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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.

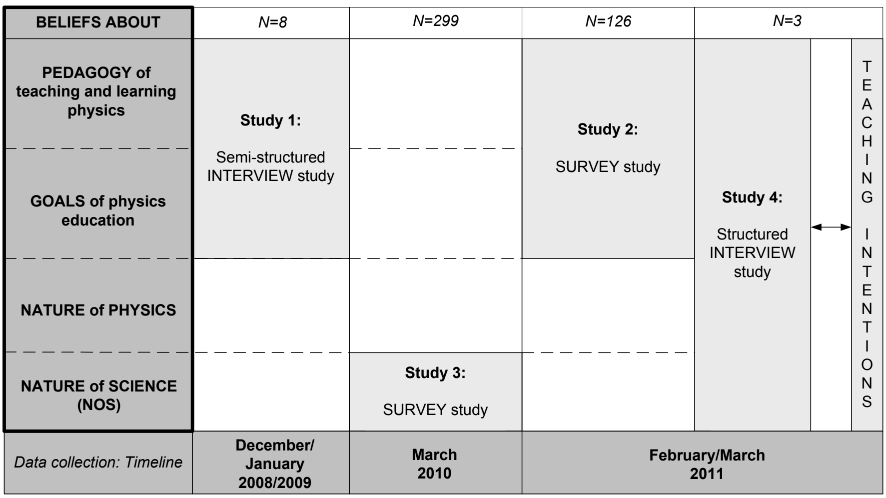

Figure 1.1. Overview of the four studies that were conducted to investigate the content and structure of physics teachers' belief systems