Author: Belo, Neeltje Annigje Hendrika
Title: Engaging students in the study of physics : an investigation of physics teachers' belief systems about teaching and learning physics
Issue Date: 2013-03-27

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).

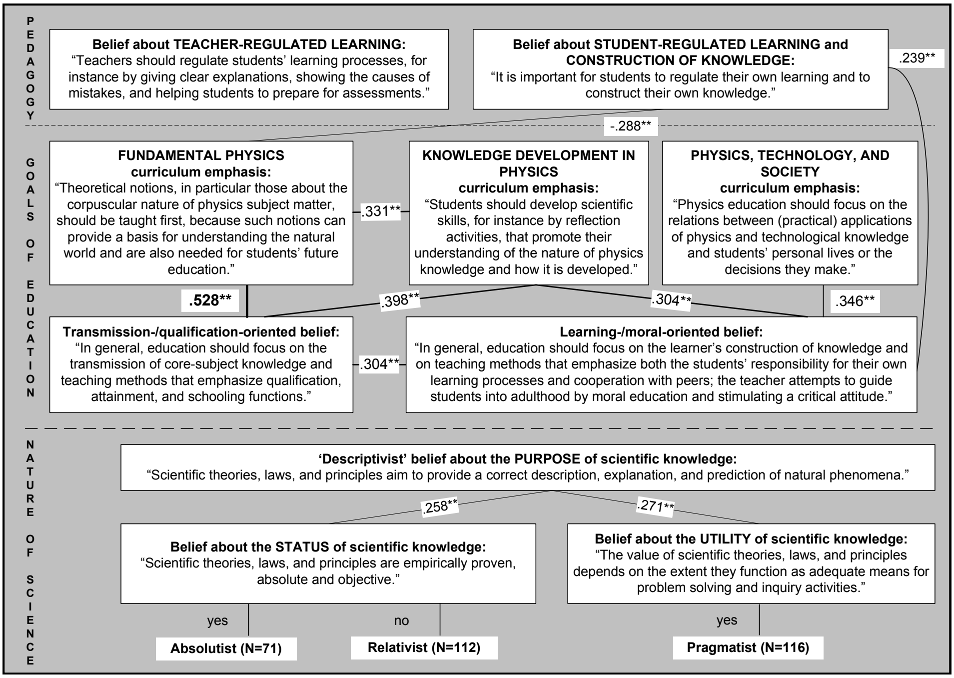

Figure 6.1. The content and structure of physics teachers' belief systems based on the mean scores of two survey studies (the figure presents bivariate Pearson correlation scores (marked by **) that were significant at the 0.01 level (2-tailed)).

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!