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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

Summary/Samenvatting

SUMMARY

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

Chapter 1: General introduction

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Chapter 6: General conclusions and discussion

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

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