *belief system*, and 3) the *educational context* and *personal characteristics* of the teacher.

First, with regard to the nature of beliefs which are investigated, the more abstract or general the beliefs, the more likely that discrepancies with practice will be found (e.g., Richardson, 1996; Stipek, Givvin, Salmon, & MacGyvers, 2001). For instance, beliefs about teaching and learning in general are less likely to become visible in actual teaching behaviour than beliefs about specific teaching and learning strategies and activities to promote students' understanding of a particular science concept.

Second, the literature reports that beliefs, organized into larger systems, do not necessarily form a cohesive unit (Pajares, 1992); teachers might even hold contradictory beliefs (e.g., Hashweh, 1996; Jones & Carter, 2007; Lombaerts, et al., 2009; Maggioni & Parkinson, 2008; Tsai, 2006). Moreover, in these belief systems some beliefs are prioritized over others (Brownlee, Boulton-Lewis, & Purdie, 2002; Hofer & Pintrich, 1997).

Third, many teachers justify inconsistencies between their beliefs and their teaching practice by referring to factors that have an impact on "the complexities of classroom life" (Fang, 1996, p. 55). For example, a lack of time and resources, mandated curriculum materials, students' preparation for final exams, existing social norms of the school community, and large classroom sizes may place serious constraints on how teachers' beliefs are manifested in practice (e.g., Clark & Peterson, 1986; Jones & Carter, 2007; Lombaerts, et al., 2009; Maggioni & Parkinson, 2008; Tillema, 2000; Wallace & Kang, 2004). In addition, personal teacher characteristics such as teaching experience (in various contexts), previous training (in content as well as pedagogy), and a possible lack of knowledge and skills needed to implement the preferred practice may have an impact on the consistency between teachers' beliefs and their practice (Jones & Carter, 2007; Lederman, 1999; Schwartz & Lederman, 2002).

1.3.2 Context of the dissertation: Science/Physics education

Traditions in research on science education

The literature on the nature and purposes of science education reveals differences in scholars' assumptions and beliefs about science learning. According to Anderson (2007), three traditions can be distinguished, namely the *conceptual change tradition*, the *sociocultural tradition*, and the *critical tradition*. These traditions all focus on the development of students' scientific literacy, including two different forms of agency, namely 'social agency' (i.e., acquiring scientific knowledge and skills provides access to jobs and communities that would otherwise be closed to students) and 'agency in the material world' (i.e., learning science enables students to describe and measure the world around them with precision, to predict and explain phenomena, and to influence natural and technological systems in an effective way). Moreover, the researchers of these traditions agree that current science education often fails to help students "learn science with understanding" (Anderson, 2007, p. 5). However, the traditions differ in their ideas about which instructional strategies are appropriate for teaching science and enhancing students' understanding of content. The next paragraph contains a brief summary of the main differences between the traditions based on the work of Anderson (2007).

The *conceptual change tradition* views students as rational but inexperienced thinkers who bring their personal ideas about content (often called misconceptions, alternative frameworks, or naïve conceptions) into the classroom. These personal ideas are developed through students' own experience. As a consequence, learning science involves a complex process of conceptual change that is primarily driven by 'conceptual conflict'. In this respect, science teachers should give students access to new experiences with the material world that are incompatible with their own ideas, as well as help students see the power of a scientific model to account for these new experiences. The *sociocultural tradition* considers students as "participants in multiple communities of practice, each with its own language, values, and practices" (Anderson, 2007, p. 18). In order to participate in scientific practices (e.g., inquiry and application of scientific concepts), students should learn to adopt the language, values, and social norms of the scientific community of practice. In this respect, science teachers should attempt to bridge linguistic and cultural differences by "the development of congruent third spaces in classrooms" (p. 19). In these spaces, 'sociocultural conflicts' can be resolved by negotiating and merging everyday and scientific discourses and knowledge and creating new understanding. According to the *critical tradition*, students are participants in institutions and power relationships. Thus, some students are excluded from access to the power of scientific knowledge and practices whereas others are in a privileged position. Therefore, scholars in this tradition advocate the development of 'critical literacy'. This means that students "need to learn not only how to participate in scientific communities but also to question and criticize the relationships between those communities and other powerful interests" (p. 24). In this respect, teachers should try to get students to achieve critical literacy, for instance by including changed power relationships in the school (e.g., out-of-school programs) and paying attention to knowledge that is currently outside the regular curriculum of school science.

The content of science curricula

It is reasonable to expect that the goals and content of science curricula have been influenced by a blending of ideas from the different traditions in research on science education. Bybee and DeBoer (1994) reviewed the curricula of science education from the 1960s to the 1990s. They concluded that the following three major goals have shaped curriculum and instructional practices: understanding *scientific knowledge*, understanding and using *scientific methods*, and promoting students' *personal-social development*. In line with this, Hodson (1992, pp. 548-549) stated that the general goals of science education can be characterized as 1) *learning science* (i.e., developing and acquiring conceptual and theoretical knowledge), 2) *doing science* (i.e., developing expertise and engaging in scientific inquiry and problem-solving), and 3) *learning about science* (i.e., developing an understanding of the nature and methods of science and an awareness of the complex interactions between science and society).

Besides these general goals, the specific content of science curricula might reflect different ideas over the course of time. According to Wubbels and Brekelmans (1997), since the 1980s the developments of science curricula have been influenced by three main ideas, namely *science for all*, *teaching science in context*, and *constructivism*. The 'science for all' perspective advocates that science education should improve our standards of living by providing students "with a way of thinking and inquiry that is the most powerful currently available for everyday living, for scientific research, for fostering the technological and economic growth of the societies in which they live" (Keeves & Aikenhead, 1995 cited in Wubbels & Brekelmans (1997, pp. 448-449) (cf. Osborne & Dillon, 2008). 'Teaching science in context' promotes the idea that students should get the opportunity to investigate the contextual, social, practical, and political dimensions of science (cf. Lederman, 2007; Sadler, Burgin, McKinney, & Ponjuan, 2010). In addition, the various contexts that are provided for learning science may play an important role in retaining students' attention and facilitating the application of scientific concepts. 'Constructivism' refers to the idea that the student (actively) constructs his or her own knowledge and that "the student's views become subjects for explicit social discourse with peers and the teacher" (Wubbels & Brekelmans, 1997, pp. 448-449) (cf. Wells & Claxton, 2002). In this learning process, the teacher can act as a facilitator, guide, challenger, and stimulator (cf. Vermunt & Verloop, 1999).

Secondary physics education in the Netherlands

The studies of this dissertation were conducted in the context of secondary physics education in the Netherlands. In the past two decades, Dutch secondary education faced two major curriculum reforms, namely the introduction of a common curriculum called *Basisvorming* [basic education] in lower secondary education (students aged 12-15) and the introduction of the so-called *Tweede Fase/Studiehuis* [Second Phase/Studyhouse] in upper secondary education (students aged 16-18) in 1998-1999. In particular, the Second Phase involved a radical modernization of the curriculum: examination programs were revised for all subjects, two new compulsory subjects were added (for all students), including the subject *Algemene Natuurwetenschappen (ANW)* [Science, Technology, and Society], and subjects were clustered into four different 'curriculum profiles' (Culture & Society, Economy & Society, Science & Technology, and Science & Health) to prepare students for higher education in a more focused way. In addition, the Studyhouse aimed at a change in pedagogy and organization of teaching and learning by emphasizing activity-based and self-regulated learning, a variation in resources and environments for learning, the development of higher-order skills, and a shifting teacher role from instructor to coach/facilitator of learning (Terwel, Volman, & Wardekker, 2003; Van den Akker, 2003). In 2000-2001 and 2007, the Second Phase was revised. For example, in 2007 the number of subjects per curriculum profile changed and the subject *Natuur, Leven en Techniek (NLT)* [Nature, Life, and Technology] was introduced as a new and optional subject forming part of the curriculum profiles 'Science & Technology' and 'Science & Health' (Huijssoon, Van Tooren, & Groenewegen, 2007).

With regard to Dutch secondary physics education, a proposal for revising the curriculum for senior general secondary education [*havo*] and pre-university secondary education [*vwo*] was presented in 2006. In a document called *Natuurkunde leeft* [Physics is alive], the following three statements were formulated to express the main intentions of the future examination program of Dutch secondary physics education: 1) teaching and learning physics content in a meaningful context in which aspects of modern physics and technology (both as a scientific research field and profession) play an important role, 2) paying attention to the connections between physics and other science subjects, such as chemistry, biology, and mathematics, and 3) a flexible curriculum content in which hands-on activities are emphasized (Commissie Vernieuwing Natuurkundeonderwijs havo/vwo [Committee revision physics education], 2006, p. 5). In addition, exemplary curricular modules were developed and piloted (e.g., Van Bemmel, 2010). The overall intention was to make contemporary physics education more engaging and to improve students' preparation for higher education.

The three main intentions expressed in the document 'Physics is alive' lead to a controversy between proponents and opponents, popularly called the *NiNa versus LeNa (Nieuwe Natuurkunde versus Leerbare Natuurkunde)* [New Physics versus Learnable Physics] debate. For example, the opponents (LeNa) formulated 18 statements and distributed these at the national *Woudschoten* physics conference in 2009. The main arguments of the LeNa camp were that 1) the image of physics is not enhanced by a trendy examination program but by enthusiastic teachers who are aided by efficient instructional means and supplies, 2) the task of the NiNa-committee was only to revise the examination program and that they were not entitled to prescribe a new pedagogy of teaching physics (e.g., by stating that physics should be taught in meaningful authentic contexts), and 3) there is a huge risk of students getting bored or frustrated by the new NiNa examination program, due to the lack of coherence between the various curricular modules and the committee's premature thoughts about how to teach (compulsory) content (Biezeveld, 2009). Proponents at the NiNa side agreed with the first two arguments of LeNa. However, with regard to the third argument, they emphasized that the curricular modules together with the proposed pedagogy were in the state of being piloted and evaluated (Van Weert & Pieters, 2009), which meant that they thought there was not enough evidence yet to support such a firm conclusion.

On June 6th, 2012 the content of the new physics examination programs for senior general secondary education [*havo*] and pre-university secondary education [*vwo*] was established by the Dutch government and it was decided that these programs would be introduced at the schools in summer 2013 (De Minister van Onderwijs [The minister of education], 2012). The examination programs contained a description of the various content domains with an overview of important skills and conceptual knowledge to be assessed. However, with regard to the 'NiNa versus LeNa' debate, an official statement concerning the 'appropriate' pedagogy of making physics engaging and comprehensible for secondary students failed to appear. The government expected the schools and teachers themselves to take responsibility for deciding what pedagogy of teaching and learning physics was most appropriate.

1.3.3 Physics teachers' beliefs about teaching and learning physics

In the daily practice of physics education, teachers' beliefs play an important role in shaping teachers' instructions and providing learning opportunities for students. In this respect, teachers' beliefs about teaching and learning in general and their domain-specific beliefs are deemed important (Richardson, 1996; Stipek, et al., 2001; Thompson, 1992). Instructional decisions such as determining specific lesson objectives, selecting particular content, and choosing 'appropriate' teaching and learning activities are, to a greater or lesser extent, influenced by teachers' beliefs about 1) *the pedagogy of teaching and learning physics*, 2) *the goals of physics education*, and 3) *the nature of physics and science* (because physics is part of the domain of science).

First, in this dissertation the word 'pedagogy' concerns the interplay between teaching and learning; it indicates the fact that "teaching influences learning and learning influences teaching" (Loughran, 2010, p. 36). Teachers' beliefs about the pedagogy of teaching and learning physics refer to opinions about 'what' students are learning and 'how' they are learning. The NiNa versus LeNa debate in the context of Dutch physics education (see section 1.3.2) suggests that teachers might differ in their beliefs about what content should be taught, what instructional activities contribute to the comprehensibility of physics content, and what effective ways there are for motivating secondary students to learn the content. These beliefs are possibly related to the more general goals of physics curricula (e.g., 'learning physics', 'doing physics', and 'learning about physics' (cf. Hodson, 1992)). Moreover, there might be relations between these beliefs and teachers' *conceptions of learning*. According to Meirink and colleagues (2009), beliefs about learning can often be characterized by one of two different conceptions, namely 'learning as acquisition' (involving the mastery of new knowledge and skills) and 'learning as construction/participation' (involving students' active construction of knowledge by making sense of the world and conducting teaching and learning activities in a meaningful context) (cf. Scott, Asoko, & Leach, 2007). Furthermore, since the Dutch curriculum reform called 'Second Phase/Studyhouse' (see section 1.3.2) promoted self-regulated learning, it is reasonable to expect that teachers hold *beliefs about the regulation of students' learning processes*. For example, some teachers might value teacher-regulated teaching and learning activities over shared regulation (i.e., regulation by both teacher and students) or student-regulated activities, and vice versa (cf. Oolbekkink-Marchand, 2006).

Second, although the goals of physics education are often explicitly stated in examination programs and physics curricula, teachers hold personal beliefs about the goals of education in terms of general development and schooling (Van Veen, et al., 2001). For instance, some teachers focus on the transmission of knowledge and skills to ensure that students are qualified for further education, whereas others focus on guiding students to adulthood and preparing them for participating in a democratic society (Denessen, 1999). Besides these *beliefs about the goals of education in general*, teachers often have a particular intent or purpose in teaching content. They "not only want their students to learn specific subject matter, but also aim at more general science [physics] learning goals that lie beyond the subject itself" (Van Driel, Bulte, & Verloop, 2008, p. 108). These domain-specific beliefs are called *curriculum emphases* and "provide an answer to the student question: 'Why am I learning this?" (Roberts, 1982, p. 245 cited in Van Driel et al., 2008).

Third, in the process of teaching and learning physics, both teachers and students are confronted with the complex web of physics concepts and the evolving nature of conceptual physics knowledge. As a result, teaching and learning physics involves a particular way of investigating and thinking about the world (Hodson, 1992). The personal ideas teachers have, particularly about the *nature of physics* and, in the broader context, the *nature of science* (cf. Jones & Carter, 2007), are either explicitly conveyed to students or implicitly inform teachers' instructional decisions (Matthews, 1994). As a consequence, these beliefs might influence what students learn about the status of scientific knowledge claims, the aims and purposes of scientific inquiry, the nature of scientific methods, and so on. According to Lederman (2007), some teachers hold 'naïve' beliefs about the common aspects of the nature of science, whereas the beliefs of others are more 'informed/sophisticated'. '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 aspects of the nature of science, 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 embedded in a social and cultural context (Abd-El-Khalick & Lederman, 2000; Akerson & Hanuscin, 2007). Even though it is worthwhile to know more about the content of teachers' beliefs about the nature of physics and science in itself, still little is known about whether and in what way beliefs about the nature of physics and science are related to each other and to other beliefs, as about the pedagogy of teaching and learning physics.

1.4 OUTLINE OF THE DISSERTATION

1.4.1 Main aim of the research

This dissertation reports on four studies that were conducted among physics teachers teaching in secondary education (students aged 12-18) in the Netherlands. The main aim of these studies was twofold: 1) Gaining more insight into the content of teacher belief systems by investigating teacher beliefs about the *pedagogy* of teaching and learning physics, the *goals* of physics education, and the *nature of physics and science* (because physics is part of the domain of science), and 2) Exploring the structure of teacher belief systems by investigating the relationships between particular types of beliefs. Besides this main aim, one of the four studies explored to what extent teacher beliefs are reflected in teaching intentions, in an attempt to gain more insight into the complicated relationship between beliefs and the practice of teaching. The overall research question was: *What is the content and structure of physics teachers' belief systems with regard to teaching and learning physics?*

1.4.2 Overview of the studies including design and research questions

In an attempt to enhance the readability of this dissertation, it was decided to present the studies in a logical rather than sequential (chronological) order.

Study 1 (Chapter 2)

Study 1 focused on the content and structure of teachers' beliefs about the *goals* and *pedagogy* of teaching and learning physics. A small-scale semi-structured in depth interview study was conducted to explore beliefs about making physics comprehensible and about specific ways to motivate students to learn the content. Participants were selected by purposeful sampling. Besides experienced physics teachers (N=4), the sample included physics teacher educators (N=4), to investigate the full range of those beliefs, which play an important role in teaching and learning physics. Data were collected in December and January, 2008/2009 and were analyzed via an iterative process by qualitative methods.

Study 1 was guided by the following three research questions:

1. What are physics teachers' and physics teacher educators' beliefs about a) *making the subject of physics comprehensible* for secondary students (aged 12-18) and b) *specific ways to motivate these students* to learn the content?
2. What goals of physics education (i.e., 'learning physics', 'doing physics', and 'learning about physics' (cf. Hodson, 1992)) are reflected in the beliefs mentioned in 1?
3. What *types of regulation* were expressed in the beliefs mentioned in 1?

Study 2 (Chapter 3)

Study 2 focused on teachers' beliefs about the *pedagogy* of teaching and learning physics as well as their beliefs about the *goals* of physics education. A survey study (N=126) was conducted in March 2011 to investigate the content of teachers' beliefs about learning and the regulation of students' learning processes, their beliefs about the goals of education in general, and teachers' curriculum emphases. It was assumed that these beliefs were rather explicit and consequently easy to access and that teachers would have (strong) preferences concerning, for example, particular goals and types of regulation. Therefore, the choice was made to use (adapted versions of existing) questionnaires to measure these beliefs. The content and structure of these beliefs were analyzed by quantitative methods such as two-way ANOVAs, computation of bivariate Pearson correlations, and hierarchical cluster analysis.

Study 2 was guided by the following research questions:

1. What is the content of physics teachers' 1) *beliefs about teaching and learning in general* (i.e., orientation towards instruction as well as the goals of education, and beliefs about learning and the regulation of students' learning processes) and 2) *domain-specific beliefs* (i.e., curriculum emphases in teaching physics)?

2. What relations and/or patterns can be identified between the beliefs mentioned in 1?

Study 3 (Chapter 4)

Study 3 focused on the content and structure of teachers' beliefs about the nature of science. The literature on beliefs about the nature of science reports on many small-scale interview studies with only questions about consensus aspects of the nature of science. In an attempt to obtain a more generalized picture of the content and structure of teachers' beliefs about the nature of science, it was decided to conduct an investigation at a large scale. Therefore, a questionnaire was developed by using contrasting ideal types derived from the philosophy of science. Data were collected by conducting a large-scale survey study (N=299) in March 2010 among physics teachers at secondary schools (students aged 12-18). Data were analyzed by quantitative methods such as Principal Axis Factoring, computation of bivariate Pearson correlations, and hierarchical cluster analysis. However, one of the assumptions was that teachers' beliefs about the nature of science were more tacit than, for example, their beliefs about the pedagogy of teaching and learning physics or the goals of physics education. For this reason, a follow-up study (study 4) was planned to enable triangulation with qualitative data.

Study 3 was guided by the following research question:

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

Study 4 (Chapter 5)

Study 4 focused on the content and structure of teachers' beliefs about 1) the *pedagogy* of teaching and learning physics, 2) the *goals* of physics education, and 3) the *nature of physics and the nature of science (NOS)*. Moreover, this study included an exploration of the extent to which these beliefs were reflected in particular teaching intentions. Three physics teachers were selected by purposeful sampling, representing the three different clusters of teachers with similar NOS beliefs identified in Study 3. Structured interviews were conducted in February 2011. The interview format contained a series of open-ended questions (partly derived from an existing and validated instrument to measure teachers' beliefs about the nature of science) and an assignment in which the teacher was asked to design a 50-minute lesson to introduce physics to secondary students (aged 12-14). The choice to focus on an introductory physics lesson was based on the assumption that this type of 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 science. The assignment was not only used to investigate a teacher's intentions but also to further discuss a teacher's beliefs about the nature of physics and science, the goals of physics education, and the pedagogy of teaching and learning physics. Data were analyzed via an iterative process that started with open coding, followed by the discussion of similarities and differences in teachers' beliefs and intentions until consensus was reached.

Study 4 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?

General conclusions and discussion (Chapter 6)

In the last chapter, the main conclusions of the four studies are summarized and discussed in relation to the overall research question. In addition, this chapter contains theoretical implications and suggestions for further research on teacher beliefs, and in a broader sense, teachers' practical knowledge, as well as practical implications for teaching physics, teacher education, and professional development programs.

An overview of the four studies including information about focus (beliefs) and a timeline of data collection is provided in Figure 1.1.

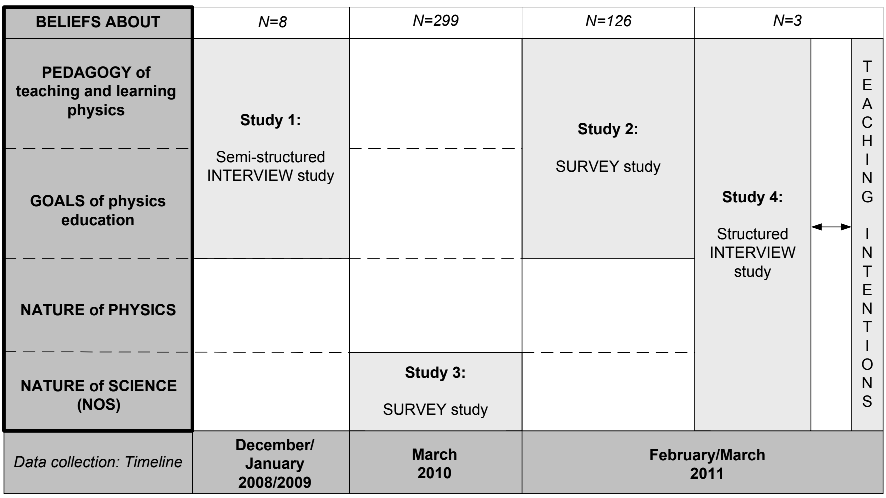

Figure 1.1. Overview of the four studies that were conducted to investigate the content and structure of physics teachers' belief systems

Chapter 2

An exploration of teacher beliefs about making physics comprehensible, motivating students, and different types of regulation: An interview study[1]

1 This chapter has been submitted for publication in an adapted form as:

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An exploration of teacher beliefs about making physics comprehensible, motivating students, and different types of regulation: An interview study

ABSTRACT

This chapter aims to explore the range of teacher beliefs about making physics comprehensible and motivating secondary students (aged 12-18) to learn physics content. After purposeful sampling, semi-structured interviews were conducted with physics teachers (N=4) as well as physics teacher educators (N=4) in the Netherlands. An iterative process of data analysis focused on the content of these beliefs related to the goals of physics education (i.e., 'learning physics', 'doing physics', and 'learning about physics'). In addition, data were coded on the types of regulation (teacher-regulation, regulation by both teacher and students, and student-regulation) that were reflected in the expressed beliefs. Results showed no sharp contrast between beliefs about making physics comprehensible and motivating students in relation to the goals of 'learning physics' and 'doing physics'. However, with regard to the goal of 'learning about physics', beliefs about making physics comprehensible referred to learning about the nature of physics knowledge and scientific methods, whereas beliefs about motivating students were associated with learning about interactions between physics, technology, and society. Another main finding was that the sample could be divided into two groups based on the types of regulation that were expressed in their beliefs. Half of the sample expressed only beliefs about teacher- and shared-regulated learning whereas the other half also expressed beliefs about student-regulation. The discussion focuses on the relations between the content of these beliefs, the goals of physics education, the types of regulation, the conceptions of learning, and concludes with instructional guidelines for secondary physics education.

2.1 INTRODUCTION

The image of secondary physics and science education has been problematic for the past two decades. All over Europe, the declining interest in science among young students has received policy maker's undivided attention (Rocard et al., 2007). Although students are interested in science itself (Osborne, Simon, & Collins, 2003) and are convinced of the importance of science and technology for society (Matthews, 2007), many of them lose interest due to the way science is taught. Students often perceive science education as limited; for instance, the content of school assignments differs significantly from students' own intrinsically motivated scientific questions (Aikenhead, 2007; Baram-Tsabari, Sethi, Bry, & Yarden, 2006; Rocard, et al., 2007). Moreover, students associate science subjects (e.g., physics) with such image aspects as masculinity and complexity (Kessels, Rau, & Hannover, 2006). As a consequence, many attempts have been made to solve the problem by developing and implementing new curricula or lesson series which emphasize the connections between science, technology, and society (Aikenhead & Ryan, 1992), or by introducing a context-based approach to teaching science (e.g., Bennett & Holman, 2002). At the same time, it is becoming more and more clear that students' enjoyment of science subjects is highly affected by science teachers' teaching behaviour (Darby, 2005; Zacharia, 2003), so that there is increased attention among researchers for the role of science teachers (Osborne, Simon, et al., 2003).

The way teachers teach their subject is related to, among other things, their beliefs. According to Pajares (1992) these beliefs play a critical role in organizing knowledge and information, as well as defining and understanding (student) behaviour. Moreover, beliefs are organized into a system: knowledge and beliefs are inextricably intertwined and beliefs are prioritized according to their relations with other beliefs or with other affective and cognitive structures. This means that some beliefs function as peripheral beliefs, and others as priorities or core beliefs (Brownlee, et al., 2002). When it comes to teaching behaviour, in particular beliefs about teaching and learning in general, epistemological and domain-specific beliefs are deemed important (Richardson, 1996; Stipek, et al., 2001; Thompson, 1992). For that reason, some studies have been conducted on teachers' beliefs about the goals of teaching science and the characteristics of instruction (Magnusson, Krajcik, & Borko, 1999), or on teachers' personal epistemologies about knowing and their conceptions of the nature of science (Kang, 2008; Lederman, 1992). Other research focused on the relations between different types of beliefs. Van Driel and colleagues (2007), for example, explored both teachers' general educational beliefs and their domain-specific beliefs from the perspective of curriculum emphases; in addition, Henze and Van Driel (2006) investigated the relationship between experienced science teachers' general educational beliefs and their subject-specific cognitions in the context of educational innovation.

In this study we explored physics teachers' beliefs about the goals and pedagogy of secondary physics education (students aged 12-18). We focused on their beliefs about making the subject comprehensible for students and specific ways to motivate them to learn the content. We have chosen to focus on the subject of physics because it is particularly this subject that many students associate with negative image aspects (Kessels, et al., 2006).

2.2 LITERATURE REVIEW

As mentioned above, this study focuses on teachers' beliefs about the goals and pedagogy of physics education. According to Loughran (2010), the word *pedagogy*, interpreted in line with the European tradition, concerns the interplay between teaching and learning. In other words, it is used to indicate the fact that "teaching influences learning and learning influences teaching" (p. 36). As such, pedagogy involves the following two aspects of learning: 1) it is "associated with what and how students are learning" and 2) it considers "the teacher as a learner", in the sense that teachers are learning about teaching and building their own expertise (p. 37). In this study we will primarily use the word *pedagogy* to refer to the first aspect of learning, i.e., *what* students are learning and *how* they are learning. Beliefs about 'what' students are learning are related to the *goals of physics education*. In addition, beliefs about 'how' students are learning comprise *conceptions of learning in general*, beliefs about *the regulation of students' learning processes*, beliefs about *teaching procedures to enhance students' comprehension of content*, and beliefs about *student engagement and motivation*.

2.2.1 Beliefs about 'what' students are learning

General goals of science education

We discuss the goals of physics education by focusing on the general goals of science education because physics is a sub domain of science. As a consequence, the general goals of physics education are often comparable to those of science education.

Science is characterized by the interplay between scientific concepts, skills and values (Bishop, Clarke, Corrigan, & Gunstone, 2006; Ogborn, 2008; Schulz, 2009). This interplay has been reflected in many science curricula, which often include a focus on understanding scientific *knowledge*, understanding and using scientific *methods*, and promoting *personal-social development* (Bybee & DeBoer, 1994). In line with this, Hodson (1992, pp. 548-549) categorized the goals of science education as: 1) *learning science* (i.e., acquiring and developing conceptual and theoretical knowledge), 2) *doing science* (i.e., engaging in and developing expertise in scientific inquiry and problem-solving), and 3) *learning about science* (i.e., developing an understanding of the nature and methods of science, and an awareness of the complex interactions between science and society).

First, the *learning science* goal is often operationalized in science curricula as learning scientific knowledge such as scientific concepts, laws, theories, and principles. In addition, learning science aims at the understanding of conceptual schemes and the relations between scientific concepts (Bybee & DeBoer, 1994; Hodson, 1992). Second, *doing science* comprises both problem-solving and inquiry. It involves an understanding of the processes and methodologies of the sciences and the application of scientific methods and skills in inquiry and problem-solving activities. In this respect, skills such as analysing and modelling a physical process, applying theory and theoretical concepts to a broad spectrum of problems, hypothesizing, gathering data, logical data-based decision-making, and critical and creative thinking are deemed important (Bybee & DeBoer, 1994; Hodson, 1992; Talisayon, 2008). Third, *learning about science* is associated with learning about the nature of scientific knowledge (including scientific research as a profession) and relations between science and society (e.g., understanding the applications of science in daily life and scientific literacy (cf., Bybee & DeBoer, 1994; Hodson, 1992; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Osborne, Simon, et al., 2003; Sadler, et al., 2010; Weinstein, 2008; Wong & Hodson, 2009, 2010). In general, science curricula provide an overview of those concepts, skills, and values that should be taught to students in view of goals that are considered important by teachers, policy makers, and the educational research community.

2.2.2 Beliefs about 'how' students are learning

Conceptions of learning in general

When it comes to learning science concepts, Scott et al. (2007) claim that the literature shows two fundamentally different perspectives on learning, illustrated by the metaphors of 1) learning as *acquisition* and 2) learning as *participation* (Sfard, 1998 cited in Scott, et al., 2007). This distinction is confirmed and broadened by Meirink and colleagues (2009), who claim that learning is often characterized by three different conceptions: 1) learning as *acquisition*, involving the mastery of new knowledge and/or skills in order to fill gaps in knowledge, 2) learning as *construction*, in which learners are seen as active constructors of knowledge that make sense of the world, and learn by interpreting events through their existing knowledge and beliefs, and 3) learning as *participation*, in which learning and learning activities are considered part of the context in which they take place. Meirink and colleagues suggest that a combination of the latter two conceptions might be helpful in understanding learning.

The regulation of students' learning processes

Essentially, these different conceptions of learning directly pertain to the degree of initiative taken by the students; in learning theories this is often called *regulation* (cf. Pieters & Verschaffel, 2003). During the last two decades, an increasing number of educational researchers have pleaded for *self-regulated learning*, in which students are assumed to be "active participants in their own learning" (Zimmerman, 1994, p. 3 cited in Patrick & Middleton, 2002, p. 27). By providing opportunities for collaboration with peers on tasks, and allowing students to have an active role in the construction of knowledge, by giving them more responsibilities in conducting investigations, asking questions, formulating learning goals, and/or choosing specific strategies for learning (science) concepts, students are expected to display higher levels of motivation and engagement (Koballa & Glynn, 2007; Lombaerts, et al., 2009; Patrick & Middleton, 2002; Schraw, Crippen, & Hartley, 2006). In this process, teachers can have different responsibilities and roles. For instance, a teacher might function as diagnostician, challenger, model learner, activator, monitor, or evaluator (Vermunt & Verloop, 1999). However, it is possible that some teachers mostly value teacher-regulated teaching practices, whereas others are more focused on student-regulated activities or shared regulation (i.e., regulation by both teacher and students) (cf. Meirink, et al., 2009; Oolbekkink-Marchand, 2006).

Teaching procedures to enhance students' comprehension of content

In order to enhance students' comprehension of particular content, teachers have a variety of teaching procedures to choose from. According to Loughran (2010), some of these procedures are related to *building on students' prior knowledge*, whereas other procedures relate to *processing information* and focus on metacognitive thinking skills such as *linking*, *translating*, and *synthesizing* (cf. Vermunt & Verloop, 1999). In the following paragraph these different teaching procedures will be briefly discussed.

Teaching procedures associated with *building on students' prior knowledge* imply that "new entry points to learning are made available to them that invite them to see a way in to the subject so that it makes sense to them" (Loughran, 2010, p. 61). For instance, a teacher might use teaching and learning activities such as the probing of existing views, making a concept map, or brainstorming. The *processing of new information* is enhanced by teaching procedures that assist students in moving beyond "just knowing the information" into "being able to apply it in different ways and situations" (p. 78). It not only requires the student to absorb propositional knowledge (e.g., facts, definitions and formulas), but also asks the teacher to organize information in such a way that it becomes meaningful to students. This can be done, for example, by using question and information grids, analysing pictures and/or models, or asking students to write a short piece on a text they had to read. Teaching procedures that are related to *linking*, such as making mind maps, creating analogies, asking 'what if…' questions, or linking subject matter to real life, aim at "making connections across ideas so that prior knowledge and new knowledge can interact in ways that will further develop a student's understanding of the topic being studied" (p. 91). Procedures associated with *translation* focus on the cognitive manipulation of ideas and information, often presented and learned in one specific form, in order to apply them in a different way and a different setting (p. 104); activities such as making a model, creating a story from a graph or vice versa, or writing your own method might be helpful in this respect. Finally, *synthesizing* concerns "the process of putting all the parts of something together to make up a coherent whole" (p. 125). Students extend their knowledge and make sense of the individual content elements by applying various thinking skills such as analysing, reasoning, and summarizing. For example, teaching procedures such as predicting, learning from a discussion and structured thinking aim at helping students see how different elements of content fit together in a meaningful way.

Student engagement and motivation

The term *student engagement* is often used to indicate that a student is *actively* involved in classroom tasks and activities that facilitate learning (Baker, Clark, Maier, & Viger, 2008). However, the literature shows "little consensus about definitions and contain substantial variations in how engagement is operationalized and measured" (Appleton, Christenson, & Furlong, 2008, p. 370). Although scholars do agree about the multidimensionality of the construct, some propose a two-component model whereas others distinguish three or four components of engagement. According to Appleton and colleagues (2008), models with two components consist of *behavioural* (e.g., effort, positive conduct, participation) and *emotional or affective* engagement (e.g., interest, positive attitude about learning, identification). Some extend these models with a third component, namely *cognitive* engagement, which refers to self-regulation, investment in learning, and the setting of learning goals. Finally, four-component models (e.g., Christenson et al., 2008) differentiate between *academic* (e.g., time on task, homework completion, credits earned toward graduation), *behavioural* (e.g., attendance, voluntary classroom participation, suspensions), *cognitive* (e.g., relevance of schoolwork for future endeavours, self-regulation, value of learning, autonomy, personal goals), and *psychological* engagement (e.g., feelings of belonging or identification, relationships with peers and teachers).

Another theoretical construct that is closely related to student engagement is student *motivation*. However, a comprehensive discussion of the relationship between engagement and motivation, including the diversity of motivational theories, is beyond the scope of this chapter. Roughly speaking, motivation concerns answering the question of 'Why am I doing this?' and refers to the intensity, direction, and quality of one's energies. In this respect, motivation is "necessary, but not sufficient for engagement" (Appleton, et al., 2008, p. 379). In an attempt to increase student motivation teachers have various options. For instance, they could arouse students' interest by conducting activities and experiments that act on their curiosity or that violate their expectations and consequently arouse wonder. In addition, hands-on activities, collaborative learning (e.g., group work), and bringing novelties into the classroom are also indicated as factors that stimulate student motivation (Bergin, 1999; Mitchell, 1993; Stolberg, 2008).

Baker and colleagues (2008) argue that teachers should use classroom management strategies that are characterized by a high level of teacher *support* concurrent with sufficient *structure* to enhance student motivation and engagement. For example, teachers could support students by individual help, motivating and friendly talk, reinforcement, and specific praise. In addition, providing structure, both proactive (e.g., monitoring and reminding) and reactive (e.g., redirection and adjusting the task), is also an effective way to help students engage in learning the content. In this respect, many teachers face the challenge of finding the appropriate balance between support and structure, partly because this is related to the degree of initiative taken by the students.

2.3 RESEARCH QUESTIONS

As mentioned before, this study aimed at exploring physics teachers' beliefs about making physics comprehensible for students and their beliefs about specific ways to motivate students to learn the content. In order to investigate the range of those beliefs, which play an important role in teaching physics, we decided also to include physics teacher educators in our sample. This was because these teacher educators 1) may have more explicit beliefs about the pedagogy of teaching physics subject matter than physics teachers, 2) are often indirectly influential in physics education, since they are educating the next generation of physics teachers, and 3) are often former physics teachers with many years of teaching experience. This study was guided by the following research questions:

1. What are physics teachers' and physics teacher educators' beliefs about a) making the subject of physics comprehensible for secondary students (aged 12-18) and b) specific ways to motivate these students to learn the content?
2. What goals of physics education (i.e., 'learning physics', 'doing physics', and 'learning about physics' (cf. Hodson, 1992)) are reflected in the beliefs mentioned in 1?
3. What types of regulation were expressed in the beliefs mentioned in 1?

2.4 METHOD

In order to gain more insight into the content of different beliefs about making physics comprehensible and specific ways to motivate students, we decided to conduct a small-scale interview study among physics teachers and teacher educators in the Netherlands. We believed the qualitative nature of this study would make it possible to acquire more knowledge about, for example, the reasoning behind different instructional strategies, and the content and/or sequence of specific teaching and learning activities, because teachers and teacher educators had the opportunity to explicate their beliefs.

2.4.1 Data collection

Sample

We selected physics teachers (N=4) and physics teacher educators (N=4) by purposeful sampling, using the following guidelines in order to cover a wide variation of beliefs: 1) both teachers and teacher educators have been teaching physics for at least five years, 2) the sample should include teachers working in senior general secondary education and pre-university secondary education (students aged 12-18), and 3) the sample should include teacher educators appointed at institutes of higher vocational education and universities, teaching pre-service teachers for lower-secondary education (students aged 12-15) and upper-secondary education (students aged 16-18), respectively. After selection, the sample consisted of one female and three male physics teachers working at two different secondary schools; two male teacher educators working at an institute for higher vocational education; and two teacher educators, female and male, both working at a university. The study was conducted in the Netherlands.

Instrument

In order to investigate teachers' beliefs about physics education we developed an interview format with a range of questions about different themes, such as the *physics content* that should be taught (e.g., conceptual and formalized physics knowledge, goals of the curriculum, and knowledge about the nature of physics), *strategies to teach physics*, the role and characteristics of the *student*, the content and focus of *assessment*, and characteristics of the *community* via which teaching and learning physics are enhanced. In formulating questions we used the categorization of a general framework called 'How People Learn', developed by Bransford and colleagues (2005), as a starting point. Moreover, we also formulated some general questions, for instance about the teachers' and teacher educators' main tasks and activities, their priorities and concerns, and their beliefs about the main goals of education. After conducting pilot interviews (N=4) in November 2008, we determined the content of questions for the final script of the interview (Appendix 1).

Procedure

The interviews were conducted in December and January 2008/2009. The setup of the interviews was semi-structured, with a duration ranging from 47 to 83 minutes; the average length was 65 minutes. All interviews were audio taped and fully transcribed.

2.4.2 Data analysis

Data were analysed via an iterative process characterized by the two main phases: 1) selection of those interview fragments that clearly showed teachers' and teacher educators' beliefs about making physics comprehensible for secondary students as well as beliefs about specific ways to motivate them to learn content, and 2) an in-depth analysis of the contents of the selected interview fragments, by coding beliefs on the basis of the three research questions mentioned in section 2.3 of this chapter.

Selection of interview fragments for analysis

The first phase started with a thorough reading of all interview transcripts. We selected those interview fragments in which the teacher or teacher educator expressed beliefs about making physics comprehensible and engaging for secondary students, such as fragments in which the reasoning behind choosing specific instructional strategies or teaching and learning activities was explained, or fragments in which we could identify beliefs about factors that enhance or obstruct student comprehension and/or engagement. All selected fragments were reviewed and discussed with a second researcher until consensus was reached; fragments that did not clearly meet our criteria were excluded from further analysis. This resulted in the selection of 165 interview fragments.

Coding and interrater agreement

In the second phase all selected interview fragments were coded. First, on the basis of the problem definition all fragments received a code for either *belief about making physics comprehensible* or *belief about motivating students*. Second, in line with our first research question, we identified the underlying goals of physics education by coding all fragments in accordance with an adapted version of Hodson's (1992) categorization, namely *learning physics*, *doing physics*, and *learning about physics*. Third, in relation to the second research question, all fragments received a code concerning the type of regulation expressed; we used an adapted version of the codes developed by Oolbekkink-Marchand (2006), consisting of *Teacher-regulation (T)*, *regulation by Both teacher and student (B)*, and *Student-regulation (S)*.

In order to determine the percentage of rater agreement a total of 34 interview fragments was randomly selected (i.e., each fifth fragment from the list of total interview fragments was chosen), and coded independently by two researchers. Next, the results of both raters were compared and discussed in order to find out to what extent the code descriptions might be vague or overlapping. With reference to the coding of beliefs about making physics *comprehensible* and *motivating students*, there was confusion about the code *belief about motivating students*. As a consequence, both researchers decided that this code should refer to beliefs about generally motivating students to learn physics content, and beliefs about factors that enhance positive attitudes of students towards the subject of physics. Second, with regard to the coding of the goals of physics education, it became clear that the codes *learning physics* and *doing physics* were overlapping. As a consequence, it was decided that the code *learning physics* referred to learning and applying conceptual and formal physics knowledge; in other words, to gaining an understanding of those theoretical concepts of physics that are treated in textbooks and/or curricula. The code *doing physics* indicates the development of expertise in problem-solving and scientific inquiry, the development of a scientific attitude by observing and questioning, and the learning of specific skills that are needed for problem-solving and/or conducting inquiry or experiments. Finally, comparison and discussion of the codes for regulation showed up inconsistencies in the interpretation of the code *regulation by Both teacher and student (B)*. Both raters agreed on the decision rule that the code *Student-regulation (S)* should indicate that students are wholly or partly *responsible* for their own learning processes, and that learning activities are conducted at the *student's own initiative*. The code *regulation by Both teacher and student (B)* refers to the situation that the planning, sequence, and content of instruction activities is wholly or partly determined by a *student's ideas and questions and student thinking*.

After reaching consensus about the description of the codes, another 34 interview fragments were randomly selected and independently coded by the same two researchers. After this second round of coding we calculated Cohen's kappa for each of the three coding categories mentioned above. The results were satisfying, namely a Cohen's kappa of .74 (coding of beliefs about *making physics comprehensible* and *motivating students*), .80 (coding of the *goals* of physics education), and .88 (coding of *regulation*), indicating a rater agreement of 85.3%, 89.7%, and 93.8%, respectively. In Table 2.1 an overview of codes and descriptions is presented.

Table 2.1. *Overview of codes and descriptions used to analyse teacher beliefs about making physics comprehensible, motivating students, and the goals of physics education, as well as different types of regulation*

Category	Codes	Description
Beliefs about making physics comprehensible and motivating students	*Making physics comprehensible*	The enhancement of student understanding either by explaining and conveying subject matter to students, or by active knowledge construction.
	Motivating students	The enhancement of students' positive attitudes towards the subject matter of physics by arousing students' interest and/or motivating them to active participation in teaching and learning activities.
Beliefs about the goals of physics education	*Learning* physics	Acquiring and developing conceptual and theoretical knowledge, i.e., formalized knowledge (such as formulas, physics theories, and laws) that can be found in textbooks and physics curricula.
	Doing physics	Engaging in and developing expertise in scientific, systematic inquiry and problem-solving. This includes learning practical skills and/or standardized methods used in scientific inquiry and problem-solving, and the development of a scientific attitude by observing and questioning.
	Learning about physics	Developing an understanding of the nature of physics and physics knowledge, the nature of science and scientific research in the field of physics (e.g., methods, measurements, conducting reliable and valid experiments, etc.), and an awareness of the complex interactions between physics and society, such as the applications of physics knowledge in daily life and/or technology.

Table 2.1. *Overview of codes and descriptions used to analyse teacher beliefs about making physics comprehensible, motivating students, and the goals of physics education, as well as different types of regulation* (continued)

Category	Codes	Description
Types of regulation	*Teacher*-regulation (T)	The teacher is primarily responsible for students' learning processes. Students are expected to work hard and to participate in teacher-directed activities.
	Regulation by *Both* teacher and student (B)	Both teacher and students are responsible for students' learning processes. Students' questions, ideas and reasoning influence and/or determine the content and sequence of learning activities; the teacher is monitoring students' learning processes.
	Student-regulation (S)	Students are primarily responsible for their own learning processes. Students are expected to initiate and monitor their own learning activities.

2.5 RESULTS

In this study, the first two research questions focused on the content of 'beliefs about making physics comprehensible' and 'beliefs about specific ways to motivate students to learn the content' in relation to the three goals of physics education, namely 'learning physics', 'doing physics', and 'learning about physics'. We present an overview of the results in three corresponding tables; thus, Table 2.2 shows the content of all beliefs that were coded as 'learning physics', Table 2.3 presents the beliefs about 'doing physics', and Table 2.4 gives an overview of the beliefs about 'learning about physics'. In each table, the columns represent the responses of both teachers and teacher educators. The second and third columns indicate if a specific belief was expressed in relation to 'making physics comprehensible', whereas the fourth and fifth columns represent beliefs about 'motivating students'. The third research question focused on the types of regulation that were expressed in these beliefs. In this respect, the letters T, B and S refer to 'Teacher-regulation' (T), 'regulation by Both teacher and students' (B), and 'Student-regulation' (S), as mentioned in section 2.4.2 of this chapter. Finally, some letters in the table are marked with a footnote indicator; these numbers correspond to the examples that are discussed in the following sections.

2.5.1 Learning physics

Table 2.2 presents both teachers' and teacher educators' beliefs in relation to the goal of *learning physics* (i.e., learning conceptual physics knowledge). Regarding the content of these beliefs the following two remarks can be made. First, both teachers and teacher educators made a distinction between a) *learning new conceptual knowledge*, i.e., students are confronted with new information (e.g., formulas, theories, concepts) that needs to be connected with prior knowledge, and b) *processing and applying conceptual knowledge*, i.e., students are using and applying the same knowledge in different circumstances (e.g., linking, translation, or synthesizing) in order to master it. Second, in line with the work of Meirink et al. (2009), referred to in

Table 2.2. *Physics teachers' and physics teacher educators' beliefs about 'learning physics'*

Learning physics	Making physics comprehensible								Motivating students to learn physics content							
	Teachers				Teacher educators				Teachers				Teacher educators			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
In the phase of teaching and learning 'new' conceptual knowledge, it is important…																
- to visualize content		T B	T	T												T
- to pay attention to the relevance of the subject matter for students					T	T				T		T	T	T		
- to take students' questions and thinking as a starting point for learning		T			T					T B[2]	B	T			T	
- to take differences in students' learning styles into account	T				T		T			B						
- to take differences in students' competences into account		T					T B							T	B	
- to take a practical or practice as a starting point for learning				T			T							S		T
- to pay attention to the distinction between reality and model	T			B	T[1]											
- that the content is challenging/has a certain level of complexity										T						
- to arouse students' interest										T				B S	T	
- to include hands-on activities in physics lessons													B		B	
- to make use of contemporary modern means											T			T		
In the phase of teaching and learning 'new' conceptual knowledge, it is important that students actively construct knowledge by…																
- working on the basis of a specific problem and/or question				B	S	S[3]							S	B S	T B S	
- conducting a practical and/or observing phenomena				S								B S	T S			T
- taking students' own questions and/or reasoning as a starting point for learning														S		
- collaboration with peers									B							
In the phase of processing and applying conceptual knowledge, it is important that students…																
- conduct a practical or have practical experiences		B				S			B		T				T	
- verbalize content		T B			B		B S[4]									
- repeatedly make assignments			T	T	T											
- actively think and reason					B		T									

T=Teacher-regulated learning B=Regulation by both teacher and students S=Student-regulated learning

The numbers of the footnote indicator correspond to the examples that are discussed in the text.

section 2.2.2, some of the beliefs about 'learning new conceptual knowledge' reflected a conception of learning as '*active construction of knowledge*'. We will now provide some examples from the interviews to illustrate the beliefs listed in Table 2.2.

With reference to beliefs about 'learning new conceptual knowledge', teacher educator 1 stated that it is important to pay attention to the distinction between reality and model, in order to make physics comprehensible (Example 1):

"Look, when physicists don't know the answers – I mean real Physicists, with a capital P – they create a model. That means that some things are ignored, for instance friction caused by the air, and other types of friction. You throw all that out of your model, because it complicates things. Then you play out the model by means of an experiment in a laboratory and you say: 'Hooray! It works!' Your model is correct. But it does not correspond to reality. Well, I admit, it's a little bit exaggerated. Of course, there are a lot of situations for which the model is correct. I think that as a teacher you should point out when reality is imitated and when it is not. And very often, you read: "we will ignore friction…", or "we will ignore this…" or "just pretend that…", but those kids, they are at a stage of life in which they are exploring that world! So, they are absorbing it, and the world is very important to them. And then all of a sudden they have to do physics and they read: 'Yes, but that's not-, you know, let's not imitate reality for a while.' That's just asking for trouble! (*laughing*) So that's a bit difficult with this subject."

Teacher 2 expressed the belief that, in order to motivate students, it is important to take their questions and thoughts as a starting point for instruction (Example 2):

"For example, there was this student talking about carbon monoxide. There had been some cases of carbon monoxide poisoning the weekend before, and it was also in the paper. Well, then you start a discussion about it, because that's fun! They're totally absorbed in it at those moments it's fantastic! Yes, it's really fun, and you're also really chuffed when you see that the students themselves bring it up, it's fantastic!"

Regarding beliefs that reflect a conception of learning as 'active knowledge construction', teacher educator 2 claimed that it is important that students should construct their own knowledge on the basis of a specific problem or question (Example 3):

"The process of working towards that law of nature, that formula, is very important for the development of understanding. And yes, sometimes you need a phase of confusion, or lack of clarity, maybe even frustration, in order to suddenly see: 'Ah, I get it!' 'Yes, and now you understand, so when I give you this formula you'll be able to work with it.' So, to have that clear overview at content level is sometimes difficult, but you could still provide structure on procedural level by saying: 'Look, we're solving this problem, we already know that we are going to find our solution in that area', for example by conducting experiments or by making certain assignments, or you could say 'we need to read some theory first in order to get a better understanding.'"

Finally, most beliefs about 'processing and applying conceptual knowledge' related to making physics comprehensible. For instance, teacher educator 3 stated that it is important that students verbalize the content by explaining it to peers (Example 4):

"So, if you ask a student who does understand the topic to explain the stuff to a student who doesn't get it, they are gaining an even better understanding, because putting the problem into words is slightly different from just understanding it. You also motivate students to go even further: a different skill is required. It's an excellent experience for them to formulate a second time what they've written down before, and to make it transferable. And the information is explained to the other student in accessible language."

2.5.2 Doing physics

Table 2.3 presents teachers' and teacher educators' beliefs about making physics comprehensible and motivating students in relation to the goal of *doing physics*. As mentioned in section 2.2.1 above and in line with the work of Hodson (1992), 'doing physics' comprises both *problem-solving* and *inquiry*. 'Problem-solving' refers to specific problems, both structured and ill-structured, to which students are challenged to find a solution by integrating theory (e.g., formulas) in practice as well as applying existing knowledge and skills (e.g., problem-solving skills or mathematical skills). 'Inquiry' refers to conducting experiments in a scientific way. For instance, a phenomenon is investigated in a systematic way, characterized by different steps and phases, such as hypothesizing, data collecting (e.g., repeated measurements), data analysis, drawing conclusions, and presenting or discussing results. As was the case for learning conceptual physics knowledge, both teachers and teacher educators made a distinction between *learning new skills, methods and knowledge*, i.e., students are confronted with new skills, methods and information, and *training and applying skills, methods and knowledge*, i.e., students are training and applying the same skills, methods and knowledge in different circumstances in order to become skilled and competent. We will now briefly elaborate on the content of the beliefs presented in Table 2.3 by giving some illustrative quotes. Again, the numbers of the footnotes in the table correspond with the numbers of the examples.

With regard to beliefs about problem-solving, the majority of interviewees indicated that it is important to learn specific problem-solving skills and methods in order to make physics comprehensible. For instance, teacher 3 expressed it as follows (Example 1):

"I notice that most students have to cross the barrier of knowing how to solve a problem. I think that's one of the first, major things they should learn in upper-secondary education: knowing, when you are confronted with a problem, what the actual question is. 'How can I set up a specific line of reasoning, supported by formulas, by information derived from BINAS (*i.e.,*

Table 2.3. *Physics teachers' and physics teacher educators' beliefs about 'doing physics'*

Doing physics	Making physics comprehensible								Motivating students to learn physics content							
	Teachers				Teacher educators				Teachers				Teacher educators			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
With regard to problem-solving, it is important that students…																
- learn specific problem-solving skills and methods		T	T[1]	T	T		T									
- learn specific computational and mathematical skills				T												
- memorize basic conceptual knowledge (e.g., formulas)				T												
With regard to the training and application of problem-solving skills, methods, and knowledge it is important…																
- to pay attention to the content/context, the level of complexity, and the definition of problems			T			T S								T[3] S	B	
- that students solve problems in a systematic way and/or by using multiple sources	B						S								B	
- that students solve problems in a collaborative way	B						T				B					
- that students train problem-solving skills and methods by making assignments			T	T[2]		T										
- that students train to apply conceptual knowledge by making assignments						T										
With regard to inquiry, it is important that students…																
- learn specific inquiry skills and methods						T	T B	T B[4]			T	T			T	
- learn to collaborate								T	B			S				
- learn specific practical skills				T			T	T								
With regard to the training and application of inquiry skills, methods and knowledge it is important that students…																
- investigate questions and phenomena in a systematic way by conducting experiments						S	S				B				S	
- conduct inquiry in a collaborative way			B[5]	S	S											
- train different skills by conducting inquiry							B									

T=Teacher-regulated learning B=Regulation by both teacher and students S=Student-regulated learning

The numbers of the footnote indicator correspond to the examples that are discussed in the text.

a textbook containing an overview of important physics formulas), tables and graphs, and so on, in order to solve that problem eventually?' Many students start, let's say, from the other side. They start by looking up a lot of things that turn out to be of no use at all. They start calculating things which they don't know how to fit into the main line of reasoning. In my opinion, well, how shall I put it, the way I see it is: Once students know a general approach to solving a problem, the specific content or topic you teach doesn't matter anymore. (…) So, by demonstrating it, as a teacher, several times; by forcing students at a certain moment to think aloud during the lesson: 'How are you going to handle this problem? Don't immediately start calculations, but start by setting up a line of reasoning. What are the steps we're going to take?' And most of the students will get it sooner or later."

Besides learning specific problem-solving skills and methods, two teachers and one teacher educator also stressed that training these skills and methods via assignments enhances student understanding. This belief is illustrated in the following interview fragment from teacher 4 (Example 2):

"Look, something like constructions, in particular 'forces', is perceived by students as very difficult. (…) They would like to have something comparable to a regular, numerical formula immediately, which gives them that solution (i.e., the value of the resultant force). So, suppose a force has a certain value, they would like to work with that specific value. But, starting by making a diagram with your ruler, in which you only draw vectors and you sketch points of application in dotted lines, and then asking yourself: 'Of what particular force can I calculate the value in order to get the solution?' – that they don't have a clue about. Then, you also sketch this force in the diagram, and finally you start construing. So, in fact, the process towards the solution, that's something they have to start to learn in upper-secondary education. I mean, dividing a solution into different phases, making a plan for how to solve problems. (…) The weaker students really need to be trained in these steps over and over again!"

With regard to particular ways to motivate students, it is also important to pay attention to the type of problems students are confronted with. For instance, teacher educator 2 said (Example 3):

"I think it is very important, and that's what I try to make clear to my pre-service teachers throughout the year, that you have to arouse their interest. You must collect fascinating problems that connect to both students' social world and their competences. So, a problem you tackle must be challenging. It should not be either too easy or too complicated, because in the latter case students are not encouraged to start. And it should deal with something concrete; it must not be something abstract that students have lost touch with."

With reference to beliefs related to inquiry, most teacher educators thought that the comprehensibility of physics is enhanced by learning specific skills and methods. Teacher educator 4, for instance, expressed this belief as follows (Example 4):

"Laboratory activities play a major role in, well, in that scientific way of operating and thinking. They are part of… well, when you're talking about conducting inquiry, we say: 'A student should learn to think about what laboratory activities should be carried out.' When you're talking about regular physics lessons, you could say: 'Well, students should learn to handle essential equipment.' So that, when they are conducting inquiry on their own, they know: 'I can measure it in this and that way with that particular device,' and so on."

Finally, some interviewees emphasized the importance of collaboration between students when they have to conduct inquiry. Teacher 3 indicated (Example 5):

"We create assignments in which students are expected to collaborate and to reflect on this. For example, last year, the practical assignment in upper-secondary education was: 'Find somebody to work with, formulate a research question, find some theory, …' and so on. The students should work together in pairs. (…) So, later on you create groups of four students and they give feedback on each other's work. This way they have learned twice: They learned to collaborate; you know, it should be finished at a certain moment. So they learn to collaborate, not only in planning, but also in giving feedback with respect to content."

2.5.3 Learning about physics

Table 2.4 presents teachers' and teacher educators' beliefs about making physics comprehensible and motivating them to learn the content in relation to the goal of *learning about physics*. In making physics comprehensible, it was considered important for students to learn more about the nature of both physics knowledge and the process of developing physics knowledge. Beliefs about motivating students related to both learning about physics as a research field and/or profession, and the interactions between physics and society. Again, we will illustrate the content of the table with some quotations from the interviews.

Three out of four teachers and one teacher educator expressed the belief that it is important for students to learn about the tentative nature of physics knowledge. Teacher 2 put it as follows (Example 1):

"There is this ongoing development, and there are more and more opportunities to (…) For example: electricity. The actual direction of the power is the other way around. You know, the flow of electrons is in the opposite direction of electric power. They thought the particle was positive (…) I think that's important, you know, it's also part of science teaching, yes, I really think so (…) It's not that fixed, it's relatively certain. We're in an ongoing process to discover more things."

Table 2.4. *Physics teachers' and physics teacher educators' beliefs about 'learning about physics'*

Learning about physics	Making physics comprehensible								Motivating students to learn physics content							
	Teachers				Teacher educators				Teachers				Teacher educators			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
It is important that students learn…																
- about the tentative nature of physics knowledge		T[1]	T	T	T											
- that conceptual knowledge is empirical/derived from experiments		T				S[2]										
- about the accuracy of measurements and the consequences				T												
- that experiments are theory-laden						S										
- about the nature of physics as a research field and/or profession													T B[3]			B
- about physics knowledge development in a social and cultural context										T					T	
- about applications of physics knowledge in daily life										T[4]						

T=Teacher-regulated learning B=Regulation by both teacher and students S=Student-regulated learning
The numbers of the footnote indicator correspond to the examples that are discussed in the text.

Teacher educator 2 believed that learning about the nature of knowledge development, particularly by focusing on the theory-laden aspect of experiments, enhances student understanding. This was illustrated by an example from daily teaching practice (Example 2):

"At a certain moment, the question was asked: 'Does a gas really consist of those specific particles?' Because the model had not been introduced as 'a gas exists of these kind of little particles', but as: 'Suppose a gas behaves in the same way as this collection of little balls' (…) And then, students start thinking about it, like: 'Yeah, suppose it doesn't, then what's the use?' and 'When do I know if gas really behaves like that? Or if it turns out to be different?' Well, at a certain moment, somewhere during the series of lessons, they have to make a prediction, in fact they have to predict the Brownian motion. And then, they see it; they were shown that Brownian motion because we had them look through a microscope, and that's a very, very concise way to bring things home to them when they are learning about the nature of science. All of a sudden, they realize: 'I predicted a phenomenon that I've never seen before, but I predicted it on the basis of the model, and now I actually see it! In that case, some of it must be true!' And that, just getting that feeling, creates an awareness of: 'Oh, so that's how knowledge develops!'"

Regarding motivating students to learn physics, some interviewees stated that it is important to learn about the nature of physics as a research field and/or profession. For instance, according to teacher educator 1 (Example 3):

"I think, the image given off by physics education is, let's say: 'Okay, this is the way it is.' Period. Done. Finished. End of story. Not very dynamic. That's why I say: Have them conduct an experiment without them knowing either what the result will be or how the findings should be explained. That is always a surprise. It shows them that there is a reason for people getting paid to investigate these things!"

Finally, teacher 2 expressed the belief that it is important to learn about the application of physics knowledge in students' daily life in order to make them enthusiastic (Example 4):

"I say to my students: 'You all have a new mobile phone. If you'd like to have a better one next year with more pixels, and more internet options, it is important for those masts to be put up.' I say: 'So we need people with a background in the exact sciences!' (…) That's an example of a way of trying to-, you have to really bring it to the students!"

2.6 CONCLUSIONS AND DISCUSSION

2.6.1 Main conclusions

Beliefs about 'making physics comprehensible' and 'motivating students'

One of the main findings, which provided an answer to research questions 1 and 2, is that we found no sharp contrast between beliefs about 'making physics comprehensible' and 'motivating students' in relation to two of the three goals of physics education, namely *learning physics* and *doing physics*. For example, with regard to the goal of *learning physics*, some teachers and teacher educators expressed beliefs such as 'paying attention to the relevance of subject matter for students', 'taking students' questions and thinking as a starting point for learning', 'working on the basis of a specific problem and/or question', and 'conducting a practical or having practical experiences' in relation to 'making physics comprehensible' whereas others thought these activities were effective ways of motivating students. Likewise, with respect to the goal of *doing physics*, beliefs such as 'solving problems in a systematic way and/or by using multiple sources', 'learning specific inquiry skills and methods', and 'investigating questions/phenomena in a systematic way by conducting experiments' were also found to be beliefs about 'making physics comprehensible' as well as 'motivating students'. However, with regard to the goal of *learning about physics* we found that beliefs about making physics comprehensible primarily concerned aspects of the nature of scientific *knowledge* (i.e., tentative, empirical) and *methods* (i.e., accuracy of measurements, theory-laden experiments) whereas beliefs about motivating students mainly referred to the complex *interactions between physics and society* (i.e., physics as a research field and/or profession, physics knowledge development in a social/cultural context, and applications of physics knowledge in daily life).

Types of regulation that were expressed in teachers' and teacher educators' beliefs

The third research question concerned the types of regulation that were expressed in teachers' and teacher educators' beliefs about making physics comprehensible and motivating students. In other words, we explored the extent to which teachers expressed different beliefs about the degree of initiative taken by the students in learning physics content. Two main findings were derived from the interview data in this respect. First, we found that the sample could be divided into two groups: Half of the sample (i.e., teachers 1, 2, 3, and teacher educator 4) expressed only *two* types of regulation, namely teacher-regulation (T) and regulation by both teacher and students (B). The other half, namely teacher 4 and teacher educators 1, 2, and 3 expressed all *three* types of regulation; thus the beliefs of the latter also reflected student-regulation (S). Second, we did not find clear relations between the different types of regulation and beliefs about either 'making physics comprehensible' or 'motivating students'. Neither did we find clear relations between types of regulation that were expressed and the three goals of physics education, namely *learning physics*, *doing physics*, and *learning about physics*.

The first group of interviewees (i.e., teacher 1, 2, 3, and teacher educator 4) mainly expressed beliefs about teacher-regulated learning (T), in the sense that the teacher is primarily responsible for transmitting and clarifying physics content (*learning physics*), learning new problem-solving and inquiry skills (*doing physics*), or learning about the tentative nature of physics knowledge (*learning about physics*). In some cases they referred to regulation by both teacher and students (B). For example, they explained that the content and sequence of learning activities could depend on students' questions, ideas, reasoning, learning styles, and competences (*learning physics*), that it is important to include collaborative problem-solving activities or inquiry in which students are partly responsible for the way they conduct experiments (*doing physics*), or that students should learn about the nature of physics as a research field and/or profession (*learning about physics*). The beliefs of the second group of interviewees (i.e., teacher 4 and teacher educators 1, 2, 3) reflected student-regulated learning (S). They were primarily in favour of students constructing conceptual physics knowledge by themselves, for instance by solving a specific problem, working on the basis of a particular question, conducting a practical, and observing phenomena (*learning physics*). In this respect, all interviewees of the second group emphasized that the teacher should monitor and guide this process by asking questions or providing 'procedural structure' (i.e., showing students the function and aim of learning activities). Moreover, this teacher and these teacher educators thought it was important for students to solve problems and to conduct inquiry on their own and to show initiative in collaborative learning activities (*doing physics*). Furthermore, teacher educator 2 also expressed beliefs about student-regulated learning in relation to the goal of *learning about physics*; she explained that students should learn from their own experience that conceptual knowledge is empirical and that experiments are theory-laden.

2.6.2 Discussion

Limitations of the present study

Because this was a small-scale study, it is hard to make generalizations about what physics teachers and teacher educators generally believe about 'making physics comprehensible' and 'motivating students', and what types of regulation are preferred in this respect. The results, however, do provide suggestions for future research and implications for practice.

Beliefs related to the goals of 'Learning physics' and 'Doing physics'

The interviewees in the present study differed both in the type and the variety of instructional strategies that they considered to be effective for enhancing the comprehensibility of physics and motivating students. For example, teacher 1 expressed only beliefs about taking differences in students' learning styles into account and the importance of collaborative learning experiences and hands-on activities. In contrast, teachers 3 and 4 expressed beliefs about how to make physics come alive for students, various strategies for practicing knowledge application and skills, and learning about the nature of physics. Likewise, teacher educator 4 mainly expressed beliefs about inquiry and hands-on activities, whereas the other teacher educators also expressed beliefs about what problems are suitable for learning new physics concepts and what specific assignments are appropriate for cognitive processing of knowledge or practicing various skills. Moreover, we noticed that some teachers primarily stressed the importance of 'science process skills' such as problem-solving and inquiry (e.g., teachers 3 and 4); other interviewees mainly talked about 'learning physics' either by student-regulated construction of physics concepts (e.g., teacher educator 2) or by processing and applying conceptual knowledge in teacher-regulated or shared-regulated hands-on activities (e.g., teachers 1 and 2).

A possible explanation for these findings is that there are differences in the content and versatility of both teachers' and teacher educators' instructional repertoire. For instance, some teachers and teacher educators possess a larger variety of instructional strategies to enhance students' comprehension of content compared to others due to differences in years of teaching experience or the content of teacher education and professional development programs. Another explanation is that teachers and teacher educators can differ in their orientations towards teaching physics: some teachers might possibly value the teaching of conceptual physics knowledge over the training of inquiry skills and vice versa (cf. Magnusson, et al., 1999; Wongsopawiro, 2012, p. 47).

Furthermore, the majority of our sample emphasized that the comprehensibility of physics content is particularly enhanced by *practice*. For instance, students should repeatedly make assignments in order to cognitively process conceptual knowledge (e.g., active thinking and reasoning, verbalizing) (cf. Loughran, 2010) and to train problem-solving and inquiry skills (including mathematical skills and the application of formulas). However, some interviewees pointed at the risk of students losing motivation during practice because time, training, and sometimes perseverance is needed to learn both the 'technique' of problem-solving and inquiry and to 'play with' physics concepts (i.e., to gain insight into what physics knowledge is applicable to what situations). For that reason, they stressed the importance of arousing students' interest (for example by making use of contemporary, modern means) and including hands-on activities.

Beliefs related to the goal of 'Learning about physics'

Neither teachers nor teacher educators (in this sample) expressed many beliefs about the goal of *learning about physics*. One possible explanation is that it is not teachers' and teacher educators' main priority to pay attention to aspects of the nature of physics. Another explanation is that they are lacking knowledge about (views on) the nature of science as well as how to include these insights in contemporary secondary physics education (cf. Barrett & Nieswandt, 2010; DeBoer, 2000; Duschl, 2008; Holbrook & Rannikmae, 2007). In addition, there is a chance that teachers and teacher educators are not sure about what instructional strategies are appropriate for teaching about the nature of physics, particularly when practical constraints such as a lack of time, facilities, and supplies are taken into account.

Because we found that the teacher educators in this sample did not express many beliefs in relation to *learning about physics*, there is a chance that this goal is not regularly or explicitly taught at contemporary physics teacher education. Therefore, it would be worthwhile to investigate teachers' beliefs about whether contemporary physics teacher education and professional development programs offer sufficient (instructional) tools for creating a balanced curriculum in relation to the different goals of *learning physics*, *doing physics*, and *learning about physics* (cf. Osborne & Dillon, 2008). Finally, it would be interesting to explore the relations between teachers' personal beliefs about the nature of science and beliefs about what aspects of the nature of science should be taught to secondary students (cf. Lederman, 2007; Weinstein, 2008).

Types of regulation, conceptions of learning in general, and student engagement

One of the main findings of the present study is that half of the sample expressed beliefs about student-regulated learning and the other half did not. This finding suggests that the interviewees held different conceptions of learning in general. In line with Meirink et al. (2009), the conceptions of the first group (whose beliefs reflected teacher-regulation and regulation by both teacher and students) could be characterized by the metaphor of 'learning as acquisition', whereas the second group (who expressed all three types of regulation including student-regulation) seemed to hold the conception of 'learning as construction/participation' (cf. Scott, et al., 2007). However, we emphasize that all interviewees expressed beliefs about the importance of teacher-regulated and shared-regulated activities, regardless of the possible differences in their conceptions of learning. This finding supports the notion of Vermunt and Verloop (1999) that teachers can have different roles and responsibilities with regard to students' learning processes (e.g., they might function as challenger, diagnostician, activator, evaluator, and so on).

As expected all teachers and teacher educators strived for students' positive conduct and active participation; they expressed beliefs about the importance of arousing students' interest as well as trying to stimulate them to adopt positive attitudes about learning. However, the second group of teachers, which expressed beliefs about student-regulated learning, reported that is was important to pay attention to the relevance of schoolwork for students' future endeavours and that students should set their own learning goals. In this respect, it seems that all interviewees referred, to a greater or lesser extent, to 'behavioural', 'emotional/affective', and 'cognitive' student engagement (cf. Appleton, et al., 2008). A possible explanation for the differences found in beliefs about the regulation of students' learning processes is that these beliefs are coloured by implicit assumptions about students' levels of development. For instance, in line with the work of Schraw et al. (2006), some teachers might assume that their students learn best by modeling ('observational' level) or social guidance and feedback ('imitative' level), whereas others might think that their students are able to function at a 'self-controlled' or 'self-regulated' level.

Implications for secondary physics education

To conclude this chapter, we summarize the beliefs that were expressed in relation to both 'making physics comprehensible' and 'motivating students', into the following five instructional 'guidelines' for secondary physics education (cf. Bergin, 1999; Mitchell 1993): 1) *letting students conduct inquiry and hands-on activities* (e.g., taking a practical or an experiment as a starting point for learning new conceptual knowledge, observing phenomena and having practical experiences to learn and process conceptual knowledge, learning specific inquiry skills, and learning about physics as a research field and profession), 2) *letting students solve challenging and carefully selected problems* (e.g., working on the basis of a specific problem or question to learn new conceptual knowledge, paying attention to the context and complexity of problems, and systematic problem-solving by using multiple sources), 3) *trying to make (abstract) physics content come alive for students* (e.g., visualizing content, paying attention to the relevance of subject matter for students, making use of modern means and applications of physics knowledge in daily life, and learning about physics knowledge development in a social/cultural context), 4) *letting students collaborate with peers* (e.g., collaborative learning of new conceptual knowledge, solving problems in a collaborative way, and learning to collaborate in inquiry), and 5) *taking the diversity of students and their personal characteristics into account* (taking students' own questions and reasoning as a starting point for learning new conceptual knowledge, taking students' learning styles and competences into account while learning new knowledge, and assuring that physics content is challenging and has a certain level of complexity).

Besides these guidelines, the most important factor is clearly the teacher. Teachers who are dedicated to helping students get the best from their minds play a crucial role in making the subject of physics comprehensible and engaging. "After all, what people enjoy most is finding they can comprehend what they thought they couldn't" (Hewitt, 2011, p. 416).

Chapter 3

Beyond the dichotomy of teacher- versus student-focused education: A survey study on physics teachers' beliefs about the goals and pedagogy of physics education[2]

2 This chapter has been submitted for publication in an adapted form as:

Belo, N.A.H., Van Driel, J.H., Van Veen, K., & Verloop, N.
Beyond the dichotomy of teacher- versus student-focused education: A survey study on physics teachers' beliefs about the goals and pedagogy of physics education

ABSTRACT

This chapter aims to explore the content and structure of physics teachers' beliefs on teaching and learning in general in relation to their domain-specific beliefs, which has hardly been explored. A questionnaire was administered to a sample of 126 Dutch secondary school teachers in physics and measured beliefs about teaching and learning physics in secondary education (students aged 12-18) in the Netherlands. The questionnaire measured beliefs about teaching and learning in general (i.e., orientation towards instruction and beliefs about learning and the regulation of students' learning processes) and domain-specific beliefs (i.e., curriculum emphases in teaching physics). The results of this study showed that physics teachers' beliefs about the goals of education in general (i.e., orientation towards instruction) and beliefs about the goals of physics education (i.e., curriculum emphases) formed an interrelated belief system consisting of both content-oriented and student-oriented beliefs. Moreover, teachers agreed with the importance of both teacher-regulated and student-regulated learning. As a result, we argue that labels such as 'teacher-focused' and 'student-focused', which are often used in the educational literature, might be inappropriate for describing differences in teachers' belief systems and instructional practices.

3.1 INTRODUCTION

In the daily practice of teaching, beliefs play a significant role in shaping teachers' instructions. Beliefs about teaching and learning in general, as well as domain-specific beliefs, are deemed especially important in this respect (e.g., Richardson, 1996; Stipek, et al., 2001; Thompson, 1992). According to Jones and Carter (2007), teachers hold a complex web of attitudes and beliefs that influence more or less every aspect of teaching, "including knowledge acquisition and interpretation, defining and selecting instructional tasks, interpreting course content, and choices of assessment" (p. 1067). For this reason, teacher beliefs are examined with regard to a wide array of topics, such as teaching and learning (Meirink, et al., 2009), classroom management (Weinstein, 1998), the nature of knowledge and knowing (Hofer & Pintrich, 1997), and educational reforms (Luttenberg, Van Veen, & Imants, 2011).

According to Pajares (1992), beliefs are organized into a system: "beliefs are prioritized according to their connections or relationship to other beliefs" and "the filtering effect of belief structures ultimately screens, redefines, distorts, or reshapes subsequent thinking and information processing" (p. 325). Thus, in order to understand the specific role of beliefs in shaping teachers' instructional practices, we need to acquire insight into both content and structure of teachers' belief systems. Until now, empirical studies of teacher beliefs have mainly focused on one specific type of belief, for example about teaching, learning and instruction in general (e.g., Boulton-Lewis, 2001); epistemological beliefs (e.g., Duell & Schommer-Aikins, 2001); or domain-specific beliefs, such as (in the domain of science education) teachers' curriculum emphases (e.g., Van Driel, et al., 2008).

Some studies focused on belief structures by investigating relationships between different types of beliefs. However, the literature reports on findings that are not always in line with each other: Some studies found consistencies in teachers' belief systems whereas other studies showed that individual teachers held mixed and divergent beliefs. For example, Tsai (2002) studied science teachers' beliefs about teaching, learning, and science (N=37). He found that the majority of teachers held not only 'traditional' beliefs about teaching (e.g., "science is best taught by transferring knowledge from teacher to students") but also 'traditional' beliefs about learning (e.g., "learning science is reproducing knowledge from credible sources"). In addition, other teachers held 'constructivist' beliefs about both teaching and learning (e.g., "science is best taught by helping students construct knowledge" and "learning science is constructing personal understanding", respectively). Because many teachers were consistent in their beliefs, Tsai concluded that teachers' belief systems could be seen as *nested epistemologies*. In another study, Van Driel, Bulte, and Verloop (2007) explored the relationships between chemistry teachers' general beliefs about teaching and learning on the one hand and their domain-specific curricular beliefs (i.e., curriculum emphases) on the other. They identified two different belief structures, namely a combination of 1) subject-matter oriented educational beliefs and a 'fundamental chemistry' curriculum emphasis (i.e., the opinion that theoretical chemistry concepts should be taught first in order to provide a basis for understanding the natural world and students' future education) and 2) learner-centred educational beliefs and a 'chemistry, technology, and society' curriculum emphasis (i.e., the idea that technological and societal issues should play an explicit role within the chemistry curriculum). A large-scale study by Seung and colleagues (2011) on elementary pre-service teachers' beliefs about teaching and learning science (N=106) showed that many of the participants had both traditional and constructivist views. Furthermore, two teachers in the study of Tsai (2002) held 'divergent' beliefs (i.e., 'process' beliefs about teaching and 'constructivist' beliefs about learning science and vice versa). Finally, Bryan's (2003) study on one pre-service elementary teacher's belief system revealed that this system included 'foundational' beliefs (i.e., more central beliefs) and 'dualistic' beliefs. The foundational beliefs referred to the value of science and science teaching, the goals of science instruction and nature of scientific concepts, and control in the science classroom. The dualistic beliefs were about how children learn science, the students' role in science instruction, and the teacher's role in science instruction. According to Bryan, these dualistic beliefs formed two sets of compatible and intricately related beliefs.

Until now, however, little is known about the relations between different types of beliefs within a teacher's belief system. Therefore, the aim of this study is to explore the content and structure of teachers' beliefs about teaching and learning in general and their domain-specific beliefs. The present study was conducted in the context of Dutch secondary physics education (students aged 12-18).

3.2 THEORETICAL FRAMEWORK

3.2.1 Research on teacher beliefs

Research on teacher beliefs is complicated due to a lack of consensus about appropriate definitions of the construct of 'beliefs' as well as different perspectives on the relationship between knowledge and beliefs (Jones & Carter, 2007; Pajares, 1992). In general, scholars agree that teacher beliefs are organized into larger belief systems. In these systems, beliefs are related not only to other beliefs but also to cognitive and affective constructs such as self-efficacy, epistemologies, attitudes, and expectations (Jones & Carter, 2007; Lombaerts, et al., 2009; Pajares, 1992). Furthermore, some beliefs function as priorities or core beliefs, whereas others are more peripheral (Brownlee, et al., 2002; Hofer & Pintrich, 1997; Keys, 2003). In the literature teacher beliefs are sometimes distinguished from teacher knowledge (e.g., Den Brok, 2001), but this distinction remains somewhat arbitrary since in the mind of a teacher knowledge and beliefs are intertwined (Keys, 2003; Lombaerts, et al., 2009; Meijer & Van Driel, 1999; Pajares, 1992; Verloop, et al., 2001).

Another factor that enhances the complexity of research on teacher beliefs is the 'fact' that beliefs are often tacit (Pajares, 1992; Thompson, 1992). This means that teacher beliefs must be inferred, for example, by taking into account the congruence of teachers' belief statements, the intentionality to behave in a predisposed manner, and the actual behavior related to the belief in question (Kagan, 1990; Lombaerts, et al., 2009).

3.2.2 Assumptions about teacher beliefs

In the present study on teachers' beliefs about teaching and learning physics, we use the reviews of Pajares (1992) and Jones and Carter (2007) together with the work of Richardson (1996) and Calderhead (1996) to formulate some fundamental assumptions about teacher beliefs. These assumptions refer to the *stability*, *organization*, and *functionality* of teacher beliefs:

- Beliefs about teaching and learning (in general) are well established by the time (pre-service) teachers enter teacher education and start their educational careers. As a consequence, teacher beliefs tend to be relatively stable and resistant to change. This is particularly true for teachers with many years of teaching experience. In contrast, pre-service and novice teachers' beliefs seem less resistant to change. Moreover, limited pedagogical and content knowledge may hinder a change of teachers' beliefs (*stability*).
- Teacher beliefs are part of larger belief systems. These systems contain *beliefs about teaching and learning in general* (e.g., conceptions of learning and beliefs about a range of topics such as the regulation of students' learning processes, goals of education, the nature of knowing and knowledge development, assessment, and so on) and *domain-specific beliefs* (e.g., beliefs about the nature of the subject, curricular goals, instructional strategies for teaching particular content, and so on) (*organization*).
- Teacher beliefs play a key role in knowledge interpretation and cognitive monitoring. The processing of new information is mediated by these beliefs because they function as perceptual filters. Moreover, beliefs serve as mental exemplars for constructing and evaluating teachers' own teaching practices (*functionality*).

3.3 LITERATURE REVIEW

3.3.1 Research on science teachers' beliefs about teaching and learning science

Metaphors to describe teachers' beliefs about teaching and learning in general

In the domain of science education, research on teachers' beliefs about teaching and learning science reveals that these beliefs comprise a wide array of topics. For instance, Simmons and colleagues (1999) found that beginning science (and mathematics) teachers hold a range of beliefs about how to interact with subject content and processes, what activities to employ in the classroom, what teaching is all about, and how they perceived themselves as classroom teachers.

In order to explore these beliefs and the assumptions that teachers apply to their teaching practices, *metaphors* have proved to be useful (Jones & Carter, 2007). For example, Buaraphan (2011) investigated beginning teachers' beliefs about teaching and learning science in Thailand (N=110). He found that the participants mostly used the following four metaphors to express their *beliefs about teaching and learning in general*, namely the teacher as a 'nurturer/cultivator', 'knowledge provider', 'superior authoritative figure', and 'cooperative, democratic figure'. The metaphor of 'nurturer/cultivator' represents the belief that a teacher should nourish students' potential capabilities within a caring environment because the student is a developing organism and learning occurs when students develop at their own pace. The 'knowledge provider' metaphor refers to the opinion that a teacher should transmit knowledge to students because learning occurs when students, as passive recipients of knowledge, accumulate this knowledge. The metaphor of the teacher as a 'superior, authoritative figure' reflects that idea that a teacher should control the learning process because learning occurs when students follow instruction and obey the teacher. Finally, the 'cooperative, democratic figure' metaphor represents the belief that a teacher should coordinate the learning activities in the classroom in such a way that students, as active participants in the community of practice, could learn in a process of collaborative knowledge construction (together with the teacher).

Science teachers' beliefs about teaching and learning science

The four metaphors seem to reflect the findings of other studies on teacher beliefs about teaching and learning science. For instance, Yerrick & Hoving (2003) conducted a study among 32 pre-service earth science teachers and found that they viewed teaching primarily as 'disseminating facts'. In addition, Markic and Eilks (2012), following the quantitative and qualitative data of 36 physics pre-service teachers, concluded that the majority of the participants held 'traditional' beliefs. These teachers expressed the opinion that they should control classroom activities and that learning is passive and controlled by a dissemination of knowledge. In this respect, a teaching style in which the teacher lectures and the students watch and listen was preferred. Furthermore, Tsai (2002) interviewed 37 science teachers who worked in secondary education. The majority of the interviewees expressed 'traditional' beliefs about teaching and learning science: they thought that the best way to teach science is to transfer knowledge from teacher to students and that science is learned by acquiring and reproducing knowledge from credible sources. However, some teachers held 'constructivist' beliefs, namely indicating that teachers should teach science by helping students construct knowledge because learning science was seen as constructing personal understanding. Moreover, Simmons et al. (1999) investigated the beliefs of 116 science and mathematics teachers and found that the majority of teachers "wobbled" in their beliefs about teaching and learning: they possessed both 'teacher-centered' and 'student-centered' beliefs. The 'teacher-centered' beliefs reflected the idea that the teacher is responsible for organizing, delivering, and transmitting content knowledge to students by employing primarily teacher-directed instructional methods with minimal student input. The 'student-centered' beliefs referred to the idea that students are primarily responsible for acquiring and processing their own knowledge and that they gain (content) knowledge through active participation in group work, hands-on activities, laboratory investigations, and project work. In this learning process, the teacher acts as a guide and facilitator. To summarize, the beliefs expressed in the study of Yerrick and Hoving (2003) together with the traditional and teacher-centered beliefs identified in the other three studies (mentioned above) seem to be captured best by the metaphors of the teacher as 'knowledge provider' and 'superior, authoritative figure'. With respect to the latter two studies, it seems that the constructivist and student-centered beliefs are reflected in the metaphors of the teacher as 'nurturer/cultivator' and 'cooperative, democratic figure'.

Besides these beliefs about teaching and learning in general, some teachers participating in the studies of Tsai (2002) and Simmons et al. (1999) expressed *domain-specific* beliefs. For example, Tsai found that four teachers held 'process' beliefs about teaching and learning science, namely that science education should focus on the processes of science and problem-solving procedures. Likewise, Simmons and colleagues found that some teachers expressed beliefs related to a 'conceptual teaching style'. These teachers held the idea that science education should focus primarily on (students' understanding of) the key concepts of content and the processes of science, for instance by emphasizing the explanatory nature of science, focusing lab sessions and demonstrations on concepts, attempting to change students' unscientific ideas, focusing on the connections within the conceptual framework of scientific knowledge, encouraging students to ask procedural and conceptual questions, and so on.

3.3.2 Teacher beliefs about teaching and learning in general

The four metaphors mentioned above reflect teachers' beliefs about teaching and learning in general, particularly their beliefs about 1) the *goals of education in general* (e.g., to provide, transmit and disseminate knowledge to students or to nourish students' capabilities and to stimulate their personal development), 2) *learning* (e.g., passively receiving and accumulating knowledge or actively constructing knowledge), and 3) the *regulation of students' learning processes* (e.g., the teacher should control the learning process and the students should obediently follow the instruction or teacher and students collaborate while the teacher coordinates the learning activities in the classroom).

First, teachers' beliefs about the goals of education in general refer to the goals that are considered important in terms of general development and schooling (cf. Van Veen, et al., 2001). The literature reveals that these beliefs can usually be divided into two 'orientations', namely an orientation towards 1) *qualification and schooling* (i.e., a focus on students' qualifying for further education and jobs in terms of the necessary knowledge and skills) and 2) *personal and moral development of students in general* (i.e., a focus on guiding students to adulthood and preparing them for functioning in a democratic society) (Denessen, 1999; Van Veen, et al., 2001). These orientations are often reflected in the way that teachers prepare, practice, and evaluate instruction. In other words, a specific 'orientation towards the goals of education' is often reflected in a particular 'orientation towards instruction'. According to Van Veen and colleagues (2001), there are generally two prototypical ideologies that underlie these 'orientations towards instruction'. In the first place, some teachers hold *content-oriented* beliefs, which place a strong emphasis on imparting subject matter and on knowledge reproduction by students. In the second place, other teachers hold *learning-oriented* beliefs, which focus on supporting student learning (cf. Meirink, 2007).

Second, with regard to teachers' beliefs about learning, the literature shows two fundamentally different conceptions of learning (Meirink, et al., 2009; Scott, et al., 2007). The first conception perceives learning as *acquisition*: it involves the mastery of new knowledge and skills, for instance by knowledge reproduction, in order to fill 'knowledge-gaps'. The second conception regards learning as *construction/participation*. In this respect, learners are seen as active constructors of their own knowledge; they make sense of the world and learn by participating in authentic and meaningful learning activities. The latter conception is related to a paradigm shift from cognitive to social-constructivist accounts of learning in the past three decades (Palincsar, 1998). Social-constructivist theories view learning and understanding as inherently social. As a consequence, cultural activities and tools such as artefacts, symbol systems, and language are seen as conditions for conceptual development. According to Palincsar, this paradigm shift led to an increased focus on the process of personal construction of meaning and the active construction of knowledge by students (cf. Hermans, Van Braak, & Van Keer, 2008; Kember, 1997; Trigwell & Prosser, 2004).

Third, beliefs about the regulation of students' learning processes are often divided into beliefs favoring either *teacher-regulated learning* or *student-regulated learning* (Meirink, et al., 2009; Pintrich, 2004). Teacher-regulated learning refers to a situation whereby the teacher actively regulates and evaluates students' learning processes, for instance by determining learning goals and the sequence of learning activities or providing structure in lesson content. In addition, teachers who favour teacher-regulated learning might also prefer instructional strategies that promote the transmission of knowledge, such as lecturing and reproducing knowledge. In contrast, student-regulated learning refers to the situation whereby learners, to a greater or lesser extent, control, monitor, and regulate certain aspects of their own learning process (e.g., students are formulating their own learning goals) (Azevedo, 2009; Lombaerts, et al., 2009; Patrick & Middleton, 2002; Winne, 2010). Due to the paradigm shift mentioned before, notions of 'learning to learn', students' active participation in learning activities, shared responsibilities in both setting and achieving learning goals, and 'lifelong learning' gained prominence and led to the promotion of self-regulated learning (e.g., Del Río & Álvarez, 2002; Wells & Claxton, 2002). In this respect, the teacher primarily acts as a guide and facilitator (Meirink, et al., 2009).

3.3.3 Domain-specific teacher beliefs

Apart from beliefs about teaching and learning in general, teachers also possess domain-specific beliefs. The findings of the studies of Tsai (2002) and Simmons (1999) suggest that these beliefs (i.e., 'process' beliefs and beliefs related to a 'conceptual teaching style) are related to the domain-specific goals of the science curriculum. The review of Bybee and DeBoer (1994) showed that three major goals have shaped the content of science curricula and instructional practices in the past four decades, namely 1) understanding scientific knowledge, 2) understanding and using scientific methods, and 3) promoting students' personal-social development. It is possible that these major goals are reflected (to some extent) in teachers' domain-specific beliefs about teaching and learning science.

According to Van Driel and colleagues (2008), teachers often have a particular intent or purpose in teaching subject matter; they "not only want their students to learn specific subject matter, but also aim at more general science learning goals that lie beyond the subject itself" (p. 108). These more general objectives are termed *curriculum emphases* (Roberts, 1982) and "provide an answer to the student question: 'Why am I learning this?" (Roberts, 1982, p. 245 cited in Van Driel et al., 2008). Van Driel and colleagues combined and clustered the seven curriculum emphases distinguished by Roberts, and investigated chemistry teachers' curriculum emphases by means of the following scales: 1) *fundamental chemistry* (i.e., the idea that theoretical notions should be taught first because these are needed for students' future schooling and can provide a basis for understanding the natural world), 2) *chemistry, technology and society* (focusing on relations between applications of chemical and technological knowledge and students' personal lives or the decisions they make), and 3) *knowledge development in chemistry* (i.e., the development of scientific skills and of an understanding of the nature of chemical knowledge and its developmental process). In line with this, De Putter-Smits and colleagues (2011) rephrased the domain-specific items of this questionnaire in order to measure, among other things, teachers' curriculum emphases in teaching the subject *science*. They found that on average Dutch physics teachers (N=95) agreed to a larger extent with the *fundamental science* curriculum emphasis than with *science, technology and society*.

3.4 RESEARCH QUESTIONS

In this study we explored the content and structure of physics teachers' belief systems by focusing on 1) their beliefs about teaching and learning in general and 2) their domain-specific beliefs. We narrowed the focus by formulating the following two research questions:

1. What is the content of physics teachers' 1) *beliefs about teaching and learning in general* (i.e., orientation towards instruction as well as the goals of education, and beliefs about learn-

ing and the regulation of students' learning processes) and 2) *domain-specific beliefs* (i.e., curriculum emphases in teaching physics)?

2. What relations and/or patterns can be identified between the beliefs mentioned in 1?

3.5 METHOD

In order to explore the content of physics teachers' beliefs we conducted a survey study among physics teachers teaching in secondary education (students aged 12-18) in the Netherlands.

3.5.1 Data collection

Sample and procedure

Data were gathered by means of a sample from another study conducted in spring 2010, in which we used the directory of the Dutch *Digischool* online educational community network as a starting point for sampling (see Chapter 4). Of this sample 223 physics teachers did previously indicate that they were willing to participate in a follow-up study. In March 2011 we sent them an invitation letter with a personal identification number and a link to the online version of a questionnaire measuring 1) beliefs about teaching and learning in general (i.e., orientation towards instruction as well as the goals of education) and 2) domain-specific beliefs (i.e., curriculum emphases). The identification number made it possible to relate teachers' responses in the present study to data gathered in the previous study, in which we measured, among other aspects, beliefs about learning (i.e., knowledge construction versus knowledge reproduction) and the regulation of students' learning processes. A total of 158 teachers (70.9%) responded to our invitation; the useful response was 126 (56.5%). General characteristics of the respondents are summarized in Table 3.1.

Instruments

Teachers' beliefs about teaching and learning in general and their domain-specific beliefs were investigated by using shortened and/or adapted versions of three existing Dutch instruments.

First, we measured teachers' orientation towards instruction and the goals of education by using a shortened version (15 items) of a questionnaire developed by Van Veen and colleagues (2001). The questionnaire contained *learning-oriented*, *moral-oriented,* and *transmission/qualification-oriented* items. The *learning-oriented* items represented a focus on the learner's construction of knowledge and on teaching methods that emphasize both the students' responsibility for their own learning processes and cooperation with peers; the *moral-oriented* items represented a focus on students' general and moral development (i.e., the teacher attempts to guide students into adulthood by moral education and stimulating a critical attitude); and the *transmission/qualification-oriented* items referred to a focus on the transmission

Table 3.1. *General characteristics of the physics teachers in the survey study (N=126)*

Variable	Categories	Frequency	Percentage
Gender	Male	109	86.5
	Female	17	13.5
Age	19-25 years	1	0.8
	26-35 years	26	20.6
	36-50 years	46	36.5
	51-65 years	51	40.5
	> 65 years	2	1.6
Years of teaching experience	0-2 years	9	7.1
	3-5 years	16	12.7
	6-10 years	35	27.8
	11-20 years	22	17.5
	> 20 years	44	34.9
Previous education of teacher	Category 1: Teacher education physics - *Higher vocational education*	45	35.7
	Category 2: Teacher education physics - *University Master's degree*	43	34.1
	Category 3: No teacher education physics – *Physics University Master's degree and/or other previous education*	36	28.6
	Category 4: Unknown	2	1.6

of core-subject knowledge and teaching methods that emphasize qualification, attainment, and schooling functions.

Second, teachers' beliefs about learning and the regulation of students' learning processes were measured by using a shortened version (28 items) of an instrument developed by Meirink and colleagues (2009). This instrument contained items representing beliefs about both *knowledge construction* and *knowledge reproduction* in order to investigate teachers' beliefs about learning. In addition, teachers' beliefs about the regulation of students' learning processes were measured by statements representing beliefs about either *teacher-* or *student-regulation* of learning processes.

Third, teachers' curriculum emphases were investigated by using a shortened and adapted version (i.e., items were adapted to physics content (cf. De Putter-Smits, et al., 2011)) of the questionnaire developed by Van Driel and colleagues (2008). The questionnaire (13 items) contained items representing the *fundamental physics* (FP), *physics, technology and society* (PTS), and *knowledge development in physics* (KDP) emphases. *Fundamental physics* refers to the idea that theoretical notions, in particular those about the corpuscular nature of physics subject matter, are taught first, because such notions can provide a basis for understanding the natural world and are also needed for students' future education. The emphasis *physics, technology, and society* represents the idea that practical applications of physics as well as technological knowledge are often related to students' personal lives, in the sense that it is assumed that these applications are interrelated with students' decisions. *Knowledge development in physics* refers to the idea that students are expected to develop scientific skills, for instance by reflection activities that promote their understanding of the nature of physics knowledge and how it is developed (cf. De Putter-Smits, et al., 2011; Van Driel, et al., 2008).

All items of the questionnaires 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 the questionnaire items, translated from the Dutch, are presented in Appendix 2.

3.5.2 Data analysis

Because we used adapted versions of existing questionnaires, (i.e., we selected those items that were relevant for secondary physics education, and questionnaire items were sometimes adapted to physics content), we were interested to see if our data revealed the same factor structure as found by Van Veen et al. (2001), Meirink et al. (2009), and Van Driel et al. (2008). For this reason, we analyzed our data by conducting Principal Axis Factoring on the answers to the items from the different parts of the questionnaire. In order to determine the factor structure at item level we used Varimax with Kaiser Normalization as rotation method. Since oblique rotation resulted in the same factor structure at item level, further analyses were conducted on the basis of an orthogonal factor structure. 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 factor loadings of less than .30) or ambiguous items (i.e., items with factor loadings on multiple scales and differences between these factor loadings are ≤ .05) were excluded from further analysis. In addition, we created scales based on the factor structure and conducted a reliability analysis on each of the scales by computing Cronbach's alpha coefficient scores; items that threatened reliability were eventually removed. After computing the mean scores for each of the scales identified, we conducted a two-way ANOVA, in order to compare means among different groups of respondents; here we used background variables such as *gender*, *age*, *years of teaching experience*, and *previous education* as grouping factor.

To investigate patterns within physics teachers' belief systems we conducted the following analyses: 1) computation of bivariate Pearson correlations between mean scale scores to investigate the relationships between physics teachers' beliefs about teaching and learning in general and their domain-specific beliefs, 2) hierarchical cluster analysis to investigate distinctive patterns in teacher beliefs, and 3) the creation of a difference variable, indicating the extent to which a teacher has relatively higher mean scores on one of the scales measuring orientation towards instruction and the goals of education than on the other. This difference variable functioned as a grouping factor for comparing the mean scale scores of the other scales.

3.6 RESULTS

3.6.1 The underlying factor structure of teachers' beliefs

With reference to teachers' *orientation towards instruction and the goals of education*, two different factors were extracted, explaining 37.40% of the total variance; two items were excluded from further analysis. The first factor was called 'learning-/moral-oriented' (LMO, 9 items, α=.81, N=126), and the second was labeled 'transmission-/qualification-oriented' (TQO, 4 items, α=.79, N=126).

Furthermore, with regard to teachers' *beliefs about learning and the regulation of students' learning processes*, three different factors were extracted, explaining 29.80% of the total variance; three items were excluded from further analysis. The first factor referred to 'student-regulated learning and knowledge construction' (SRLCON, 14 items, α=.80, N=126), the second was called 'knowledge reproduction' (REP, 4 items, α=.78, N=126), and the third factor indicated 'teacher-regulated learning' (TRL, 7 items, α=.70, N=126).

With respect to teachers' *curriculum emphases in teaching physics*, three factors were extracted, explaining 38.50% of the total variance; two items were excluded from further analysis. These three factors corresponded to the three original scales used in the existing instruments of Van Driel and colleagues (2008) and De Putter-Smits and colleagues (2011). The first factor referred to the curriculum emphasis of 'physics, technology, and society' (PTS, 4 items, α=.73, N=126), the second factor was labeled 'fundamental physics' (FP, 3 items, α=.73, N=126), and the third factor was associated with the 'knowledge development in physics' emphasis (KDP, 4 items, α=.62, N=126). Tables 3.2a, 3.2b, and 3.2c show the accompanying rotated factor matrices. The first column contains the scale items we eventually used in further analyses, the other columns show the factor loadings of each item per factor.

Table 3.2a. *Rotated factor matrix (rotation converged in three iterations): Orientation towards instruction and the goals of education (N=126)*

Scale	***Factor***	
Item	*1*	*2*
LMO 1	.679	
LMO 2	.605	
LMO 3	.605	
LMO 4	.596	
LMO 5	.584	.371
LMO 6	.574	
LMO 7	.542	
LMO 8	.451	
LMO 9	.433	
-	.368	.327
-		
TQO 1		.771
TQO 2		.762
TQO 3		.660
TQO 4		.558

Table 3.2b. *Rotated factor matrix (rotation converged in five iterations): Beliefs about learning and the regulation of students' learning processes (N=126)*

Scale	***Factor***		
Items	*1*	*2*	*3*
SRLCON 1	.699		
SRLCON 2	.546		
SRLCON 3	.499		
SRLCON 4	.494		
SRLCON 5	.492		
SRLCON 6	.491		-.347
SRLCON 7	.490		
SRLCON 8	.467		
SRLCON 9	.450	-.359	
SRLCON 10	.438		
SRLCON 11	.438		
SRLCON 12	.407		
SRLCON 13	.361		
SRLCON 14	.339		

Table 3.2b. *Rotated factor matrix (rotation converged in five iterations): Beliefs about learning and the regulation of students' learning processes (N=126)* (continued)

Scale	***Factor***		
Items	*1*	*2*	*3*
REP 1		.690	
REP 2		.668	
REP 3		.633	
REP 4		.584	
-			
TRL 1			.560
TRL 2			.555
TRL 3			.529
TRL 4		.389	.513
TRL 5			.489
TRL 6			.466
TRL 7			.378
-		.328	.369

Table 3.2c. *Rotated factor matrix (rotation converged in five iterations): Curriculum emphases in teaching physics (N=126)*

Scale	***Factor***		
Items	*1*	*2*	*3*
PTS 1	.836		
PTS 2	.798		
PTS 3	.499		
PTS 4	.428		
FP 1		.755	
FP 2		.693	.302
FP 3		.568	
KDP 1			.617
KDP 2			.585
KDP 3			.563
-	.340		.366
KDP 4			.332
-			

3.6.2 Means and standard deviations of questionnaire scales

An overview of the descriptive statistics of the various questionnaire scales is presented in Table 3.3. Questionnaire items were scored on a five-point Likert scale, namely: 1=totally disagree, 2=disagree, 3=neither agree, nor disagree, 4=agree, and 5=totally agree.

Table 3.3 reveals that on average our respondents agreed not only with the statement that instruction and education should be focused on students' construction of knowledge and their moral development in general (M_{LMO}=4.04, *SD*=.45), but also that education is about the transmission of core subject knowledge and students' qualifying for higher education (M_{TQO}=4.09, *SD*=.53). Furthermore, physics teachers' beliefs about learning and the regulation of students' learning processes were on average characterized by an agreement with not only the importance of student-regulated learning and knowledge construction (M_{SRLCON}=3.83, *SD*=.40), but also the importance of teacher-regulated learning, for instance by giving clear explanations, showing the causes of mistakes, and helping students to prepare for assessments (M_{TRL}=3.44, *SD*=.51). In addition, the teachers in this sample on average thought that knowledge reproduction, such as memorizing, was not important for learning physics content (M_{REP}=2.30). However, we found a larger deviation on this scale (*SD*=.69) than on the other questionnaire scales. With regard to our respondents' curriculum emphases, no explicit preference was found. The teachers in this study thought on average that all three curriculum emphases were important (M_{PTS}=3.87, *SD*=.60; M_{FP}=3.99, *SD*=.62; M_{KDP}=3.77, *SD*=.59).

We investigated mean differences between scale scores by conducting a series of two-way ANOVAs. Here, background variables such as age, years of teaching experience, and teachers' previous education were used as grouping factors. For the variable gender we conducted a *t*-test to investigate mean differences. We found a significant main effect of previous education

Table 3.3. *Descriptive statistics of questionnaire scales (N=126)*

Beliefs	Scale description	n items	Cronbach's alpha	N	M	SD
Orientation towards Instruction and the goals of Education (OIE)	Learning-/Moral-oriented (LMO)	9	.81	126	4.04	.45
	Transmission-/Qualification-oriented (TQO)	4	.79	126	4.09	.53
Learning and the Regulation of students' learning processes (L&RL)	Student-regulated learning and knowledge construction (SRLCON)	14	.80	126	3.83	.40
	Knowledge reproduction (REP)	4	.78	126	2.30	.69
	Teacher-regulated learning (TRL)	7	.70	126	3.44	.51
Curriculum Emphases in teaching Physics (CurEm)	Physics, Technology and Society (PTS)	4	.73	126	3.87	.60
	Fundamental Physics (FP)	3	.73	126	3.99	.62
	Knowledge Development in Physics (KDP)	4	.62	126	3.77	.59

on the TQO-scale ($F(2,110)=6.881$, $p=.002$, partial $\eta^2=.111$). Post hoc comparisons were conducted by using Tukey HSD, since Levene's test of equality of error variances was not significant ($F(11, 110)=1.285$, $p=.243$). We found that those teachers who had done their (physics) teacher training at an institute of higher vocational education (N=45) on average scored lower on the TQO-scale ($M_{TQO}=3.82$, $SE=.08$) than the teachers who had done their training at university level ($M_{TQO}=4.22$, $SE=.08$; N=43), and the teachers either without teacher training or with another type of schooling ($M_{TQO}=4.17$, $SE=.10$;) N=36), see Table 3.1. No other significant main effects and interaction effects were found.

3.6.3 Bivariate Pearson correlations between the mean scale scores

In order to investigate relations between physics teachers' beliefs about teaching and learning in general and their domain-specific beliefs, we computed bivariate Pearson correlations between teachers' mean scale scores. Significant correlations are shown in Table 3.4.

We used the following rule of thumb to determine the strength of a relationship: < .30 were 'weak' correlations, correlations ≥ .30 and < .50 were called 'moderate', and correlations ≥ .50 were seen as a 'strong' relationship (Weinberg & Knapp Abramowitz, 2002). With regard to *beliefs about teaching and learning in general*, we found a moderate positive relation (.304) between the two scales measuring orientation towards instruction and the goals of education. This means that teachers who agreed with learning-/moral-oriented (LMO) items, on average, also tended to agree with transmission-/qualification-oriented (TQO) items. Other significant correlations were weak and in most cases positive.

With regard to *domain-specific beliefs*, a moderate positive correlation (.331) was found between the 'fundamental physics' (FP) and 'knowledge development of physics' (KDP) curriculum emphases. In other words, teachers who thought that it is important to teach theoretical notions first in order to provide a basis for understanding the world, also tended on average to hold the belief that it is important for students to develop scientific skills, as well as to construct knowledge in order to understand the nature of knowledge development in physics.

With respect to *relations between beliefs about teaching and learning in general and curriculum emphases in teaching physics*, we found a strong positive correlation (.528) between transmission-/qualification-oriented beliefs (TQO) and the 'fundamental physics' (FP) curriculum emphasis, and a moderate positive correlation (.346) between learning-/moral-oriented beliefs (LMO) and the 'physics, technology, and society' (PTS) emphasis. In addition, moderate positive correlations were found between the 'knowledge development in physics' (KDP) curriculum emphasis on the one hand, and the orientation towards instruction and the goals of education on the other (i.e., KDP and LMO =.304; KDP and TQO =.398). The other significant correlations found were weak.

Table 3.4. *Bivariate Pearson correlation matrix of mean scale scores (N=126)*

		LMO	TQO	SRLCON	REP	TRL	PTS	FP	KDP
Orientation towards instruction and the goals of education (OIE)	Learning & Moral-oriented (LMO)	1							
	Transmission / Qualification-oriented (TQO)	.304**	1						
Beliefs about Learning and Regulation of students' learning processes (L&RL)	Student-regulated learning and knowledge construction (SRLCON)	.239**	-.182*	1					
	Knowledge reproduction (REP)		.181*	-.195*	1				
	Teacher-regulated learning (TRL)		.196*		.225*	1			
Curriculum Emphases in teaching Physics (CurEm)	Physics, Technology and Society (PTS)	.346**					1		
	Fundamental Physics (FP)	.185*	.528**	-.288**	.194*		.192*	1	
	Knowledge Development in Physics (KDP)	.304**	.398**				.183*	.331**	1

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

3.6.4 Identifying patterns in teachers' beliefs

We conducted a hierarchical cluster analysis on teachers' scale scores representing beliefs about teaching and learning in general (i.e., LMO, TQO, SRLCON, REP, and TRL) and domain-specific beliefs (i.e., curriculum emphases PTS, FP, and KDP) by means of Ward's cluster method; we chose this particular method because descriptive statistics of the questionnaire scales showed relatively small standard deviations (Norusis, 2010). However, it was difficult to interpret the characteristics and mean differences of the clusters that were found.

Since the literature suggests that there is a relation between content-oriented beliefs and teacher-regulated learning on the one hand, and learning-oriented beliefs and student-regulated learning on the other (see section 3.3.2), we were interested in finding patterns in the way teachers scored the items on specific scales. In particular, we wondered if teachers with a higher mean score on the TQO scale than the LMO scale 1) considered teacher regulation (TRL) to be more important than student-regulated learning and construction of knowledge (SRLCON), and 2) regarded the 'fundamental physics' (FP) curriculum emphasis to be more important than 'physics, technology and society' (PTS), and vice versa. Thus, we created a new variable by computing the difference between a teacher's mean scores on the two scales measuring orientation towards instruction and the goals of education (LMO and TQO). With regard to the newly created variable, the absolute difference score indicated the extent to which a teacher valued one scale over the other. We decided that difference scores ranging from |0 through .50| indicated that neither scale was considered more important, whereas difference scores of more than |.50| indicated that one scale was valued over the other.

Inspection of the difference scores for the LMO and TQO scales resulted in the identification of three groups of teachers. Teachers belonging to group A (N=29) had higher mean scores on the TQO-scale than on the LMO scale, group B teachers (N=79) had relatively equal scores on both scales, and teachers in group C (N=16) had higher mean scores on the LMO scale than on the TQO scale. Mean scale scores for each group are presented in Table 3.5 and Figure 3.1 is a graphical representation of these means on each of the questionnaire scales.

The majority of teachers belonged to group B (N=79). Although on average these teachers had equal mean scores for the scales representing learning-/moral-oriented and transmission-/qualification-oriented beliefs (M_{LMO}=M_{TQO}=4.07), they showed a stronger agreement with statements about the importance of student-regulated learning and knowledge construction (M_{SRLCON}=3.82) than with statements about the importance of teacher-regulated learning (M_{TRL}=3.43). In addition, for statements about 'knowledge reproduction' they mostly chose the 'disagree' option (M_{REP}=2.34).

Table 3.5. *Group means on questionnaire scales (N=124)*

Beliefs	**Questionnaire scales**	*Group A (N=29)*	*Group B (N=79)*	*Group C (N=16)*
OIE	Learning-/moral-oriented (LMO)	3.70	4.07	4.51
	Transmission-/qualification-oriented (TQO)	4.45	4.07	3.50
L&RL	Student-regulated learning and knowledge construction (SRLCON)	3.68	3.82	4.18
	Knowledge reproduction (REP)	2.32	2.34	2.05
	Teacher-regulated learning (TRL)	3.48	3.43	3.36
CurEm	Physics, technology and society (PTS)	3.58	3.93	4.11
	Fundamental physics (FP)	4.11	4.05	3.44
	Knowledge development in physics (KDP)	3.79	3.80	3.58

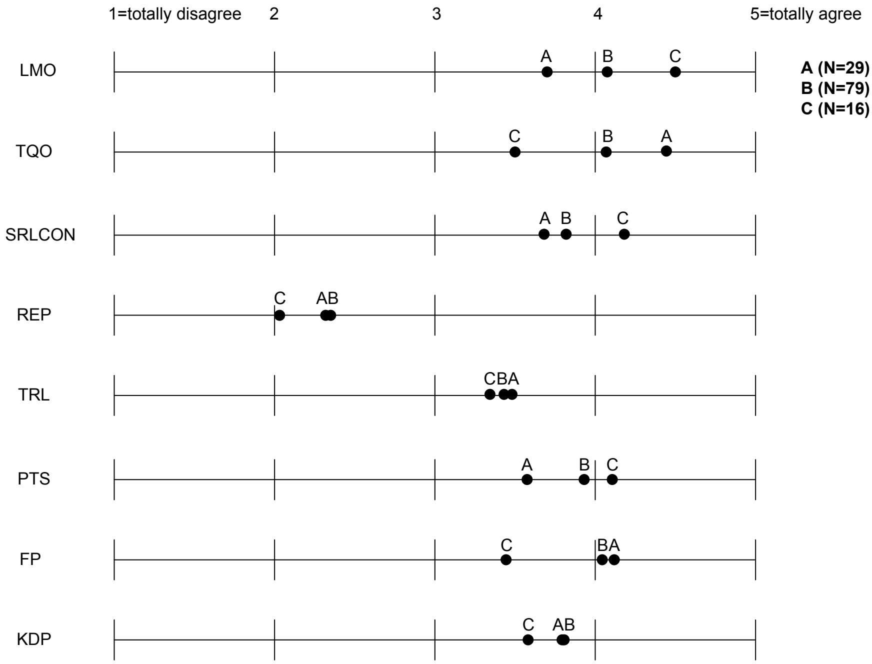

Figure 3.1. Group means on the various questionnaire scales (N=124)

Teachers in group A (N=29) differed from those in groups B and C in their strong orientation on transmission/qualification (M_{TQO}=4.45). This orientation was reflected in a stronger preference for the 'fundamental physics' curriculum emphasis (M_{FP}=4.11) compared to the other two emphases. Remarkably, despite the fact that teachers in group A were strongly transmission-/qualification-oriented, they still had higher scores on the scale representing beliefs about student-regulated learning and knowledge construction (M_{SRLCON}=3.68) than on the scale associated with beliefs about teacher-regulated learning (M_{TRL}=3.48). However, group means on the SRLCON scale were the lowest for group A as compared to the other two groups.

With regard to group C (N=16), these teachers differed from those in groups A and B in their stronger agreement with learning-/moral-oriented statements (M_{LMO}=4.51). This preference was strengthened by a stronger agreement with items reflecting beliefs in favor of student-regulated learning and knowledge construction (M_{SRLCON}=4.18) as well as a stronger disagreement with statements reflecting beliefs in favor of knowledge reproduction (M_{REP}=2.05) compared to groups A and B. Despite their strong agreement with learning-/moral-oriented items, on average, teachers in group C still agreed with items reflecting the importance of teacher-regulated learning (M_{TRL}=3.36).

3.7 CONCLUSIONS AND DISCUSSION

3.7.1 Conclusions

One of the main conclusions of this study, which provided an answer to the first research question, is that on average physics teachers held both learning-/moral-oriented (LMO) and transmission-/qualification-oriented (TQO) beliefs. They also agreed on the importance of student-regulated learning and knowledge construction (SRLCON), as well as the importance of teacher-regulated learning (TRL). Moreover, the teachers in this sample had no explicit preference for one of the curriculum emphases (FP, PTS, KDP); they thought that all three curriculum emphases were important. It was difficult to make a meaningful interpretation of the differences in beliefs that were found based on either the mean scores of the belief scales or by taking background variables such as gender, age, and years of teaching experience into account. On average, the physics teachers held similar beliefs concerning what goals of education, both in general and domain-specific, and what types of regulation were important in the context of physics education.

Another main conclusion, which provided an answer to the second research question, is that teachers' orientations towards instruction and the goals of education (TQO and LMO) were significantly related to the three curriculum emphases in teaching physics. We found a strong positive correlation between the scale measuring transmission-/qualification-oriented (TQO) beliefs and the 'fundamental physics' (FP) curriculum emphasis. The other significant correlations were moderate and positive. Thus, this study showed that the beliefs of physics teachers about the goals of education in general and their domain-specific beliefs about the goals of physics education (i.e., curriculum emphases) formed an interrelated belief system. However, the relations between these beliefs and beliefs about the regulation of students' learning processes were less clear-cut: these correlations were only weak or non-significant (see Figure 3.2).

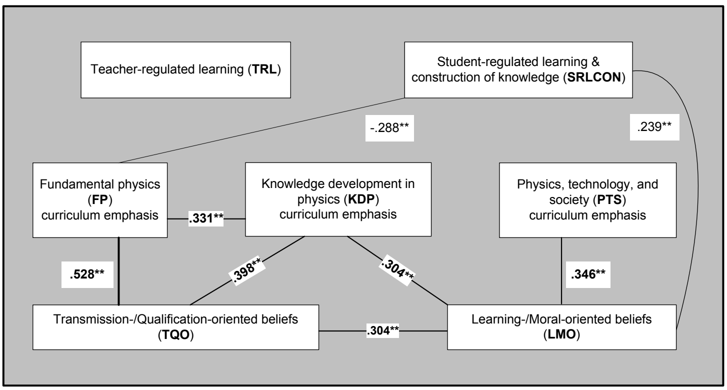

Figure 3.2. Graphic representation of bivariate Pearson correlations (that are significant at the .01 level, marked with **) between teachers' beliefs about the goals of physics education and the regulation of students' learning processes (N=126)

3.7.2 Discussion

When exploring the patterns in teachers' beliefs about teaching and learning in general we noticed some differences in the way teachers scored on specific scales. We found that the majority of teachers (group B, N=79) had roughly equal mean scores on the TQO and LMO scales (cf. Geelan, Wildy, Louden, & Wallace, 2004). In addition, even if teachers showed stronger agreement with one of the two scales (groups A and C), they had, on average, 1) higher individual mean scale scores on the scale measuring beliefs about student-regulated learning and knowledge construction (SRLCON) than on the scale representing beliefs about teacher-regulated learning (TRL), and 2) roughly equal group means on the TRL scale (see Table 3.5). Thus, our findings suggest that the orientation towards instruction and the goals of education, as well as beliefs about learning and the regulation of students' learning processes consist of at least two dimensions (cf. Denessen, 1999).

A possible explanation for the finding that teachers in this study valued not only student-regulated learning and knowledge construction (SRLCON), but also teacher-regulated learning (TRL) is related to the complicated process of learning formalized physics concepts. This is often accompanied by a comparison of different ideas, consistent and logical reasoning, deciding what theories are 'best' for explaining natural phenomena, and sometimes even conceptual conflicts. According to Mulhall and Gunstone (2008), many physics teachers agree that it is their role and responsibility to actively guide students in their search for a clear understanding of the conceptual framework of physics knowledge. For instance, they think it is important to ask the 'right' questions, to encourage students to make their reasoning explicit or to reason through conceptual conflicts, and to provide a clear structure for modeling and problem-solving (e.g., establishing explicit connections with prior knowledge or showing a sequence of steps in finding solutions). Another explanation refers to the nature of the domain. Physics content includes both procedural and conceptual knowledge (i.e., 'knowing how' and 'knowing why'). In this respect, transmission-/qualification-oriented instruction might be associated with the acquisition of procedural knowledge, whereas learning-/moral-oriented instruction possibly aims at students' learning of conceptual knowledge (cf. Hodson, 1992; Wong, 2009). This might explain why the teachers in our sample held beliefs about both student-regulated learning and knowledge construction and teacher-regulated learning.

With respect to beliefs about learning and the regulation of students' learning processes, we found only weak correlations between these beliefs on the one hand, and the three curriculum emphases plus the orientation towards instruction and the goals of education on the other. This result might be explained by the conceptual distance between beliefs about learning and the regulation of students' learning processes and the other beliefs mentioned. For instance, the former beliefs concern aspects of learning in general, whereas curriculum emphases and the orientation towards instruction and the goals of education are related to aspects of the instructional context of secondary physics education. Another explanation might be that beliefs about learning and the regulation of students' learning processes are less explicit than the other beliefs (cf. Mathijsen, 2006).

Limitations of the present study

In this study it was difficult to interpret the clusters or patterns in physics teachers' belief systems in a meaningful way. This might be explained by the types of beliefs we investigated and the instrument used. The relatively small variances in the questionnaire scale scores indicate that the teachers in our sample, on average, held similar beliefs about teaching and learning in general and the goals of the physics curriculum. Furthermore, research on teacher beliefs is complicated because these beliefs are often tacit (Pajares, 1992), with the added problem that the questionnaires we used might offer only limited possibilities to measure these beliefs. In addition, the questionnaire measured only teachers' beliefs about teaching and learning physics in general, not those about specific teaching situations or contexts. More research is needed if we are to gain knowledge about the relations between these variables, the direction and/or causality of these relations, and how teacher beliefs are manifested in both the planning of specific lessons and the way teachers actually deal with the complexity of the daily school context.

Implications

In the educational literature there is a tendency to characterize teachers' instructional practices as either 'teacher-focused' or 'student-focused' (Struyven, Dochy, & Janssens, 2010). In this respect, the former approach to teaching is associated with a focus on information transmission and the latter with a focus on conceptual change (e.g., Prosser & Trigwell, 1999, 2006). Furthermore, it is sometimes suggested that there is a hierarchy between teacher-focused and student-focused approaches to teaching, in the sense that student-focused approaches mean a better quality of instruction and learning outcomes. For instance, Prosser and colleagues (2005) state that teachers who adopt a more teacher-focused perspective "lack an awareness of a more student-focused perspective in the situation in which they find themselves, while teachers with more student-focused perspectives have an awareness of the more teacher-focused perspectives" (p. 138). In addition, they found that teachers who reported a more 'information transmission-/teacher-focused' approach to teaching had students reporting a more surface learning approach, whereas teachers with a more 'conceptual change-/student-focused' approach had students reporting a deeper learning approach.

Increasingly, both the hierarchy and the one-dimensionality of this categorization have been questioned. For example, Meyer and Eley (2006) found that teachers generally will not be accommodated within single conception categories and Arenas (2009) advocated that the quality of student learning should be improved by a variety in teacher approaches to teaching. In addition, Struyven and colleagues (2010) pointed to the possibility that 'traditional' teachers, who adopt a direct instruction approach to teaching, might be as much oriented towards conceptual change as 'alternative' teachers, who adopt more activating teaching methods. The results of the present study showed that physics teachers' belief systems comprise beliefs about both teacher-regulated and student-regulated learning as well as transmission-/qualification-oriented and learning-/moral-oriented beliefs. In other words, it seems more realistic to consider both approaches to teaching as two independent dimensions instead of a binary opposition (cf. Denessen, 1999). Thus, the terminology of 'teacher-focused' and 'student-focused' might be confusing and not distinctive enough to describe the differences between teachers based on the content of their belief systems.

Therefore, policy makers, educational innovators, teacher educators, and/or designers of professional development programs should be aware of the fact that teachers' beliefs are a multidimensional construct, often related to a specific context (Denessen, 1999; Meyer & Eley, 2006; Pajares, 1992), and that teaching is a multifaceted activity (Doyle, 2006). The complexity of the actual instructional context, which is a dynamic interplay between particular concerns, practical constraints, and context-specific opportunities, might lead to a shift in teachers' first priorities and the centrality of particular teacher beliefs. Depending on individual students' needs, competences, or ambitions, and the content to be taught, teachers may differentiate between the goals they want to achieve, the selection of instructional methods, and the extent to which they let students regulate their own learning processes (cf. Prosser, et al., 2005). Or, to state it differently, if classroom teaching is compared to a play, "it is an act played by both parties (teacher and student), yet it is the responsibility of the teacher to write the script" (Wong, 2009, p. 382). In writing this script, every teacher is 'student-focused', but deciding what should be the content of the script, and to what extent students are allowed to improvise or to write parts of the script themselves, is a matter of continuous deliberation.

Chapter 4

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

3 This chapter has been submitted for publication in an adapted form as:

Belo, N.A.H., Van Driel, J.H., & Verloop, N.
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.

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.

Chapter 6

General conclusions and discussion

6.1 INTRODUCTION

The way teachers teach a certain subject is, among other things, related to their beliefs. In particular, beliefs about teaching and learning in general and domain-specific beliefs as well as the connections between these beliefs are deemed important (Richardson, 1996; Stipek, et al., 2001; Thompson, 1992). The main purpose of this dissertation was to investigate the content and structure of teachers' belief systems in the domain of science education. More specifically, we studied the beliefs of physics teachers working at secondary schools (students aged 12-18) in the Netherlands. Four studies were conducted to investigate the content and structure of teachers' beliefs about 1) the *pedagogy* of teaching and learning physics, 2) the *goals* of physics education, and 3) the *nature of physics content* and (in a broader sense) the *nature of science* (NOS).

The overall research question was:

> *What are the content and structure of physics teachers' belief systems with regard to teaching and learning physics?*

As mentioned in the general introduction (see chapter 1), the four studies were based on some fundamental assumptions about the *stability*, *organization*, and *functionality* of teacher beliefs (Calderhead, 1996; Jones & Carter, 2007; Pajares, 1992; Richardson, 1996). In short, it is assumed that beliefs are relatively stable. They are organized into larger multidimensional belief systems in which some beliefs are prioritized over others, and beliefs play a critical role in organizing knowledge and information because the filtering effect of belief structures distorts, redefines, screens, and reshapes information processing and subsequent thinking.

6.2 SUMMARY OF THE MAIN CONCLUSIONS OF THE FOUR STUDIES

In this chapter, the conclusions of two survey studies (study 2 and 3) and two small-scale interview studies (study 1 and 4) are combined in order to deepen our understanding of the content and structure of physics teachers' belief systems. We start by summarizing the main conclusions of each study, in relation to the research questions.

6.2.1 Small-scale semi-structured interview study (Study 1, chapter 2)

Study 1 focused on physics teachers' (N=4) and physics teacher educators' (N=4) beliefs about the *goals* and *pedagogy* of teaching and learning physics. We investigated their beliefs about making physics comprehensible for secondary students and specific ways to motivate students to learn the content.

The study was guided by the following research questions:

1. What are physics teachers' and physics teacher educators' beliefs about a) making the subject of physics comprehensible for secondary students (aged 12-18) and b) specific ways to motivate these students to learn the content?
2. What goals of physics education (i.e., 'learning physics', 'doing physics', and 'learning about physics' (cf. Hodson, 1992)) are reflected in the beliefs mentioned in 1?
3. What types of regulation were expressed in the beliefs mentioned in 1?

One of the main conclusions, which provided an answer to the first two research questions, was that most beliefs reflected the goals of 'learning physics' and 'doing physics'. In addition, we found no sharp contrast between beliefs about 'making physics comprehensible' and 'motivating students'. The interviewees thought that it was important to actively involve students in learning the content, for instance by using a variety of inquiry and hands-on activities, challenging problems and assignments, and examples or visualizations of content to concretize the meaning and relevance of physics. Moreover, they stressed the importance of teaching and learning basic problem-solving and inquiry skills, repeated practice of assignments in which students are encouraged to apply conceptual knowledge in various situations, collaboration with peers, and ensuring the appropriate cognitive level and complexity of content. The few beliefs that reflected the goal of 'learning about physics' referred to gaining knowledge about the empirical and tentative nature of scientific knowledge and applications of physics in daily life.

Another main conclusion of study 1, which provided an answer to the third research question, was that the sample could be divided into two groups. Half of the sample expressed beliefs in which we identified only two types of regulation, namely teacher-regulation and regulation by both teacher and students. The other half expressed beliefs that reflected all three types of regulation, including student-regulation. We did not find clear relations between specific types of regulation and beliefs about either 'making physics comprehensible' or 'motivating students'. Neither did we find clear relations between particular types of regulation and the goals of 'learning physics', 'doing physics', and 'learning about physics'.

6.2.2 Survey study (Study 2, chapter 3)

Study 2 explored physics teachers' belief systems by using a questionnaire. We aimed at a further exploration of the relations between beliefs about the goals of physics education and beliefs about the regulation of student's learning processes at a larger scale. Therefore, we investigated the content and structure of teachers' beliefs about the *goals* of physics education as well as the *pedagogy* of teaching and learning physics. The study was guided by the following research questions:

1. What is the content of physics teachers' 1) beliefs about teaching and learning in general (i.e., orientation towards instruction as well as the goals of education, and beliefs about

learning and the regulation of students' learning processes) and 2) domain-specific beliefs (i.e., curriculum emphases in teaching physics)?
2. What relations and/or patterns can be identified between the beliefs mentioned in 1?

One of the main conclusions of study 2, which provided an answer to the first research question, was that, on average, physics teachers (N=126) held similar beliefs about the goals of physics education. In addition, they held similar beliefs about what types of regulation were important with regard to students' learning processes. More detailed, physics teachers held both transmission-/qualification-oriented and learning-/moral-oriented beliefs about the goals of education in general. They also thought that both teacher-regulated learning and student-regulated learning and knowledge construction were important. Surprisingly, they also had no explicit preference for one of the three curriculum emphases; on average, we found no significant differences between the three curriculum emphases. In other words, the physics teachers in our sample thought that 'knowledge development in physics', and 'physics, technology, and society' curriculum emphases were, more or less, equally important as the 'fundamental physics' curriculum emphasis. We found some significant differences based on the mean scores of the belief scales by taking background variables such as gender, age, previous education, and years of teaching experience into account. However, post hoc comparisons and hierarchical cluster analysis did not result in any meaningful differences and clusters.

Another main conclusion, which provided an answer to the second research question, was that the beliefs of physics teachers about the goals of education in general (i.e., transmission-/qualification-oriented and learning-/moral-oriented beliefs) and domain-specific beliefs about the goals of physics education (i.e., curriculum emphases in teaching physics) formed an interrelated belief system with predominantly moderate positive correlations. However, relations between these beliefs and beliefs about the regulation of students' learning processes (i.e., beliefs about teacher-regulated learning and student-regulated learning and knowledge construction) were less clear; the significant correlations found indicated only weak relations, whereas other correlations were non-significant.

6.2.3 Large-scale survey study (Study 3, chapter 4)

Study 3 explored the content and structure of physics teachers' beliefs about the *nature of science* (NOS) at a large scale (N=299). We were interested in the content of these beliefs because study 1 showed that the goal of 'learning about physics' was not often reflected in teachers' beliefs about 'making physics comprehensible' and 'motivating students'. The beliefs that were expressed in relation to this particular goal concerned, among other aspects, the empirical and tentative nature of scientific knowledge (see chapter 2). In study 3 we were interested in whether teachers held different beliefs about these aspects of scientific knowledge. We developed a questionnaire with statements that were based on ideal types of contrasting philosophical positions concerning the nature and status of scientific knowledge claims. In this respect, we used three dimensions (intentional, epistemic, and methodological). The 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)?

The main conclusion of study 3 regarding the content of teachers' beliefs about the nature of science was that a distinction could be made between beliefs about the *purpose*, *status*, and *utility* of scientific knowledge. Furthermore, with reference to the structure of these beliefs, we found (significant) weak positive correlations between beliefs about the purpose of scientific knowledge on the one hand and beliefs about the status and utility of scientific knowledge on the other.

On average, the physics teachers in our sample held similar beliefs about the *purpose* of scientific knowledge; they thought that scientific theories, laws, and principles aim to provide a correct description, explanation, and prediction of natural phenomena. However, we found differences in teachers' beliefs about the *status* and *utility* of scientific knowledge. In this respect, three clusters of teachers were identified which we labeled 'absolutist' (N=71), 'relativist' (N=112), and 'pragmatist' (N=116). Teachers in the 'absolutist' cluster believed that scientific theories, laws, and principles are empirically proven, absolute and objective (i.e., belief about the status of scientific knowledge). In contrast, teachers in the 'relativist' cluster agreed to a greater or lesser extent with the relative status of scientific knowledge. Teachers in the 'pragmatist' cluster on average neither disagreed nor agreed with items representing either 'absolutist' or 'relativist' beliefs about the status of scientific knowledge. The latter teachers held 'pragmatist' beliefs about the utility of scientific knowledge. They 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 activities. The teachers grouped in the 'absolutist' and 'relativist' clusters, on average, neither disagreed nor agreed with items measuring beliefs about the utility of scientific knowledge. No significant differences between teacher beliefs were found when background variables such as gender, age, years of teaching experience, and teachers' previous education were taken into account.

6.2.4 Structured interview study (Study 4, chapter 5)

In study 4 we interviewed three physics teachers that were purposefully selected from each of the clusters identified in study 3. Thus, the sample consisted of one teacher from the 'absolutist', one teacher from the 'relativist', and one teacher from the 'pragmatist' cluster. Because teachers' beliefs about the nature of physics and science are often tacit, one of the aims of study 4 was to further investigate the content of these beliefs by qualitative methods. Moreover, we were interested in whether these beliefs were related to other beliefs about teaching and learning physics (including beliefs about the goals of physics education). Another aim of study 4 was to explore whether and, if so, to what extent these beliefs were reflected in a teacher's teaching intentions. The study was guided by the following 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?

One of the main conclusions of study 4, which was related to the first research question, was that the content of teachers' beliefs about the nature of physics and science was characterized by (different) beliefs about 1) *the aim of scientific inquiry* (e.g., testing and verifying theories, constructing theories), 2) *the purposes of physics as a research field* (e.g., explaining the essential processes within nature by theories and experiments, trying to discover new things, applying physics knowledge in technology and devices), 3) *the tentativeness of scientific theories* (e.g., advancement of scientific methods, change of scientific insights and methodological rules), and 4) *the difference between scientific 'theories' and 'laws'* (e.g., theories and laws are synonyms, theories eventually become laws, laws are mathematical relations between variables and theories explain these relations). However, the teachers in our sample did not clearly differentiate between the broader domain of physics (e.g., physics as a research field and profession) and the *school subject* physics. Another main conclusion was that these teachers expressed different priorities concerning the goals of physics education. In particular, they differed in their beliefs about what *knowledge* and *skills* should be taught and what *attitudes* are important for students to adopt. However, the rationale behind these priorities often remained to a greater or lesser extent tacit.

Furthermore, with regard to the structure of teachers' beliefs about the nature of physics and science, and beliefs about teaching and learning physics, we concluded that beliefs about *the purpose of practical work and inquiry activities* (e.g., students' understanding of physics concepts, learning and training inquiry skills in order to conduct inquiry on your own) were related to a teacher's beliefs about 1) *the goals of physics education* and 2) *the aim of scientific inquiry* (i.e., beliefs about the nature of physics and science). With regard to the second research question, we found that teachers' teaching intentions reflected to some extent this related set of beliefs about the purpose of practical work and inquiry activities, the aim of scientific inquiry, and teachers' individual priorities concerning the goals of physics education. These beliefs were reflected clearly in a teacher's intentions concerning the *lesson objectives* and the content and sequencing of specific *teaching and learning activities* (e.g., questioning, predicting, demonstrating, observing, verifying predictions, and so on).

6.3 SYNTHESIS AND GENERAL CONCLUSIONS

A synthesis of the conclusions of the four studies resulted in the formulation of the following general conclusions. These conclusions provide an answer to the overall research question: *What are the content and structure of physics teachers' belief systems with regard to teaching and learning physics?*

1. **The questionnaire studies showed that, on average, physics teachers' belief systems about teaching and learning physics are composed of interrelated beliefs about the goals of physics education (i.e., goals of education in general and domain-specific curriculum emphases) and more or less distinct beliefs about teacher-regulated learning, student-regulated learning and knowledge construction, and the nature of physics and science (see Figure 6.1).**

a. On average, teachers held similar beliefs about the importance of focusing on the transmission of core subject knowledge and students' qualification for higher education (i.e., 'transmission-/qualification-oriented' belief), as well as focusing on learners' construction of knowledge and responsibility for own learning processes, collaboration with peers, and adoption of a critical attitude (i.e., 'learning-/moral-oriented' belief).
b. On average, teachers held similar beliefs about the importance of all three curriculum emphases in teaching physics, namely that 1) theoretical notions should be taught first, because such notions can provide a basis for understanding the natural world and are also needed for students' future education (i.e., 'fundamental physics'), 2) students should develop their understanding of the nature of physics knowledge and how it is developed ('knowledge development in physics'), and 3) physics education should focus on the relations between applications of physics and technological knowledge, and students' personal lives or the decisions they make ('physics, technology, and society').
c. On average, teachers held similar beliefs about the importance of not only teacher-regulated learning of physics content, but also student-regulated learning and students' active knowledge construction.
d. On average, teachers held similar beliefs about the purpose of scientific knowledge. They thought that scientific theories, laws, and principles aim to provide a correct description, explanation, and prediction of natural phenomena.
e. On average, teachers differed in their beliefs about the status and utility of scientific knowledge. In this respect, three clusters were identified, which we labeled 'absolutist', 'relativist', and 'pragmatist'.
f. On average, teachers' beliefs about the goals of physics education (i.e., beliefs about the goals of education in general and curriculum emphases in teaching physics) formed an

interrelated belief system with predominantly moderate positive correlations between the different beliefs (see Figure 6.1).

g. On average, no clear relations were found between the interrelated system of beliefs about the goals of physics education and beliefs about the regulation of students' learning processes (i.e., beliefs about teacher-regulated learning and beliefs about student-regulated learning and knowledge construction) (see Figure 6.1).
h. On average, weak positive correlations were found between beliefs about the purpose of scientific knowledge on the one hand, and beliefs about the status and utility of scientific knowledge on the other (see Figure 6.1).

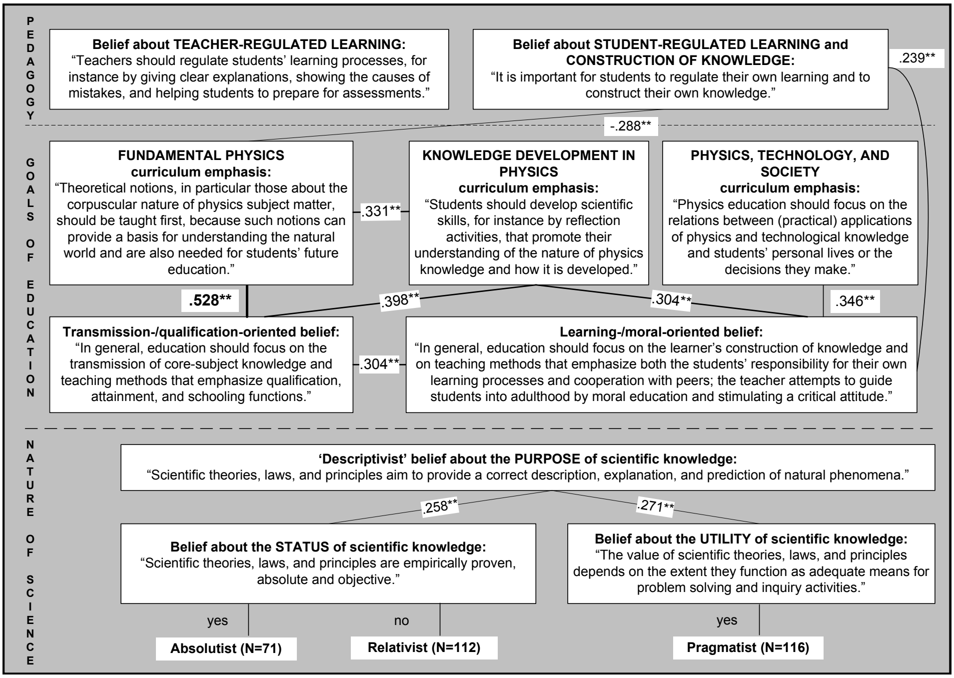

Figure 6.1. The content and structure of physics teachers' belief systems based on the mean scores of two survey studies (the figure presents bivariate Pearson correlation scores (marked by **) that were significant at the 0.01 level (2-tailed)).

2. The interview studies showed that teachers differ in their priorities concerning the goals of physics education and the extent to which their beliefs about the pedagogy of teaching and learning physics reflect student-regulated learning. In addition, the relation between beliefs about the nature of physics and science and beliefs about the goals and pedagogy of teaching and learning physics is not straightforward.

a. Teachers differed in their priorities concerning what knowledge and skills should be taught and what attitudes are important to adopt. However, the rationale behind these priorities often remained to a greater or lesser extent tacit.
b. Teachers differed in their beliefs about the purpose of practical work and inquiry activities. These beliefs seemed to be related to their priorities concerning the goals of physics education.
c. Teachers' beliefs about 'making physics comprehensible' and 'specific ways to motivate students to learn the content' showed gradual differences with regard to beliefs about the regulation of students' learning processes. Some teachers expressed beliefs reflecting only two types of regulation, namely teacher-regulation and regulation by both teacher and students. Other teachers expressed beliefs reflecting all three types of regulation, including student-regulated learning.
d. The beliefs that teachers expressed about 'making physics comprehensible' and 'specific ways to motivate students to learn the content' reflected primarily the goals of 'learning physics' and 'doing physics'. A few of the expressed beliefs reflected the goal of 'learning about physics'.
e. From teachers' beliefs about the nature of physics and science, only beliefs about the aim of scientific inquiry were, more or less, clearly related to beliefs about the purpose of practical work and inquiry activities. Other relations between beliefs about the nature of physics and science (i.e., beliefs about the purposes of physics as a research field, the tentativeness of scientific theories, and the difference between scientific 'theories' and 'laws') and beliefs about teaching and learning physics remained unclear.
f. The exploration of teachers' beliefs about the nature of physics and science revealed that the teachers in our sample did not clearly differentiate between the broader domain of physics (e.g., as a research field and profession) and the *school subject* physics.

6.4 DISCUSSION

6.4.1 The measurement of teacher beliefs

One of the aims of this dissertation was to investigate the extent to which particular beliefs were shared by larger groups of physics teachers. Another aim was to investigate the structure of teachers' belief systems. The quantitative nature of the questionnaire studies made it possible to investigate similarities and differences between the beliefs of larger groups of teachers, to compute bivariate Pearson correlations to study the structure of teachers' belief systems, and to conduct hierarchical cluster analysis to explore whether particular groups of teachers could be identified based on the content of their beliefs.

To investigate the beliefs of larger groups of teachers in the questionnaire studies, we needed to formulate the items in a more decontextualized way. However, it is likely that the differences in teacher beliefs primarily relate to particular characteristics of a teacher's instructional context (cf. Kim & Hannafin, 2008). To account for this, the interview format included questions about particular learner characteristics, the effectiveness of specific instructional strategies, important aspects of the learning environment, and so on. Thus, it is reasonable to expect that the qualitative method of interviewing did more justice to the often nuanced and contextualized nature of teacher beliefs (cf. Lederman, 2007) and that the 'conceptual distance' between these beliefs and teachers' teaching context was smaller compared to the beliefs measured in the survey study (cf. Den Brok, 2001; Mathijsen, 2006). This might be an explanation for the fact that the interview studies revealed more differences in teachers' beliefs about, for example, the goals and pedagogy of teaching and learning physics than the questionnaire studies.

6.4.2 Theoretical perspectives on teacher cognitions

The literature on teacher cognitions is characterized by different theoretical perspectives on what contributes to 'good teaching' (Feldman, 1997). For example, some scholars primarily focus on teachers' *orientations toward science teaching* as part of the broader construct of *pedagogical content knowledge (PCK)*, whereas others study teachers' *practical knowledge* or *'phronesis'*, *pedagogical constructions*, or the *competence of explicit professional reasoning*. In the next paragraphs, the conclusions of this dissertation are discussed by taking these different theoretical perspectives into account.

'Orientations toward science teaching' as part of the PCK construct

In the literature on science teachers' *pedagogical content knowledge* (PCK), one of the components of the PCK construct is called 'orientations toward science teaching' (Abell, 2007; Magnusson, et al., 1999). However, according to Friedrichsen, Van Driel, and Abell (2011), there is a lack of conceptual and methodological clarity concerning the role of these orientations in both the development of teachers' PCK and the practice of teaching science. Therefore, Friedrichsen et al. proposed "that orientations toward science teaching be reconceptualized as consisting of interrelated sets of beliefs that teachers hold" (2011, p. 372) in regard to various dimensions; "these dimensions include beliefs about the goals or purposes of science teaching, (the nature of) science, and science teaching and learning" (2011, p. 372). Moreover, Friedrichsen and colleagues suggested that one could construct profiles of science teachers' interrelated beliefs by looking for relationships between, and patterns in these beliefs.

The conclusions of this dissertation support the notion that teachers' belief systems are multidimensional (cf. Denessen, 1999). However, they challenge the suggestion that one could construct profiles of teachers' interrelated beliefs. First, we found that the interrelatedness of teacher beliefs is not clear-cut. For example, we found that teachers' beliefs about the goals of physics education formed an interrelated belief system, as did their beliefs about the nature of science. However, beliefs about the pedagogy of teaching and learning physics, namely beliefs about learning and the regulation of students' learning processes, were not clearly related to each other. Second, the relations of the interrelated belief systems were in most cases weak or moderate. Finally, we did not find clear clusters or patterns in teachers' belief systems. For instance, we did not find clear relations between beliefs about the regulation of students' learning processes and the goals of physics education or between beliefs about the nature of science and the other beliefs measured. Thus, our conclusions suggest that the dimensions within teachers' belief systems could be more or less independent (cf. Wubbels & Brekelmans, 1997).

Teachers' practical knowledge or 'phronesis'

When teachers respond to questions about, for example, the effectiveness of particular instructional strategies or what goals are important to achieve in the context of physics education, their beliefs are colored by 'professional experiences' and perceptions of actual teaching 'situations' and the classroom context (cf. Feldman, 1997; Gholami & Husu, 2010). In addition, these beliefs might reflect the professional values and principles of teaching on which teachers relied to justify their activities in these particular situations. Thus, differences in teacher beliefs are possibly explained by teachers' practical knowledge, also referred to as 'perceptual knowledge' or 'phronesis' (Korthagen, Kessels, Koster, Lagerwerf, & Wubbels, 2001; Loughran & Berry, 2005). Phronesis is the "comprehensive capacity that integrates knowledge, judgment, understanding, and intuition in order to effect appropriate and successful action, (…) to select which rules are appropriate for a given situation" (Halverson, 2004, pp. 93-94, 95). Phronesis includes not only a moral ethos (e.g., professional commitment and responsibilities, vision of the good, and so on), but also a notion of 'what works' (e.g., efficiency of action when practical constraints are taken into account; (Gholami & Husu, 2010).

In the questionnaire study (study 2, chapter 3), we asked the teachers to rate the extent to which they thought that, for example, particular goals and types of regulation were *important* for learning physics content. We concluded that teachers, on average, held similar beliefs about the goals and pedagogy of teaching and learning physics. A possible explanation is that teachers' responses to these questions were primarily influenced by their moral ethos or 'vision of the good', because these questions imply that teachers have an idea of what contributes to 'good' physics education. In the interview study we asked the teachers about *effective* instructional strategies to enhance students' understanding and motivation (study 1, chapter 2). In this respect, the teachers might have experienced a tension between their beliefs about, for example, the importance of student-regulated learning and the complexities of the teaching practice, such as the pressure to prepare students for the final exams on time, particular student characteristics (age, cognitive competence, disorders or disabilities), the perceived need to provide structure in complex physics content, and practical constraints (a lack of time, facilities, and supplies or large classroom sizes) (cf. Berry, 2008; Schraw, et al., 2006). Moreover, the teachers possibly possessed feelings of low self-efficacy or had limited knowledge about how to organize and enable student-regulated learning within the complex and multifaceted classroom situation (cf. Bandura, 1997; Doyle, 2006). Thus, a possible explanation for the fact that we found differences in how much these beliefs reflected student-regulated learning might be that these beliefs were primarily informed by their notions of 'what works'.

Teachers' pedagogical constructions

Another strand of research on teacher cognitions focuses on teachers' pedagogical constructions. 'Pedagogical constructions' are largely the result of an interaction between different types of teacher knowledge and beliefs (Hashweh, 2005; Janssen, Tigelaar, & Verloop, 2009). For example, when teachers design their lessons, they usually have notions or 'rules-of-thumb' of what a lesson should look like in order to achieve the lesson objectives. These notions reflect a teacher's 'goal system', in other words 'how' to reach a goal or 'why' to do something in a certain way (Wieringa, Janssen, & Van Driel, 2011). According to Wieringa and colleagues (2011), such 'goal systems' contain a teacher's broader teaching goals, such as learning conceptual and/or factual knowledge, fostering students' personal development, and motivating students for the lesson (cf. Wongsopawiro, 2012). The findings from the interview studies on teachers' beliefs about the goals and pedagogy of teaching and learning physics might be viewed as such 'rules-of-thumb', because they refer to instructional strategies for making physics comprehensible and motivating students, as well as what aspects of physics lessons are considered important. In this respect, the rules-of-thumb of the physics teachers who participated in our studies seemed to be characterized by a focus on students' *active involvement* and *adaptive teaching* (e.g., by taking particular student characteristics into account). Moreover, in most cases teachers' beliefs reflected a *narrow interpretation* of the overall goal of 'scientific literacy', namely a primary focus on understanding scientific knowledge and understanding and using scientific methods (i.e., 'agency in the material world'; (cf. Anderson, 2007; Bybee & DeBoer, 1994).

The differences that we found in study 1 with regard to teachers' beliefs about the regulation of students' learning processes seem to support the notion of Janssen and De Hullu (2008) about four different "basic types of teaching". According to Janssen and De Hullu, each lesson or lesson series could be viewed as a 'teaching cycle', which consists of four stages. The first stage aims at motivating students to learn, the second focuses on asking questions to provoke learning, the third requires students to answer questions or to solve problems, and the fourth stage aims at the application of knowledge and/or testing for comprehension (2008, p. 24). Every stage of the teaching cycle can be carried out by the teacher, by both teacher and students, or by the students themselves. In this respect, Janssen and De Hullu identified four basic types of teaching. 'Type 1' teaching, labeled 'answer-based teaching', starts with the third stage, which is carried out by the teacher, followed by the fourth stage, which is carried out by both teacher and students. The other three types of teaching (i.e., type 2, 3, and 4), labeled 'question-based teaching', comprise all four stages of the teaching cycle. However, they differ in how much the stages are carried out by the students. Both 'type 2' and 'type 3' teaching are characterized by the fact that the first and second stage are carried out by the teacher (i.e., teacher-regulated). However, in 'type 2' teaching, the third stage is teacher-regulated and the fourth is regulated by both teacher and students. In contrast, 'type 3' teaching is characterized by the fact that both the third and fourth stage are student-regulated or regulated by both teacher and students. In 'type 4' teaching, all four stages are student-regulated or are carried out by both teacher and students. As mentioned, the explorative interview study (study 1, chapter 2) showed that some teachers expressed beliefs reflecting only two types of regulation, whereas the beliefs of others reflected all three types of regulation (including student-regulated learning). A possible explanation is that the former group of teachers primarily thought in terms of 'type 1' or 'type 2' teaching, whereas the latter group expressed beliefs that mainly reflected 'type 3' or 'type 4' teaching.

The competence of explicit professional reasoning

According to the conclusions of this dissertation, the rationale behind teacher beliefs often remained to a greater or lesser extent implicit. Most of the interviewees were not accustomed to articulate and explicate their beliefs or had difficulties in articulating a clear line of argumentation to justify their beliefs. Thus, these findings suggest that teachers might struggle with explicating their professional reasoning, which might imply that they need to develop these competencies (cf. Kansanen, et al., 2000; Loughran & Berry, 2005). In the educational literature, teachers' competence of professional reasoning is advocated for the following two reasons.

First, education is served by thoughtful professionals, who "do more than follow their intuition based on experience and traditions" (Staub, West, & Bickel, 2003, p. 8). Thoughtful professionals consciously reflect on the basic questions that are at the core of teachers' professional reasoning, namely "Why is this specific content to be taught?" and "Why will it be taught in this particular way?" (Staub, et al., 2003, p. 8). This professional reasoning depends on teachers' beliefs about, for example, the goals of education, the pedagogy of teaching and learning particular content, and the nature of the subject, as well as teachers' knowledge about particular student characteristics and research on effective instructional practices (Staub, et al., 2003).

Second, explicit professional reasoning contributes not only to high quality learning opportunities for students, but also to "signature pedagogies" for novice teachers (cf. Zanting, et al., 2003). According to Shulman (2005), signature pedagogies "are types of teaching that organize the fundamental ways in which future practitioners are educated for their new professions" (p. 52). Therefore, practitioners who are competent in modeling deliberate practice, for example by explicit professional reasoning, contribute also to a high quality teaching and learning environment for novice teachers.

6.4.3 Strengths and limitations of the studies

Strengths

The content and structure of teacher belief systems were investigated by both quantitative and qualitative methods of data collection and analysis. We combined two survey studies with two small-scale interview studies. A strength of this research design is that it enables us to interpret some of the findings of the survey studies with help of the qualitative data of the small-scale interview studies (cf. Patton, 2002).

Another strength of the design is that we started our investigation of teachers' belief systems with an explorative interview study (study 1, chapter 2). The interview format included a broad range of questions to elicit teachers' beliefs about important goals, effective instructional strategies, the nature of physics content, student characteristics that should be taken into account, characteristics of the learning environment, forms of assessment, and so on. The differences in teacher beliefs found in this particular study informed our decisions concerning the focus of the follow-up studies. We do not claim that this approach resulted in a comprehensive view of all the beliefs that teachers possibly hold about the goals and pedagogy of teaching and learning physics. However, the research design enabled us to explore whether particular differences in the content and structure of individual teachers' belief systems were reflected by larger groups of physics teachers.

Study 4 (chapter 5) was characterized by a comprehensive focus on teachers' beliefs about the goals of physics education, the pedagogy of teaching and learning physics, and the nature of physics and science. As a consequence, the focus of this study enabled us both to interpret the conclusions of the two different survey studies by qualitative data and to investigate whether the similarities in teacher beliefs found at a large scale, for instance about important goals of physics education, were also reflected in teachers' individual priorities.

Limitations

A limitation of the study is that we did not triangulate data from multiple groups of teachers. With the exception of study 1, the teachers that participated in the other three studies were from the same sample. In addition, we used an online community of physics teachers as a method of sampling and were confronted with relatively low response rates in the survey studies. However, we expect that our sampling method did not violate the representativeness of the sample because the online community had a large group of members (over 1,600 members were identified as physics teachers working at secondary schools in the Netherlands) and the general characteristics of the teachers that participated in our survey studies showed similarities to those that participated in other studies (e.g., Meelissen & Drent, 2009).

The number of beliefs that could be measured in the questionnaire studies was limited. For each type of belief, we used at least three or four items to measure this belief and, because of the time needed to fill out the questionnaire, we aimed at relatively short questionnaires in an attempt to gain a response rate as high as possible. As a result, the questionnaire studies might not comprise the full range of beliefs about the goals and pedagogy of teaching and learning physics. However, the decisions about what beliefs should be measured were informed by both the explorative study and the educational literature.

Another limitation is that we did not investigate teachers' practices through, for example, observations in the classrooms. These observations could have provided an additional method for eliciting teachers' beliefs (e.g., stimulated-recall interviews) (cf. Meijer, et al., 2002). In addition, the data would have provided us useful insights into the actual context of teaching and the extent to which particular beliefs or priorities manifest themselves in observable teaching behavior. However, because the survey studies (study 2 and 3) showed no clear-cut relations between different types of beliefs, we decided to conduct an in-depth exploration of the content and structure of teachers' belief systems including an investigation of the relationships between beliefs and teaching intentions (study 4).

Furthermore, with regard to the investigation of teachers' beliefs about the nature of physics and science, our questionnaire study (study 3) revealed three clusters of beliefs about the status and utility of scientific knowledge. However, another conclusion was that the role of beliefs about the nature of science was not straightforward. We expected that these beliefs, to some extent, would be tacit and for that reason we triangulated the findings of the questionnaire study (study 3) with those of the small-scale interview study (study 4). The questionnaire study had a relatively low response rate, the factors that were identified explained relatively low percentages of variance, and the reliability scores of the questionnaire scales, though not outstanding, were acceptable. With regard to the interview study, most informative were the questions that prompted teachers to define (in their own words) what characterizes the nature of physics and science and what physicists aim to achieve (Appendix 4, part A). The questions from the validated and widely used open-ended *Views about Nature of Science (VNOS)* questionnaire – Form B (Lederman, et al., 2002) were less successful in eliciting teachers' beliefs in this respect. Teachers struggled to respond to these questions and the particular answers did not show clear relations to other beliefs about the goals and pedagogy of teaching and learning physics. A possible explanation might be that the VNOS focuses on those aspects of the nature of science that are explicitly stated in the targets of science curricula in the United States of America (Abd-El-Khalick, 2012). In the Netherlands, these aspects are not explicitly stated in the targets of the physics curriculum. As a result, there is no explicit need for physics teachers to think about these topics in order to teach physics content to secondary students.

6.5 IMPLICATIONS

6.5.1 Suggestions for further research on teacher beliefs

The conclusions of this dissertation imply that research on teacher beliefs is served by a combination of both quantitative and qualitative methods. Moreover, in measuring these beliefs, the instruments should differentiate between teachers' 'vision of the good' and notions of 'what works' in the complex context of teaching. We consider the following two topics important for further research, namely the *interrelatedness of beliefs in teacher belief systems* and the *manifestation of beliefs in the practice of teaching*.

First, further research is needed to investigate the extent to which it is possible to construct profiles of teachers' interrelated beliefs (Friedrichsen, et al., 2011). With respect to the exploration of teachers' 'orientations towards science teaching' as part of the broader construct of pedagogical content knowledge (PCK) (Abell, 2007), it would be worthwhile to further explore relationships between teachers' beliefs about the pedagogy of teaching and learning science, the goals of science education, and the nature of science. In this respect, a promising approach might be to investigate teachers' beliefs about the purposes of inquiry and hands-on activities in relation to their beliefs about 'scientific literacy' (i.e., goals of science education) and the 'nature of science'. This suggestion is based on the fact that one of the small-scale interview studies (study 4) revealed relations between these particular beliefs. In addition, teachers' different priorities concerning what knowledge, skills, and attitudes are important to teach in the context of physics education suggested differences in the interpretation of the overall goal of 'scientific literacy'.

Second, the manifestation of teachers' beliefs in the practice of teaching could be investigated by focusing on 1) the *interaction* between teacher *beliefs* and different types of *knowledge,* and 2) the manifestation of teacher beliefs in *observable teaching behavior*. The interaction between beliefs and different types of knowledge could be studied by exploring, for example, the development of 'pedagogical constructions' in the process of designing lessons (Janssen, et al., 2009), perceived 'tensions' in matching instructional goals with students' needs and concerns (Berry, 2008), and the interpretation of curricular content and objectives while implementing new curricula (cf. Van den Akker, 1998). In this respect, methods such as concept mapping, laddering, and think-aloud-procedures might be fruitful (Reynolds & Gutman, 1988; Wieringa, et al., 2011; Zanting, et al., 2003). The manifestation of beliefs in observable teaching behavior could be investigated by eliciting teachers' reflections on observed 'pedagogic interventions' (cf. Gholami & Husu, 2010; Loughran & Berry, 2005) by methods such as stimulated-recall interviews (Meijer, 1999).

6.5.2 Teacher education and professional development

Teacher educators play a pivotal role in the education of future teachers. According to Smith (2005), the main requirements teacher educators are expected to meet are: 1) to be a model teacher who is competent in articulating tacit knowledge of teaching and linking practical experiences to the educational literature, 2) to be involved in building a practical and theoretical knowledge base of teaching (e.g., development of new curricula and learning materials, publication of research articles, and so on), 3) to take on leadership roles within and outside the institution and have a positive impact on pre-service and in-service education of teachers, and 4) to facilitate professional development and to be involved in ongoing personal professional development (pp. 182-183). The implications of this dissertation are primarily related to the first two requirements mentioned above.

First, we found that the teachers who participated in our studies were often not accustomed to explicating their beliefs and the rationale behind their beliefs. Therefore, we emphasize the importance of *modeling,* which not only concerns the articulation of beliefs and pedagogical content knowledge (PCK) (Abell, 2007; Loughran, 2007; Loughran & Berry, 2005), but also how to build an explicit rationale for professional teaching behavior by challenging beliefs and personal routines and anchoring these to the formal knowledge base of teaching. In addition, teacher educators should stimulate pre-service teachers in articulating their beliefs and priorities, as well as thinking of what theoretical arguments would either challenge or support their beliefs (cf. Coughlan, 2000). In this respect, a possible fruitful pedagogy would be to use 'dilemma-based cases' derived from a teaching situation (Harrington, 1995). These dilemmas could be examined from a variety of perspectives, including sources of formal knowledge through which the pre-service teachers 1) become aware of alternative perspectives, 2) are challenged to explicate and justify their own rationale by using practical knowledge and formal knowledge, and 3) are stimulated to critically reflect on their teaching practice, such as what aspects of practice are problematic, how to cope with practical constraints, and what would characterize deliberate practice within this particular teaching context (Hewson, 2007). Besides such a pedagogy, teacher educators could make use of concept maps and metaphors to elicit beliefs or reflect on the appropriateness of instructional strategies based on the examples of different lesson plans (Oolbekkink-Marchand, 2006; Zanting, et al., 2003). In addition, they could trigger the rationale behind beliefs, for instance by using the method of 'laddering' (Reynolds & Gutman, 1988).

Second, we concluded that the role of teachers' beliefs about the nature of science in the context of physics education was not straightforward, partly because teachers struggled to explicate these beliefs. Therefore, teacher educators in the domain of physics and science education could play an important role in framing and underpinning an explicit discussion about what aspects of the nature of science are important to teach in the context of physics and science education, what roles teachers could or should fulfill in promoting students' 'scientific literacy' (cf. Eijkelhof, 2001), and what pedagogy contributes to achieving these goals.

In this respect, it is important that teacher educators themselves explicitly reflect on their own beliefs about the nature of science and how these beliefs impact notions of 'scientific literacy', the interpretation of curricular objectives, the purpose of inquiry, and instructional strategies that are considered to be appropriate in the domain of physics and science. Furthermore, the teacher education program could provide pre-service teachers with particular tools for paying attention to aspects of the nature of science in relation to 'scientific literacy' (cf. Corrigan, et al., 2011; Duit, Niedderer, & Schecker, 2007; Sadler, et al., 2010). For example, teacher educators could focus on what types of questions are suitable for discussing aspects of the nature of science or guiding students in the process of inquiry and technological design (Lunetta, Hofstein, & Clough, 2007; Terwel, 2009). Moreover, they could pay attention to the organization of scientific mini-debates among students about moral dilemmas concerning sustainability or the use and applications of technology in society (Boerwinkel, Veugelers, & Waarlo, 2009; Eijkelhof, 1992; Osborne & Dillon, 2008; Slater, 2010).

6.5.3 Implementation of curriculum innovations

As mentioned in the general introduction (see chapter 1), a successful implementation of a curriculum innovation depends, among other things, on the extent to which teachers perceive a match between the innovation and their personal routines and beliefs. In the context of Dutch physics education, the 'NiNa versus LeNa debate' suggested more or less fundamental differences in teachers' beliefs about the goals of physics education and the appropriate pedagogy for enhancing students' understanding of physics content. Such fundamental differences were not supported by the conclusions of the questionnaire study, because physics teachers, on average, held similar beliefs about the goals and pedagogy of teaching and learning physics. However, the differences that were found in teachers' priorities concerning what knowledge, skills, and attitudes are important to teach, as well as the gradual differences between teachers with regard to the regulation of students' learning processes are important enough to be taken into account when implementing curriculum innovations, such as the new examination program of physics in the Netherlands.

Kuiper (2009) suggested a strategy for implementing curriculum innovations that combines three approaches, namely *bottom-up*, *top-down*, and *sideways*. In the 'bottom-up' approach, the expertise and experiences of teachers that have piloted the curriculum innovation is taken as a point of departure in order to create ownership among teachers. According to teachers who have piloted the new physics curriculum in the Netherlands, one of the major factors contributing to a lack of time in teaching the curricular content, is that the general targets are too broadly interpreted by teachers (Commissie Vernieuwing Natuurkundeonderwijs havo/vwo [Committee revision physics education], 2010). In the 'top down' approach, the curriculum innovation is implemented by formal regulations, which are established by, for example, the national government. Obviously, one might expect a tension between the 'bottom-up' and the 'top-down' approach. According to Kuiper (2009), the 'top-down' approach could contribute to the implementation of curriculum innovations by providing clear guidelines and a clear 'vision statement' about the curriculum. However, if such 'top-down' guidelines are communicated in the form of strict prescriptions or rules, this might easily lead to resistance among teachers. We think that the 'top-down' approach should stimulate an explicit discussion about the core of the curriculum. Such a discussion could lead to an increased awareness among teachers and teacher educators about their individual priorities concerning the targets of the curriculum, as well as the extent to which these priorities differ from their colleagues. Moreover, such a discussion could contribute to mutual understanding in the process of peer collaboration. In the context of Dutch physics education, the 'top-down' approach could frame the discussion by providing a clear and consistent 'vision' based on different theoretical perspectives on the general targets of the curriculum, as well as how particular aspects of 'scientific literacy' and the nature of physics and science are reflected in the targets of the new examination program (cf. Anderson, 2007; Commissie Vernieuwing Natuurkundeonderwijs havo/vwo [Committee revision physics education], 2006; Duit, et al., 2007; Osborne & Dillon, 2008). Finally, the 'sideways' approach aims at teacher learning and professional development, for example by providing examples of good practice (e.g., lesson series and learning materials) and building communities of practitioners to enable the exchange of ideas and collaboration. Given the fact that we found differences in teachers' beliefs about the regulation of students' learning processes, it is important that these examples of good practice connect to different 'basic types of teaching' (cf. Janssen & De Hullu, 2008), instead of prescribing or describing just one particular pedagogy.

6.5.4 The joint responsibility of physics teachers, teacher educators, and physicists

For physics teachers, perhaps the most joyful experience is when they become aware that their students really engage in the study of physics. In other words, when students have become excited about the content they are intrinsically motivated to explore the world of physics. However, inspiring enthusiasm in students for studying physics should be considered a responsibility not only of physics teachers, but also of physics teacher educators and physicists.

To clarify this statement, we use the metaphor of physics as a country. The physicists, as citizens of that country, share certain (scientific) values and talk in a particular (scientific) language. They are aware of contemporary developments in the field and they know what 'hotspots' would make it worthwhile to visit their country. It is their responsibility to make both physics teachers and physics teacher educators aware of these developments and to provide access to exciting 'hotspots', for example by promoting the domain through demonstrations and shows at secondary schools (e.g., the successful Dutch 'Freezing Physics' road show of Rino, in which physics students of Leiden University conduct spectacular experiments with liquefied nitrogen), or to provide access to facilities of the science laboratory (e.g., the Dutch Junior Science Lab of Leiden University). The physics teacher educators could be viewed as 'expert guides'. They should know what 'trips' are suitable for students of different ages, what 'hotspots' are interesting to visit in this respect, what basic vocabulary, skills, and techniques are needed to 'survive' in the world of physics, and what information should be provided to students to prevent them from getting bored or lost during the 'trip'. It is their responsibility to act as a mediator between the physicists and the physics teachers. Moreover, they should educate physics teachers to be competent guides in the world of physics. The physics teachers are viewed as educated 'guides', who take their students on a tour through parts of the country. Sometimes they need to prepare their students for a particular 'trip' by teaching basic skills, techniques, and vocabulary. Other times, they could organize a guided tour with specific information about particular developments or 'hotspots' or they could provide their students with only a roadmap or GPS-system to enable free exploration of the countryside. In this respect, it is up to the 'guide' to decide upon what 'trip' or approach would be most suitable when particular student characteristics, time issues, and 'points of destination' are taken into account. Moreover, it is the responsibility of the teacher to keep informed about new 'hotspots' and changing insights concerning the content and education of basic skills and techniques.

Hopefully, such a joint responsibility and collaboration between physics teachers, physics teacher educators, and physicists would eventually lead to increased numbers of students who are fascinated by the domain of physics. After all, for those who are interested, there is an amazing world to explore!

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Summary/Samenvatting

SUMMARY

This doctoral thesis comprises four studies on the content and structure of physics teachers' belief systems about teaching and learning physics in secondary education in the Netherlands. The first introductory chapter is followed by four chapters, which focus on the four studies. In the final chapter, the results of the different studies are summarized and the theoretical and practical implications are discussed.

Chapter 1: General introduction

This chapter provides an overview of the research in this dissertation. Research on teacher beliefs is important, because beliefs play a critical role in organizing information and shaping teachers' instructional decisions. In particular, beliefs about the *goals* of physics education, the *pedagogy* of teaching and learning physics, and the *nature of science* are deemed important. This research aims at gaining more insight into the content and structure of physics teachers' belief systems. The studies in this dissertation are based on some fundamental assumptions about the *stability*, *organization*, and *functionality* of teacher beliefs. Moreover, we treat beliefs as part of the broader construct of teacher practical knowledge, because in the mind of a teacher, knowledge and beliefs are inextricably intertwined. Four studies were conducted among physics teachers working at secondary schools in the Netherlands (students aged 12-18).

The chapter starts with a discussion of the knowledge base of teaching to frame the research. Next, the literature is reviewed by focusing on research regarding teacher beliefs (including the relationship between beliefs and the practice of teaching), research on science education (including the content and goals of science curricula), and a description of the context of secondary physics education (students aged 12-18) in the Netherlands. Furthermore, the research literature on teachers' beliefs about the goals of physics education, the pedagogy of teaching and learning physics, and the nature of science is briefly introduced, followed by an outline of the dissertation.

Chapter 2: An exploration of teacher beliefs about making physics comprehensible, motivating students, and different types of regulation: An interview study

This chapter presents the results of a small-scale semi-structured interview study (N=8) on physics teachers' and physics teacher educators' beliefs about the *goals* and *pedagogy* of teaching and learning physics. More specifically, we investigated beliefs about effective ways for making physics comprehensible and for motivating students (aged 12-18) to learn physics content. The chapter starts with an introduction of the topic by referring to the problematic image of physics and science education for the past two decades; many students perceive science subjects as difficult or lose interest due to the way it is taught. Next, after a discussion of some general characteristics of teacher belief systems, the literature is reviewed by focusing on the general goals of physics education, conceptions of learning in general, teaching procedures to

enhance students' comprehension of content, and attempts to increase student engagement and motivation. The research questions focus on the content of beliefs about 'making physics comprehensible' and 'motivating students to learn the content', the extent to which the goals of physics education are reflected in these beliefs, and what types of regulation (i.e., regulation of students' learning processes) can be identified in teachers' and teacher educators' beliefs. The participants of this study were selected by purposeful sampling. The data were collected in December and January, 2008/2009 and were analyzed in an iterative process by qualitative methods.

One of the conclusions of this study was that most beliefs expressed by the teachers and teacher educators reflected two goals, namely 'learning and understanding conceptual physics knowledge' and 'learning and applying problem-solving and inquiry skills'. The practical implications of these beliefs could be summarized in the following five instructional guidelines for secondary physics education: 1) let students conduct inquiry and engage in hands-on activities, 2) let students solve challenging and carefully selected problems, 3) try to make (abstract) physics content come alive for students, 4) let students collaborate with peers, and 5) take the diversity of students and their personal characteristics into account. In this respect, no sharp contrast was found between beliefs about 'making physics comprehensible' and 'motivating students'. Moreover, the interviewees stressed the importance of repetitive practice in order to become skilled in problem-solving and the application of conceptual physics knowledge. A few of teachers' and teacher educators' beliefs reflected the goal of 'learning about the nature of physics knowledge development and physics as a research field'. For example, the interviewees emphasized the importance of helping students gain an understanding of the empirical and tentative nature of scientific knowledge and to become aware of applications of physics in daily life.

Another conclusion was that the sample could be divided into two groups based on the types of regulation that were expressed in the beliefs mentioned above. Half of the sample expressed only two types of regulation, namely teacher-regulated learning and regulation by both teacher and students. In other words, this part of the sample thought that the teacher is primarily responsible for transmitting and clarifying the content of physics. In addition, they emphasized the importance of collaborative problem-solving activities in which students are partly responsible for conducting experiments and processing and applying conceptual physics knowledge. The other half of the sample expressed beliefs reflecting also a third type of regulation, namely student-regulated learning. These interviewees were primarily in favor of students' constructing conceptual physics knowledge by themselves and conducting problem-solving and inquiry activities on their own. They emphasized that the teacher should guide and monitor this process, for example by providing 'procedural structure' and asking questions. Overall, no clear relations were found between the specific goals of physics education (e.g., learning conceptual physics knowledge or learning inquiry skills) and particular types of regulation.

Chapter 3: Beyond the dichotomy of teacher- versus student-focused education: A survey study on physics teachers' beliefs about the goals and pedagogy of physics education

This chapter reports on a questionnaire study on the content and structure of physics teachers' beliefs about the *goals* and *pedagogy* of teaching and learning physics. The chapter starts with an introduction of research findings about the content and structure of teachers' belief systems followed by an overview of various studies on science teachers' beliefs about teaching and learning in general and domain-specific beliefs. The research questions focus on the content and structure of physics teachers' belief systems, with a particular focus on *beliefs about teaching and learning in general* (i.e., beliefs about the goals of education in general, learning, and the regulation of students' learning processes) and *domain-specific beliefs* (i.e., curriculum emphases in teaching physics). In March 2011, a questionnaire was administered to a sample of physics teachers working at secondary schools (students aged 12-18) in the Netherlands. The sample consisted of 126 teachers (response rate 56.5%). The data were analyzed by quantitative methods such as two-way ANOVAs, bivariate Pearson correlations, and hierarchical cluster analysis.

One of the main conclusions of this study was that physics teachers, on average, held similar beliefs about the goals and pedagogy of teaching and learning physics. With regard to the goals of physics education, the teachers held both 'transmission-/qualification-oriented' and 'learning-/moral-oriented' beliefs about the goals of education in general. In other words, they thought that education should focus not only on the transmission of core subject knowledge and students' qualification for higher education, but also on learners' construction of knowledge, responsibility for their own learning processes, collaboration with peers, and the adoption of a critical attitude. With reference to teachers' beliefs about domain-specific goals, namely their curriculum emphases in teaching physics, they had surprisingly no explicit preference for one of the three curriculum emphases. In more detail, they thought that theoretical notions should be taught first, because such notions can provide a basis for understanding the natural world and are also needed for students' future education (i.e., 'fundamental physics' emphasis). In addition, they also considered it important for students to develop an understanding of the nature of physics knowledge development (i.e., 'knowledge development in physics' curriculum emphasis), as well as for physics education to focus on the relations between applications of physics and technological knowledge, and students' personal lives or the decisions they make (i.e., 'physics, technology, and society' curriculum emphasis). Furthermore, with respect to teachers' beliefs about the regulation of students' learning processes, the study showed that teachers held similar beliefs about the importance of not only teacher-regulated learning of physics content, but also student-regulated learning and students' active knowledge construction.

Another conclusion was that the beliefs of physics teachers about the goals of education in general and beliefs about the goals of physics education (i.e., curriculum emphases) formed an interrelated belief system. A strong positive correlation was found between 'transmission-/

qualification-oriented' beliefs and the 'fundamental physics' curriculum emphasis. In addition, predominantly moderate positive correlations were found between the other beliefs about the goals of education in general and the different curriculum emphases in teaching physics. However, the relationships between beliefs about the goals of physics education, both in general and domain-specific, and beliefs about the pedagogy of teaching and learning physics (i.e., beliefs about learning and the regulation of students' learning processes) were only weak or non-significant. Moreover, hierarchical cluster analysis did not result in the identification of sub groups of teachers with similar belief patterns. The chapter concludes with a discussion of labels such as 'teacher-focused' and 'student-focused', which are often used in the educational literature. These labels suggest a dichotomy, which is not supported by the empirical data of this study. Therefore, it is argued that research on teacher beliefs is served by a more refined terminology to describe the content and structure of teachers' belief systems.

Chapter 4: The use of contrasting philosophical positions to explore teacher beliefs about the nature of science: A large-scale survey study

This chapter describes the results of a large-scale survey study on the content and structure of physics teachers' beliefs about the *nature of science*. The topic is introduced by focusing on the role of teachers' beliefs about the nature of science in the practice of teaching science. Next, the main findings of research on teacher beliefs about the nature of science are reviewed, followed by a discussion of some controversial NOS issues that have been the center of the discourse of the philosophy of science. The research question of this study focuses on the content of teachers' beliefs about the nature of scientific knowledge claims. In addition, the relationships between these beliefs are explored. A questionnaire was developed containing 24 Likert-type statements that were based on ideal types of contrasting philosophical positions on three dimensions – 'intentional', 'epistemic', and 'methodological'. After piloting the questionnaire, data were collected in March 2010 by administering the questionnaire to a sample of physics teachers working at secondary schools in the Netherlands. The sample consisted of 299 teachers (response rate 17.9%). Data were analyzed by quantitative methods such as Principal Axis Factoring, bivariate Pearson correlations, and hierarchical cluster analysis.

Explorative factor analysis resulted in the extraction of three factors that were labeled beliefs about the *status*, *purpose*, and *utility* of scientific knowledge. On average, the physics teachers in this sample held similar beliefs about the 'purpose' of scientific knowledge. In particular, they thought that scientific theories, laws, and principles aim to provide a correct description, explanation, and prediction of natural phenomena. Another conclusion was that they differed in their beliefs about the 'status' and 'utility' of scientific knowledge. However, no significant differences between beliefs were found when background variables such as gender, age, years of teaching experience, and teachers' previous education were taken into account. Furthermore, with regard to the structure of these beliefs, (significant) weak positive correlations were found between teachers' beliefs about the 'purpose' of scientific knowledge on the one hand, and beliefs about the 'status' and 'utility' of scientific knowledge on the other. Hierarchical cluster analysis resulted in the identification of three clusters that were labeled 'absolutist' (N=71), 'relativist' (N=112), and 'pragmatist' (N=116). The teachers that were grouped in the 'absolutist' and 'relativist' cluster differed in their beliefs about the 'status' of scientific knowledge. The 'absolutist' cluster, on average, thought that scientific theories, laws, and principles are empirically proven, absolute and objective. In contrast, the 'relativist' cluster disagreed with this belief; they thought that the status of scientific knowledge was relative. The teachers that were grouped in the 'pragmatist' cluster had high mean scores on the scale measuring beliefs about the 'utility' of scientific knowledge. They 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 activities. The chapter concludes with a discussion of the appropriateness of the terminology that is often used to describe and categorize beliefs about the nature of science. More specifically, we argue for a more refined terminology than the often used distinction between 'naïve' versus 'sophisticated' beliefs.

Chapter 5: Depicting physics to secondary students: A small-scale explorative interview study on physics teachers' beliefs and intentions

This chapter discusses the results of a small-scale structured interview study (N=3) on the content and structure of physics teachers' beliefs about the *goals* and *pedagogy* of teaching and learning physics, as well as their beliefs about the *nature of physics and science*. Moreover, the study includes an exploration of the relationships between these beliefs and teachers' teaching intentions that were expressed in a lesson plan of an introductory physics lesson. After the introduction of the topic, the chapter starts with a presentation of the literature by means of two hypothetical examples. These examples illustrate the relationships that might be expected between the beliefs mentioned above and teachers' instructional choices concerning what content should be taught and how it should be taught. Next, a brief discussion of the literature on the relationship between beliefs, intentions, and the practice of teaching is provided. The research questions focus on the content and structure of these teacher belief systems, as well as the extent to which beliefs are reflected by a teacher's teaching intentions. The three physics teachers were selected by purposeful sampling. The sample consisted of one teacher from each of the three clusters that were identified in the previous chapter ('absolutist', 'relativist', and 'pragmatist'). The interviews were conducted in February 2011. The interview format contained a series of open-ended questions and an assignment in which the teacher was asked to design a 50-minute lesson to introduce physics to secondary students (aged 12-14). The assignment was used not only to investigate teachers' intentions, but also to explore the beliefs of teachers. Data were analysed by an interpretivist approach in an iterative process; the process started with open coding followed by an analysis of similarities and differences in teachers' beliefs and intentions.

One of the conclusions of this study was that teachers' beliefs about the nature of physics and science were characterized by beliefs about the aim of scientific inquiry, the purpose of physics as a research field, the tentativeness of scientific theories, and the difference between scientific theories and laws. In addition, the teachers did not clearly differentiate between the broader domain of physics and the school subject physics. Furthermore, teachers' beliefs about the goals of physics education revealed different priorities concerning what knowledge, skills, and attitudes were important to teach. For example, one teacher mainly focused on the transmission of conceptual physics knowledge, whereas another teacher emphasized the training of inquiry skills and teaching students to conduct inquiry on their own. However, the rationale behind these beliefs often remained to a greater or lesser extent tacit. With respect to beliefs about the pedagogy of teaching and learning physics, the conclusion was drawn that teachers differed in their beliefs about adaptive teaching and the purposes of practical work and inquiry activities. Furthermore, it was found that teachers' beliefs about the purpose of practical work and inquiry activities were related to teachers' beliefs about the goals of physics education and beliefs about the aim of scientific inquiry. These related beliefs were to some extent reflected in teachers' intentions concerning lesson objectives and particular teaching and learning activities. The chapter concludes with a discussion of the rationale behind teacher beliefs, for example by attempting to answer the question of why the rationale often remained to a greater or lesser extent tacit. In addition, the discussion focuses on the extent to which beliefs about the nature of physics and science are possibly biased by teachers' perceptions of the nature of the school subject physics.

Chapter 6: General conclusions and discussion

This last chapter starts with a summary of the main aim of the dissertation including the overall research question, which is focused on the content and structure of physics teachers' belief systems. Next, after summarizing the main conclusions of the four studies, these are synthesized into two sets of general conclusions with various sub conclusions. The questionnaire studies showed that, on average, teachers' belief systems about teaching and learning physics were composed of interrelated beliefs about the goals of physics education and more or less distinct beliefs about teacher-regulated learning, student-regulated learning and knowledge construction, and the nature of science. The interview studies showed that teachers differ in their priorities concerning the goals of physics education, as well as the extent to which their beliefs about the pedagogy of teaching and learning physics reflect student-regulated learning. Moreover, the relationship between beliefs about the nature of science and beliefs about the goals and pedagogy of teaching and learning physics is not straightforward.

The general discussion starts with the nature of the method that was used in the four studies, followed by a discussion of the conclusions in relation to different theoretical perspectives on teacher knowledge and beliefs. These perspectives comprise 'orientations towards science teaching' as part of the broader construct of *pedagogical content knowledge* (PCK), teachers' practical knowledge or 'phronesis', teachers' 'pedagogical constructions' (which are the result of an interaction between beliefs and different types of knowledge), and the competence of explicit professional reasoning. In addition, various suggestions for further research on teacher beliefs are made, such as the further exploration of the interrelatedness of beliefs in teachers' belief systems and the manifestation of beliefs in the practice of teaching. Moreover, practical implications for teacher education and professional development are discussed by emphasizing, among other things, the importance of *modeling* the articulation of beliefs, as well as focusing on how to build an explicit rationale (which is anchored to the knowledge base of teaching). Furthermore, other implications stress the importance of taking differences in teacher beliefs into account in the process of implementing curriculum innovations. For instance, with regard to Dutch physics education, suggestions are made for having an explicit discussion among physics teachers, teacher educators, and curriculum innovators about the targets of the curriculum, as well as the role of beliefs about the nature of science in relation to the overarching goal of 'scientific literacy'. The chapter concludes with a call for the joint responsibility of physics teachers, teacher educators and physicists in inspiring enthusiasm in students for studying physics.

SAMENVATTING

Dit proefschrift omvat vier deelstudies naar de inhoud en structuur van de opvattingssystemen van natuurkundedocenten over het leren en onderwijzen van natuurkunde in het voortgezet onderwijs (VO) in Nederland. Na een inleidend hoofdstuk volgen vier hoofdstukken waarin elk van de deelstudies nader wordt uitgewerkt. In het slothoofdstuk worden de bevindingen van de deelstudies samengevat gevolgd door een bespreking van de theoretische en praktische implicaties.

Hoofdstuk 1: Algemene introductie

Dit hoofdstuk biedt een overzicht van het onderzoek in dit proefschrift. Het onderzoek heeft als doel om meer inzicht te krijgen in de inhoud en structuur van de opvattingssystemen van natuurkundedocenten. Onderzoek naar docentopvattingen is relevant, omdat deze een belangrijke rol spelen in het ordenen van informatie. Bovendien beïnvloeden ze de beslissingen van docenten ten aanzien van onderwijs en instructie. Met name opvattingen over de *doelen* en *didactiek* van het natuurkundeonderwijs alsmede opvattingen over de *aard van natuurwetenschap* worden in dit kader van belang geacht.

In totaal zijn vier deelstudies uitgevoerd onder natuurkundedocenten die werkzaam zijn in het voortgezet onderwijs in Nederland (de leeftijd van de leerlingen is ongeveer 12-18 jaar). Deze deelstudies zijn gebaseerd op enkele fundamentele assumpties over de *stabiliteit*, *organisatie* en *functionaliteit* van docentopvattingen. Daarbij worden opvattingen beschouwd als een onderdeel van het bredere construct van de praktijkkennis van docenten, omdat kennis en opvattingen in het denken van een docent met elkaar verweven zijn.

Het hoofdstuk begint met een bespreking van de kennisbasis voor het onderwijs om zo dit onderzoek te voorzien van een theoretisch kader. Vervolgens wordt de literatuur besproken met een specifieke focus op onderzoek naar docentopvattingen (met inbegrip van de relatie tussen opvattingen en de onderwijspraktijk) en onderzoek naar het bèta-onderwijs (waaronder de inhoud en doelen van bèta-curricula). Na een beschrijving van de context van het Nederlandse natuurkundeonderwijs (VO) wordt de aandacht gevestigd op docentopvattingen over de doelen van het natuurkundeonderwijs, de didactiek van het leren en onderwijzen van natuurkunde en de aard van natuurwetenschap. Het hoofdstuk sluit af met een beschrijving van de opzet van de dissertatie met daarbij een kort overzicht van de inhoudelijke hoofdlijn van elke deelstudie.

Hoofdstuk 2: Een exploratie van docentopvattingen over het begrijpelijk maken van natuurkunde, het motiveren van leerlingen en verschillende regulatietypen: een interviewstudie

In dit hoofdstuk worden de resultaten van een kleinschalige, semigestructureerde interviewstudie (N=8) gepresenteerd, waarin de opvattingen van natuurkundedocenten en docentopleiders (werkzaam bij de docentopleiding natuurkunde) over de doelen en didactiek van het natuurkundeonderwijs zijn bevraagd. In het bijzonder zijn opvattingen onderzocht over effectieve manieren om leerlingen van 12-18 jaar te motiveren de vakinhoud te leren en daarnaast om de leerstof begrijpelijk te maken.

Het hoofdstuk start met een introductie van het onderwerp, waarbij gerefereerd wordt aan het feit dat het natuurkunde- en bèta-onderwijs als geheel de laatste twee decennia te kampen hebben met een problematisch imago; veel leerlingen percipiëren de inhoud van de bèta-vakken als moeilijk of verliezen hun interesse door de wijze waarop het vak onderwezen wordt. Na een bespreking van enkele algemene kenmerken van de opvattingssystemen van docenten, volgt een bespreking van de literatuur over de algemene doelen van het onderwijs, concepties van leren, instructiestrategieën om het begrip van leerlingen van de vakinhoud te vergroten en pogingen om de betrokkenheid en motivatie van leerlingen te verhogen.

De onderzoeksvragen hebben in de eerste plaats betrekking op de inhoud van (docent) opvattingen over 'het begrijpelijk maken van natuurkunde' en 'effectieve manieren om leerlingen te motiveren tot het leren van de vakinhoud'. Verder wordt onderzocht in hoeverre deze opvattingen de doelen van het natuurkundeonderwijs reflecteren en welke regulatietypen (d.i. regulatie van de leerprocessen van leerlingen) geïdentificeerd kunnen worden in de opvattingen van de docenten en docentopleiders. De participanten in deze studie zijn door middel van doelgerichte selectie geselecteerd. De data, verzameld in december en januari 2008/2009, zijn in een iteratief proces met kwalitatieve methoden geanalyseerd.

Een van de conclusies van deze studie is dat de opvattingen van de participerende docenten en docentopleiders voornamelijk twee doelen van het natuurkundeonderwijs reflecteren, namelijk 'het leren en begrijpen van conceptuele natuurkundekennis' en 'het leren en toepassen van probleemoplossende vaardigheden en onderzoeksvaardigheden'. Er is bovendien geen duidelijk onderscheid gevonden wat betreft de inhoud van opvattingen over het 'begrijpelijk maken van natuurkunde' en 'het motiveren van leerlingen'. De praktische implicaties van de onderzochte opvattingen kunnen worden samengevat in de volgende vijf richtlijnen voor instructie: 1) laat leerlingen practica doen en onderzoek uitvoeren, 2) laat leerlingen uitdagende en zorgvuldig geselecteerde problemen oplossen, 3) probeer om abstracte natuurkundige vakinhoud te verlevendigen voor leerlingen, 4) laat leerlingen samenwerken met klasgenoten en 5) houd rekening met de diversiteit en persoonlijke kenmerken van leerlingen.

De geïnterviewde personen hebben bovendien het belang van herhaaldelijk oefenen benadrukt teneinde vaardig te worden in het oplossen van problemen en het toepassen van conceptuele natuurkundekennis. Een klein deel van de onderzochte opvattingen reflecteert het doel van 'leren over de aard van natuurkundige kennisontwikkeling en natuurkundig wetenschappelijk onderzoek'. Zo hebben de geïnterviewden bijvoorbeeld aangegeven dat het belangrijk is dat leerlingen inzicht verwerven in de empirische en voorlopige aard van natuurwetenschappelijke kennis en dat zij zich bewust worden van de toepassingen van natuurkundige kennis in het leven van alledag.

Een andere conclusie is dat de groep van participerende docenten en docentopleiders opgesplitst kan worden in twee groepen op grond van de regulatietypen die in hun opvattingen zijn geïdentificeerd. In de opvattingen van de ene helft zijn twee regulatietypen onderscheiden, te weten docent-gereguleerd leren en regulatie door zowel docent als leerlingen (gedeelde regulatie). De personen in deze groep zijn van mening dat de docent primair verantwoordelijk is voor het overdragen en verhelderen van de natuurkundige vakinhoud (docent-regulatie). Daarnaast benadrukken zij het belang van samenwerking bij probleemoplossende leeractiviteiten, waarbij de leerlingen deels zelf verantwoordelijk zijn voor het uitvoeren van experimenten en het verwerken en toepassen van conceptuele natuurkundekennis (gedeelde regulatie). De opvattingen van de andere helft van de geïnterviewden reflecteren nog een derde regulatietype. Naast de bovengenoemde twee regulatietypen zijn deze personen er ook voorstander van dat leerlingen zelfstandig problemen oplossen en onderzoeksactiviteiten uitvoeren en zelf conceptuele natuurkundekennis construeren (leerling-regulatie). Zij geven daarbij wel aan dat het belangrijk is dat de docent toezicht houdt op het gehele leerproces en de leerlingen begeleidt, bijvoorbeeld door het proces 'procedureel te structureren' of door vragen te stellen.

Over het geheel genomen zijn er verder geen duidelijke relaties gevonden tussen specifieke doelen van het natuurkundeonderwijs (bijvoorbeeld het 'leren van conceptuele natuurkundige kennis' of het 'leren van onderzoeksvaardigheden') en bepaalde regulatietypen.

Hoofdstuk 3: Een stap verder dan de dichotomie van docent- en leerlinggericht onderwijs: een vragenlijststudie naar de opvattingen van natuurkundedocenten over de doelen en didactiek van het natuurkundeonderwijs

In dit hoofdstuk worden de resultaten gepresenteerd van een vragenlijststudie, waarbij de opvattingen van natuurkundedocenten over de *doelen* en *didactiek* van het natuurkundeonderwijs zijn onderzocht. De focus ligt daarbij op de inhoud en structuur van hun opvattingssystemen. Het hoofdstuk begint met een introductie van de onderzoeksliteratuur over de inhoud en structuur van opvattingssystemen (onderzocht bij docenten), gevolgd door een overzicht van diverse studies naar de opvattingen van bèta-docenten over onderwijs en leren in het algemeen. In dit kader wordt ook aandacht besteed aan onderzoek naar hun domeinspecifieke opvattingen.

De onderzoeksvragen van de vragenlijststudie betreffen de inhoud en structuur van de opvattingssystemen van natuurkundedocenten. De focus ligt specifiek op hun *opvattingen over onderwijs en leren in het algemeen* (d.i. opvattingen over de doelen van het onderwijs, leren en de regulatie van de leerprocessen van leerlingen) en *domeinspecifieke opvattingen* (d.i. 'curriculum emphases' in het natuurkundeonderwijs). In maart 2011 is een vragenlijst rondgestuurd onder natuurkundedocenten die lesgeven op scholen van het voortgezet onderwijs in Nederland. De respons was N=126 (56,5%). De data zijn met kwantitatieve methoden, zoals twee-factor variantieanalyse, bivariate Pearson-correlaties en hiërarchische clusteranalyse, geanalyseerd.

Een van de hoofdconclusies van deze studie is dat de natuurkundedocenten gemiddeld genomen weinig onderscheidende opvattingen hebben over de doelen en didactiek van het natuurkundeonderwijs. Wat betreft de doelen van het natuurkundeonderwijs is gebleken dat de docenten zowel 'transmissie-/kwalificatiegeoriënteerde' en 'leren-/moreelgeoriënteerde' opvattingen hebben over de algemene doelen van het onderwijs. Met andere woorden, ze vinden dat het in het onderwijs niet alleen moet gaan om de overdracht van vakinhoudelijke kennis en kernbegrippen en de kwalificatie van leerlingen voor het vervolgonderwijs, maar ook dat leerlingen moeten leren om hun eigen kennis te construeren, verantwoordelijk te zijn voor hun eigen leerprocessen, samen te werken met hun leeftijdgenoten en een kritische attitude te ontwikkelen.

Een verrassend resultaat met betrekking tot de domeinspecifieke opvattingen van deze docenten, namelijk hun 'curriculum emphases' in het natuurkundeonderwijs, is dat er geen expliciete voorkeur is gevonden voor een van de drie 'emphases'. Specifieker geformuleerd vinden zij dat het belangrijk is om theoretische noties eerst te onderwijzen, omdat zulke noties een basis kunnen verschaffen voor begrip van de natuur en bovendien nodig zijn voor het toekomstig onderwijs van leerlingen (d.i. 'fundamentele natuurkunde' emphasis). Daarnaast vinden zij het minstens zo belangrijk dat leerlingen een begrip ontwikkelen van de aard van natuurkundige kennisontwikkeling (d.i. 'natuurkundige kennisontwikkeling' emphasis) en dat het natuurkundeonderwijs eveneens aandacht moet besteden aan de relaties tussen toepassingen van natuurkundekennis, technische kennis en het dagelijks leven van de leerlingen of de beslissingen die ze nemen (d.i. 'natuurkunde, technologie en maatschappij' emphasis). Verder heeft deze studie aangetoond dat de docenten ook weinig onderscheidende opvattingen hebben over de regulatie van de leerprocessen van leerlingen. Zo vinden zij het niet alleen belangrijk dat het leren van de natuurkundige vakinhoud gereguleerd wordt door de docent, maar ook dat leerling-gereguleerd leren en actieve kennisconstructie plaatsvinden.

Een andere conclusie is dat de opvattingen van natuurkundedocenten over de algemene en domeinspecifieke doelen van het onderwijs aan elkaar gerelateerd zijn en zo een opvattingssysteem vormen. Er is een sterke positieve correlatie gevonden tussen 'transmissie-/kwalificatiegeoriënteerde' opvattingen en de 'fundamentele natuurkunde' emphasis. Verder zijn voornamelijk gematigd positieve correlaties gevonden tussen de andere opvattingen over de doelen en curriculum emphases van het natuurkundeonderwijs. De relaties tussen opvattingen over de doelen en didactiek van het natuurkundeonderwijs (d.i. opvattingen over leren en de regulatie van leerprocessen) zijn echter zwak of niet significant. Hiërarchische clusteranalyse heeft bovendien niet geleid tot de identificatie van subgroepen docenten met vergelijkbare opvattingspatronen.

Het hoofdstuk wordt afgesloten met een discussie over termen zoals 'docent-gericht' en 'leerling-gericht', die vaak in de onderwijskundige literatuur worden gebruikt. Deze termen suggereren een dichotomie die echter niet wordt ondersteund door de data van deze studie.

Er wordt daarom betoogd dat het onderzoek naar docentopvattingen gebaat is bij een meer verfijnde terminologie om de inhoud en structuur van opvattingssystemen te beschrijven.

Hoofdstuk 4: Een exploratie van docentopvattingen over de aard van natuurwetenschap met behulp van contrasterende filosofische posities: een grootschalige vragenlijststudie

Dit hoofdstuk beschrijft de resultaten van een grootschalige vragenlijststudie naar de inhoud en structuur van de opvattingen van natuurkundedocenten over de aard van natuurwetenschap. Het onderwerp wordt geïntroduceerd met een bespreking van de rol van docentopvattingen over de aard van natuurwetenschap in de praktijk van het natuurkundeonderwijs. Vervolgens wordt een overzicht gegeven van de hoofdbevindingen van onderzoek naar docentopvattingen over de aard van natuurwetenschap, gevolgd door een bespreking van enkele controversiële kwesties die het hart vormen van het wetenschapsfilosofisch discours over de aard van natuurwetenschap.

De onderzoeksvraag van deze studie richt zich op de inhoud van docentopvattingen over de aard van natuurwetenschappelijke kennisclaims. Daarnaast zijn de onderlinge relaties tussen deze opvattingen onderzocht. Voor deze studie is een vragenlijst ontwikkeld met 24 items op een Likert-schaal. Deze items zijn gebaseerd op de ideaaltypen van contrasterende filosofische posities op drie verschillende dimensies, namelijk een 'intentionele', 'epistemische' en 'methodologische' dimensie. In maart 2010 is de geteste vragenlijst uitgezet onder natuurkundedocenten die lesgeven aan het voortgezet onderwijs in Nederland. De response was N=299 (17,9%). Data-analyse heeft plaatsgevonden met behulp van kwantitatieve methoden, zoals factoranalyse (Principal Axis Factoring), bivariate Pearson-correlaties en hiërarchische clusteranalyse.

Exploratieve factoranalyse heeft geresulteerd in de extractie van drie factoren; deze zijn geïnterpreteerd als opvattingen over de *status*, het *doel* en de *praktische bruikbaarheid* van natuurwetenschappelijke kennis. Gemiddeld genomen hebben de natuurkundedocenten uit deze steekproef vergelijkbare opvattingen over het 'doel' van natuurwetenschappelijke kennis. Zo zijn zij van mening dat natuurwetenschappelijke theorieën, principes en natuurwetten bedoeld zijn om een correcte beschrijving, uitleg en voorspelling te geven van natuurkundige fenomenen.

Een andere conclusie is dat de docenten verschillen in hun opvattingen over de 'status' en 'praktische bruikbaarheid' van natuurwetenschappelijke kennis. Er zijn echter geen significante verschillen gevonden als gekeken wordt naar achtergrondvariabelen zoals geslacht, leeftijd, aantal jaren onderwijservaring en de vooropleiding van docenten. Verder zijn er, wat betreft de structuur van deze opvattingen, zwakke (significante) positieve correlaties gevonden tussen enerzijds docentopvattingen over het 'doel' en anderzijds opvattingen over de 'status' en 'praktische bruikbaarheid' van natuurwetenschappelijke kennis.

Hiërarchische clusteranalyse heeft geresulteerd in drie onderscheiden clusters die 'absolutistisch' (N=71), 'relativistisch' (N=112) en 'pragmatisch' (N=116) zijn genoemd. De docenten uit het 'absolutistische' en 'relativistische' cluster verschillen in hun opvattingen over de 'status' van natuurwetenschappelijke kennis. Over het algemeen vinden de docenten uit het 'absolutistische' cluster dat natuurwetenschappelijke theorieën, principes en natuurwetten empirisch bewezen, absoluut en objectief zijn. Het 'relativistische' cluster is van mening dat de status van natuurwetenschappelijke kennis relatief is. De docenten uit het 'pragmatische' cluster hebben hoge gemiddelde scores behaald op de schaal die opvattingen over de 'praktische bruikbaarheid' van natuurwetenschappelijke kennis meet. Zij zijn van mening dat de waarde van natuurwetenschappelijke theorieën, principes en natuurwetten afhangt van de mate waarin ze fungeren als adequate hulpmiddelen bij probleemoplossende activiteiten en onderzoek.

Het hoofdstuk eindigt met een bespreking van de mate waarin de terminologie die vaak wordt gebruikt bij het beschrijven en categoriseren van docentopvattingen over de aard van natuurwetenschap, voldoet. Zo wordt er gepleit voor een meer verfijnde terminologie in plaats van het veelgebruikte onderscheid tussen 'naïeve' en 'genuanceerde' opvattingen.

Hoofdstuk 5: De beeldvorming van natuurkunde bij leerlingen in het voortgezet onderwijs: een kleinschalige explorative interviewstudie naar de opvattingen en intenties van natuurkundedocenten

In dit hoofdstuk worden de resultaten besproken van een kleinschalige, gestructureerde interviewstudie (N=3) naar de inhoud en onderlinge structuur van de opvattingen van natuurkundedocenten. De onderzochte opvattingen hebben niet alleen betrekking op de *doelen* en *didactiek* van het natuurkundeonderwijs, maar ook op de *aard van natuurkunde en natuurwetenschap*. De studie bevat bovendien een exploratie van de relaties tussen deze verschillende opvattingen en de intenties van natuurkundedocenten, zoals zij die hebben geëxpliciteerd in een lesopzet voor een introductieles natuurkunde.

Het hoofdstuk begint met een introductie van het onderwerp, gevolgd door een bespreking van de literatuur met behulp van twee imaginaire voorbeelden. Deze voorbeelden illustreren de veronderstelde relaties tussen de hierboven genoemde opvattingen en de keuzes die docenten maken met betrekking tot welke leerstof onderwezen dient te worden en op welke manier. Het theoretisch gedeelte wordt afgesloten met een korte bespreking van de literatuur over de relatie tussen opvattingen, intenties en de praktijk van het lesgeven.

De onderzoeksvragen richten zich op de inhoud en structuur van de opvattingssystemen van de drie participerende docenten. Daarnaast wordt ook onderzocht in hoeverre deze opvattingen doorklinken in hun onderwijsintenties. De drie docenten zijn geselecteerd met behulp van doelgerichte selectie. Elke docent is afkomstig uit een van de drie clusters, die in de eerder beschreven studie zijn onderscheiden (d.i. 'absolutistisch', 'relativistisch' en 'pragmatistisch'). De interviews zijn afgenomen in februari 2011 met behulp van een interviewschema, dat naast een reeks open vragen ook een opdracht bevat. Deze opdracht houdt in dat de docent een les van 50 minuten ontwerpt, waarin natuurkunde wordt geïntroduceerd aan leerlingen in de tweede klas van het voortgezet onderwijs (leeftijd 12-14 jaar). De opdracht is niet alleen gebruikt om de intenties van de docenten te onderzoeken, maar ook om hun opvattingen verder te exploreren. De data zijn in een iteratief proces geanalyseerd, waarbij een interpretatieve benadering is gehanteerd. Daarbij is gestart met open coderen, gevolgd door een analyse van overeenkomsten en verschillen in de opvattingen en intenties van docenten.

Een van de conclusies van deze studie is dat de opvattingen van de participerende docenten over de aard van natuurkunde en natuurwetenschap gekarakteriseerd worden door opvattingen over het doel van natuurwetenschappelijk onderzoek, het doel van natuurkunde als onderzoeksgebied, de tijdelijke aard van natuurwetenschappelijke theorieën en het verschil tussen natuurwetten en natuurwetenschappelijke theorieën. De docenten maken daarbij geen duidelijk onderscheid tussen het schoolvak natuurkunde en het bredere domein van het vakgebied natuurkunde.

Verder wordt op grond van de onderzochte opvattingen over de doelen van het natuurkundeonderwijs duidelijk dat de docenten verschillende prioriteiten hanteren ten aanzien van welke kennis, vaardigheden en attituden onderwezen dienen te worden. Zo vindt een docent vooral de overdracht van conceptuele kennis belangrijk, terwijl een ander met name het aanleren van onderzoeksvaardigheden en het zelfstandig onderzoek doen benadrukt. De onderbouwing van deze opvattingen blijft echter vaak in meerdere of mindere mate impliciet. Daarnaast is geconcludeerd dat de docenten, voor wat betreft de didactiek van het natuurkundeonderwijs, verschillen in hun opvattingen over adaptief onderwijs en de doelen van practicumactiviteiten en onderzoek. Het is daarbij duidelijk geworden dat met name de laatstgenoemde opvattingen (over de doelen van practicumactiviteiten en onderzoek) gerelateerd zijn aan opvattingen over de doelen van het natuurkundeonderwijs, alsmede aan opvattingen over het doel van natuurwetenschappelijk onderzoek. Deze gerelateerde opvattingen zijn tot op zekere hoogte ook teruggevonden in de intenties van docenten ten aanzien van de lesdoelen en onderwijsactiviteiten van de ontworpen introductieles.

In de afsluitende bespreking van het hoofdstuk wordt dieper ingegaan op de onderbouwing van docentopvattingen. Zo wordt bijvoorbeeld een antwoord gezocht op de vraag waarom deze onderbouwing vaak in meerdere of mindere mate impliciet blijft. Verder wordt aandacht geschonken aan de mate waarin de opvattingen van een docent over de aard van natuurkunde en natuurwetenschap mogelijk gekleurd zijn door zijn of haar percepties van de aard van het schoolvak natuurkunde.

Hoofdstuk 6: Algemene conclusies en discussie

Het laatste hoofdstuk begint met een samenvatting van zowel het hoofddoel als de algemene onderzoeksvraag die voor de deelstudies van deze dissertatie leidend zijn geweest. De onderzoeksvraag wordt gekenmerkt door een focus op de inhoud en structuur van de opvattingssystemen van natuurkundedocenten. De hoofdconclusies van de vier deelstudies worden, na kort te zijn samengevat, gesynthetiseerd in twee algemene conclusies met diverse deelconclusies.

De algemene conclusies komen op het volgende neer. De vragenlijststudies tonen aan dat de opvattingssystemen van natuurkundedocenten over het leren en onderwijzen van natuurkunde, gemiddeld genomen, bestaan uit gerelateerde opvattingen over de doelen van het natuurkundeonderwijs. Bovendien bevatten deze systemen min of meer losstaande opvattingen over docent-gereguleerd leren, leerling-gereguleerd leren en kennisconstructie en opvattingen over de aard van natuurwetenschap. De interview studies maken duidelijk dat docenten verschillen in hun prioriteiten ten aanzien van de doelen van het natuurkundeonderwijs. Daarnaast is er een verschil gevonden in de mate waarin docentopvattingen over het leren en onderwijzen van natuurkunde leerling-gereguleerd leren reflecteren. Verder is de relatie tussen opvattingen over de aard van natuurwetenschap enerzijds en de doelen en didactiek van het natuurkundeonderwijs anderzijds niet duidelijk.

De algemene discussie van de conclusies begint met een bespreking van de aard van de gebruikte methode in de vier deelstudies. Vervolgens worden de conclusies in verband gebracht met verschillende theoretische perspectieven op docentkennis en -opvattingen. Deze perspectieven betreffen 'oriëntaties op het bèta-onderwijs' als onderdeel van het bredere construct van vakdidactische kennis (d.i. 'pedagogical content knowledge', PCK), 'praktijkkennis' of 'phronesis', 'pedagogische constructies' (die het resultaat zijn van een interactie tussen docentopvattingen en andere kennistypen), en de competentie van expliciet professioneel redeneren. De discussie mondt uit in diverse suggesties voor vervolgonderzoek naar docentopvattingen, zoals een verdere exploratie van de onderlinge relaties tussen opvattingen in opvattingssystemen en de manifestatie van opvattingen in de praktijk van het lesgeven.

Verder volgen enkele praktische implicaties voor de opleiding en professionalisering van docenten. Zo wordt onder andere benadrukt dat het belangrijk is dat docentopleiders de articulatie van opvattingen modelleren en dat zij tevens laten zien hoe die opvattingen voorzien worden van een expliciete onderbouwing, verankerd in de kennisbasis voor het onderwijs. Andere implicaties benadrukken dat men bij het implementeren van curriculuminnovaties rekening dient te houden met verschillen in de opvattingen van docenten. Zo wordt bijvoorbeeld, met betrekking tot het Nederlandse natuurkundeonderwijs, geopperd dat natuurkundedocenten, docentopleiders en curriculumvernieuwers expliciet de discussie aangaan over de doelen van het curriculum of over de rol van opvattingen over de aard van natuurwetenschap in relatie tot het brede doel van 'natuurwetenschappelijke geletterdheid' ('scientific literacy'). Het hoofdstuk sluit af met het standpunt dat natuurkundedocenten, docentopleiders en natuurkundigen een gezamenlijke verantwoordelijkheid dragen om leerlingen te enthousiasmeren voor een vervolgstudie in het natuurkundig domein.

Appendices

APPENDIX 1

Interview script to investigate teacher beliefs about the goals and pedagogy of teaching and learning physics (chapter 2)

Central questions

- *How do you make your subject comprehensible for your students? Please explain why you do it this way.*
- *What do you consider (effective) ways of motivating your students to learn the content? Please explain why.*

General questions

- Could you give a short characterization of your tasks and activities at this school?
- Every teacher has a specific pedagogy. What are the characteristics of your way of teaching? Please explain why.
- What, for you as a teacher, are the fun parts of physics education? Please explain why.
- Are you confronted with specific difficulties in your teaching? If yes, what difficulties exactly?

Questions about the students

- Is there a difference between the students as they are now, and students as they used to be (e.g., 10-20 years ago)? Please explain why or why not. What are the consequences for teaching/learning physics?
- There are differences between individual students, that's a fact.
  - o What are, in your opinion, the most striking discrepancies?
  - o In your teaching, is it possible to take these differences into account? If yes, to what extent do you do that?
- What image does the subject of physics have among your students?
  - o Is it necessary to motivate your students for learning physics? Please explain why or why not.
  - o If yes, in what way are you motivating your students?
- What are the specific obstacles for students when learning physics content?
  - o How are you dealing with these problems?
  - o Do you have a different approach for students in lower/upper secondary education, and for senior general secondary education/pre-university secondary education? If yes, please explain why.
- What are the basics students should at least know of physics, including those students that will not be taking a science track? What would you like to teach your students about your subject? Please explain why.

Questions about conceptual physics knowledge

- What role does the textbook play in your teaching?
- What is the function of practicals/lab sessions in your teaching?
- Do you offer physics topics in a specific sequence or structure? Please explain why.
- What do you consider important skills? Please explain why.
- What in your view are the characteristics of scientific thinking? Please explain why. How is this kind of thinking reflected in your daily teaching practice?
- To what extent is conceptual physics knowledge and/or a theory fixed? Please explain why.
- What is the relation between physics and other science subjects (e.g., chemistry, biology)?

Questions about assessment

- Is there a central policy of testing at your school, for instance tests that are developed by the science section?
  - o If yes, to what extent are you, as a teacher, free to deviate from the central testing policy at your school?
  - o If yes, are you satisfied with the testing policy at your school? Please explain why or why not.
- What physics topics are tested, and how is this done?
- What is the value of students' test results for your teaching? In what way do you give feedback to your students based on their test results?

Questions about the community

- How important is group work in your teaching? Please explain why.
- Do you manage to keep abreast of developments in the field of contemporary physics? Please explain why or why not. If yes, how do you integrate this knowledge into your teaching?
- Are there role models in the field of contemporary physics that would appeal to your students? If yes, who would you consider as a role model? Please explain why.
- To what extent does your school management take into account your interests as a physics teacher?
  - o What are your 'demands' of the management?
  - o What would be a reason for you to accept a job at another school?
- Do you inform your students about science degree courses after secondary school? Please explain why or why not.

Final questions

- What, in your opinion, is the essence of your teaching?
- Suppose we are now ten years further on. What should secondary physics education look like? What are its characteristics? Please explain why. What role could you, as a physics teacher, play in this respect?

APPENDIX 2

Examples of questionnaire items to measure teacher beliefs about the goals of physics education and the pedagogy of teaching and learning physics (chapter 3)

Orientation towards instruction and the goals of education

- Teachers should teach students how to plan their own learning (*learning-oriented*)
- The most important task of a teacher is to increase the achievement level of the students (*transmission/qualification-oriented*)

Beliefs about learning and the regulation of students' learning processes

- Students learn better when they themselves make connections between different elements of the subject matter (*knowledge construction*)
- Students learn better when they memorize subject matter (*knowledge reproduction*)
- It is important that the sequence of subject matter should be determined by me, as the teacher (*teacher regulation*)
- Students learn better when they themselves monitor if the learning process is proceeding as planned (*student regulation*)

Curriculum emphases in teaching physics

- I consider knowledge about conservation of energy important, because it aids students' understanding of a large number of different physical phenomena (*fundamental physics*)
- I think it is important that in my lessons relationships between socially relevant issues and physics topics are made explicit (*physics, technology, and society*)
- I think it is an important task of physics education to ensure that students come to understand how physics knowledge is developed in the practice of contemporary research (*knowledge development in physics*)

APPENDIX 3

Examples of questionnaire items to measure teacher beliefs about the nature of science (chapter 4)

Intentional dimension: descriptivist and instrumentalist items

- Scientific knowledge is unambiguous: only one theory can be true (*descriptivist*)
- Scientific theories, principles and laws aim to correctly describe the world around us (*descriptivist*)
- Scientific theories and models should be functional and useful (*instrumentalist*)
- Scientific theories and laws are primarily intended as tools for problem-solving (*instrumentalist*)

Epistemic dimension: absolutist and relativist items

- A scientific theory is only true when it has been empirically tested and statistically significant proof has been provided (*absolutist*)
- In a substantive discussion about a scientific topic I only value empirical evidence (*absolutist*)
- I think that in a substantive discussion about a scientific topic arguments related to personal norms and/or experiences can be just as valuable as statements that have been empirically proven (*relativist*)
- Scientific theories change over time because of changes in the beliefs, experiences, and values of the research community (*relativist*)

Methodological dimension: inductivist and deductivist items

- Scientific theorizing starts with observing the world around us in as thorough as open a way as possible (*inductivist*)
- A scientific theory is usually constructed or arises on the basis of conclusions derived from individual empirical data (*inductivist*)
- Scientific theorizing starts with testing hypotheses that are grounded in existing theories and/or researchers' own ideas (*deductivist*)
- A scientific theory is usually built on the basis of hypotheses confirmed by individual empirical observations (*deductivist*)

APPENDIX 4

Format structured interview to investigate teacher beliefs about the nature of physics and science, teaching and learning physics, and teaching intentions (chapter 5)

A. Teacher beliefs about the nature of physics

- Suppose, you are asked to define the domain of physics. What elements should this definition comprise? In other words, what characterizes the nature of your subject, what is the essence of physics in your opinion as a physicist?
- What is, in your opinion, the goal of the domain of physics? What do physicists aim at, what are they trying to achieve?

B. Teacher beliefs about the nature of science (NOS) (Lederman, et al., 2002)

- After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples. (VNOS-Form B, question 1)
- What does an atom look like? How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like? (VNOS-Form B, question 2)
- Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer. (VNOS-Form B, question 3)
- Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate. (VNOS-Form B, question 5)
- Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data? (VNOS-Form B, question 7)

C. Teacher beliefs about what image of physics he or she would like to portray to secondary students (aged 12-18)

- When a student asks you as a teacher what the domain of physics is all about. What aspects of the domain would you like to emphasize in your answer to this student's question?
    - o What are your arguments?
    - o To what extent would your answer be influenced by a student's level or age?
- What image of physics would you like to portray to your students?
    - o What particular aspects of the domain would you pay attention to? In what way?
    - o What particular aspects would you leave out of the scope on purpose? For what reasons?

D. Assignment – Imaginary case

You are teaching an introductory lesson to secondary students in grade 2 (aged 12-14) at senior general secondary education/pre-university secondary education. The aim is to provide your students an image of the content of physics, what the subject is all about. If you wish, you are assisted by a technical assistant and specific facilities and supplies are at your disposal.

Teacher beliefs about the lesson plan

- What image of physics would you like to portray?
- How to start the lesson?
- What teaching and learning activities have you planned, what assignments have you included, and in what particular sequence?
- How to finish the lesson?
- Are there any concerns with regard to lesson preparation, for example, the use of particular instructional means, facilities, or other prerequisites?

Teacher beliefs about regular physics lessons

- This introductory lesson contains particular elements that characterize the domain of physics. Do you think it's important to pay attention to these elements during regular physics lessons?
    - o If yes, in what way do you pay attention to these elements? Could you illustrate your answer with examples?
    - o If no, what are your arguments?
- Would you pay attention to different aspects of the domain of physics when teaching upper secondary students (aged 17-18) at pre-university secondary education? Could you illustrate your answer with examples?

E. End of the interview

- We are at the end of the interview. So far, are there important issues in this respect that for some reason have been left out of the conversation?

Thank you so much for participating in this interview study!

APPENDIX 5

Three lesson plans that were designed for an introductory physics lesson (chapter 5)

Teacher Ann's lesson plan

- Topic: *Sound*
- Introduction: The teacher hits a tuning fork and tells the students that the topic of the lesson is 'sound'.
- Question: The teacher tells the students: "Sound is a vibration." Then she asks: "How can you prove that?" The students make various suggestions.
- Demonstration: The teacher hits a tuning fork and holds it against a ping-pong ball. The students watch and see that the ball starts to vibrate.
- Whole-class discussion: "What exactly is a vibration? What is the relation between a vibration and sound? You hear sound, so what is a vibration? Can we ourselves produce vibrations? " and so on.
- Experiment: Students experience that sound is a vibration: Humming/producing sound and touching the neck in order to feel the vibrations of their vocal cords.
- Definition of 'vibration': "What is a vibration? A vibration is something that moves back and forth." Making a comparison with the vibrating ping-pong ball.
- Experiment: "Can we make vibrations, such as your own sound or that produced by tuning forks, visible?" Making visible different sounds (e.g., high, low, loud, and quiet) coming from multiple sources, such as voices, guitar, and piano, with help of a microphone and an oscilloscope. The students see a sinus-graph.
- Demonstration: The teacher hits a tuning fork, holds it against a second tuning fork, and holds the second tuning fork against a ping-pong ball. The tuning fork takes over the sound of the first and the ping-pong ball starts to vibrate.
- Whole-class discussion: "Can we explain what we've seen? Why did the ping-pong ball vibrate?" Students explain the principle of 'resonance' based on the concept of 'vibration'.
- Preview next lesson and homework assignment: Textbook chapter 'Sound', reading of paragraph 2 about the gramophone and making assignments.

Teacher Brandon's lesson plan

- Multiple topics; main topic: *Light*
- Question: The teacher asks the students: "What happens when light rays go through different types of materials?" Students come up with various answers.
- Introduction: The teacher asks the students: "What is physics?" Students call various things, while the teacher writes these down on the blackboard. The teacher then categorizes students' answers in two columns, namely 'biology' and 'physics'. Next, students are asked to add other words to the list of 'physics'.

- Instruction: How does a light box work and how to connect the light box to the electricity (armatures fold out from the ceiling).
- Experiment: The teacher darkens the classroom. Students connect the light boxes to the electricity and shine light rays through a prism.
- Open assignment: "Create a beautiful pattern with the light rays and the prism." The students show the colors of the spectrum on a white paper sheet.
- Focused assignment: "Create a straight light ray on your paper sheet with the light box and the prism. Trace where the light ray is coming from, draw it on a paper and answer a couple of questions" (provided by the teacher).
- Focused assignment: "Explore the reflection of the light ray with the light box and the prism. Draw this on your paper."
- Assignment met different types of prisms: Answering questions (provided by the teacher) about why something is or is not reflecting light, why some fabrics are or are not transparent, and so on.

Teacher Chris's lesson plan

- Multiple topics: *Gravity and mass, electricity, magnetism, light*
- Introduction: The teacher shows two tennis balls and keeps them two meters above the floor. The teacher tells the students "I'm about to drop these balls." He then asks: "What will happen?" and expects that the students will say something like "The balls will fall down on the floor."
- Question: The teacher asks the students: "What causes the balls to fall down?" The students will probably give various answers, including "Gravity"
- Prediction: The teacher tells the students: "We are now making a prediction. These balls are the same, there's no visible difference. Can we predict that they will reach the floor at the same time?" The students think about this question.
- Experiment: The teacher drops the balls and indeed, they reach the floor at the same time.
- Question: The teacher asks the students: "Why did this happen? Why are the balls reaching the floor at the same time? Why wouldn't one ball fall down faster than the other?" The students will probably say things like "The balls are equally heavy."
- Experiment: The teacher throws the balls into the classroom. The students catch the balls and are surprised; one ball turns out to be twice as heavy as the other (the teacher put water into that ball).
- Question: The teacher asks the students: "How come a ball that is twice as heavy at the other still falls equally fast? How to explain this?" Again, the students think about a possible explanation.
- Whole-class discussion.
- Multiple demonstrations: The teacher conducts several small experiments, for example producing a spark with an electrostatic generator. In this respect, the teacher purposefully

shifts the topic towards 'electricity'. The teacher asks the students: "Could you explain short circuiting? In what direction does the spark go?"

- Picture on the digiboard-screen: The teacher shows a picture of a shopping street and asks the students: "What topics related to physics can you identify in the picture?" The students write their answers down on a paper sheet.
- Whole-class discussion: The students tell the teacher what they have seen in the picture and the teacher calls the appropriate physics-related topic. For instance, when students say, "A tram that's driving through the street", the teacher says: "momentum". Or when students say, "The tram uses power", the teacher says: "electricity". Often, the students will call topics such as 'light', 'atoms', molecules', and so on.
- Experiment: The teacher darkens the classroom and the students connect a light box to the electricity. They use a prism in order to show the colors of the spectrum on a white paper sheet.
- Assignment: The teacher tells the students to draw the view from above concerning the position of light box, prism, and the 'rainbow' they have created on the white paper sheet.
- Whole-class discussion of the assignment: The teacher draws various views from above that were created by students on the blackboard. The teacher asks: "Which of these drawings is the right one?" The students become aware that they have to look very carefully at how the different things are positioned.
- Tidy up the classroom: The students must clear the table so that the classroom is nice and tidy again.

Publications

Poster and round-table presentations

Curriculum Vitae

Dankwoord

ICLON PhD dissertation series

PUBLICATIONS AND PRESENTATIONS

Manuscripts submitted for publication

Belo, N.A.H., Van Driel, J.H., & Verloop, N. (submitted). An exploration of teacher beliefs about making physics comprehensible, motivating students, and different types of regulation: An interview study.

Belo, N.A.H., Van Driel, J.H., Van Veen, K., & Verloop, N. (submitted). Beyond the dichotomy of teacher- versus student-focused education: A survey study on physics teachers' beliefs about the goals and pedagogy of physics education.

Belo, N.A.H., Van Driel, J.H., & Verloop, N. (submitted). The use of contrasting philosophical positions to explore teacher beliefs about the nature of science: A large-scale survey study.

SYMPOSIA AND INDIVIDUAL PAPER PRESENTATIONS

Belo, N.A.H., Driel, J.H. van, & Verloop, N. (2009, May 27-29). *Teachers' Beliefs about Teaching and Learning Physics: A three-dimensional bipolar model to describe general, epistemological, and domain-specific beliefs*. Paper presented at the Onderwijs Research Dagen (ORD), the annual meeting of the Flemish Educational Research Association and the Dutch Educational Research Association, Leuven, Belgium.

Belo, N.A.H., Driel, J.H. van, & Verloop, N. (2009, August 31 – September 4). *Teachers' beliefs about making physics engaging and comprehensible for secondary students in the Netherlands*. Paper presented at the biannual meeting of the European Science Education Research Association (ESERA), Istanbul, Turkey.

Belo, N.A.H., Driel, J.H. van, & Verloop, N. (2009, November 5). *Teachers' beliefs about making physics engaging and comprehensible for secondary students in the Netherlands*. Paper presented at the ICO Toogdag, the annual meeting of the Dutch Interuniversitary Center for Educational Research, Utrecht, the Netherlands.

Belo, N.A.H., Van Driel, J.H., & Verloop, N. (2010, March 21-25). *Development of the Teachers' Beliefs about Science Education (TBASE) Questionnaire: Theoretical Framework*. Paper presented at the ICO Spring School 2010, Niederalteich/Regensburg, Germany.

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POSTER AND ROUND-TABLE PRESENTATIONS

Belo, N.A.H., Driel, J.H. van, & Verloop, N. (2008, June 18-20). *Relaties tussen opvattingen van bètadocenten over het bètaonderwijs, hun onderwijspraktijk en percepties van leerlingen over het bètaonderwijs* [Relations between science teachers' beliefs about science education, the practice of teaching, and students' perceptions of science education]. Poster presented at the Onderwijs Research Dagen (ORD), the annual meeting of the Flemish Educational Research Association and the Dutch Educational Research Association, Eindhoven, The Netherlands.

Belo, N.A.H., Driel, J.H. van, & Verloop, N. (2009, August 24-25). *Developing an instrument to measure physics teachers' belief systems about teaching and learning physics to secondary students in the Netherlands.* Roundtable presentation at the JURE pre-conference, Amsterdam, the Netherlands.

CURRICULUM VITAE

Nelleke Belo was born in Rotterdam, the Netherlands on March 5th, 1980 and grew up in Capelle aan den IJssel. She attended secondary education at the Driestar College in Gouda and graduated in 1998. Next, she attended a three-year teacher education program at the Hogeschool de Driestar in Gouda and received her teaching degree for primary education in 2001. She worked as a primary teacher teaching children in 7th and 8th grade (aged 10-12) at the Immanuëlschool in Lopikerkapel from 2001-2005. In the evening hours, she studied Educational Sciences at Driestar Educatief in Gouda and received her Bachelor's degree, with a specialization in Special Needs Education, in 2007. In 2005, she quit her job and studied Educational Sciences at VU University in Amsterdam. In 2007, she received her Master's degree with a specialization in the Philosophy of Education.

From 2007 to 2012 she worked as a PhD candidate at ICLON Leiden University Graduate School of Teaching. The research project focused on the content and structure of physics teachers' belief systems and was part of the larger ICLON-research program with a focus on the knowledge base of teaching. She attended courses and master classes relevant to the method and topic of research that were provided by ICO, the Dutch Interuniversitary Center for Educational Research. From 2008 to 2012, she was a member of the ICO Educational Committee and the last two years of this period, she represented the Educational Committee in the ICO Management Team. Furthermore, she received a six-week visiting student scholarship to UC Berkeley (CA, USA) in 2009 and presented her work at national and international conferences. Besides, she worked from 2011 to 2012 as a teacher educator and supervisor at the teacher education program of ICLON, Leiden University Graduate School of Teaching.

She is currently employed as a postdoc researcher at Twente University. The research project focuses on the knowledge and skills teachers need to use ICT in educational settings, with a particular focus on fostering kindergartners' early literacy development. Moreover, she is employed as a teacher and supervisor at the Educational Sciences Bachelor's and Master's program of Twente University.

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Nelleke Belo
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