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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

Appendices

APPENDIX 1

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

Central questions

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

General questions

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

Questions about the students

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

Questions about conceptual physics knowledge

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

Questions about assessment

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

Questions about the community

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

Final questions

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

APPENDIX 2

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

Orientation towards instruction and the goals of education

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

Beliefs about learning and the regulation of students' learning processes

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

Curriculum emphases in teaching physics

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

APPENDIX 3

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

Intentional dimension: descriptivist and instrumentalist items

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

Epistemic dimension: absolutist and relativist items

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

Methodological dimension: inductivist and deductivist items

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

APPENDIX 4

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

A. Teacher beliefs about the nature of physics

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

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

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

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

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

D. Assignment – Imaginary case

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

Teacher beliefs about the lesson plan

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

Teacher beliefs about regular physics lessons

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

E. End of the interview

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

Thank you so much for participating in this interview study!

APPENDIX 5

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

Teacher Ann's lesson plan

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

Teacher Brandon's lesson plan

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

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

Teacher Chris's lesson plan

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

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

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

Publications

Poster and round-table presentations

Curriculum Vitae

Dankwoord

ICLON PhD dissertation series

PUBLICATIONS AND PRESENTATIONS

Manuscripts submitted for publication

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

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

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

SYMPOSIA AND INDIVIDUAL PAPER PRESENTATIONS

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

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

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

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

Belo, N.A.H., Van Driel, J.H., & Verloop, N. (2010, June 23). *Opvattingen van Docenten en Docent-opleiders Natuurkunde – Welke Vakdidactische Aspecten bevorderen de Aantrekkelijkheid en Begrijpelijkheid van het vak?* [Physics teachers' and teacher educators' beliefs: What pedagogical aspects enhance the appeal and comprehensibility of the subject?] Paper presented at the Onderwijs Research Dagen (ORD), the annual meeting of the Flemish Educational Research Association and the Dutch Educational Research Association, Enschede, the Netherlands.

Belo, N.A.H., Van Driel, J.H., & Verloop N. (2011, April 3-6). *Secondary teachers' beliefs about teaching physics.* Paper presented at the annual meeting of the National Association of Research in Science Teaching (NARST), Orlando (FL, USA).

Belo, N.A.H., Van Driel, J.H., & Verloop, N. (2011, June 8-10). *Relaties tussen opvattingen van natuurkundedocenten over instructie, 'curriculum emphases' en de praktische invulling van natuurkundeonderwijs* [Relations between physics teachers' beliefs about instruction, 'curriculum emphases', and the practice of teaching physics]. Paper presented at the Onderwijs Research Dagen (ORD), the annual meeting of the Flemish Educational Research Association and the Dutch Educational Research Association, Maastricht, the Netherlands.

Belo, N.A.H., Van Driel, J.H., & Verloop, N. (2012, June 20-22). *Exploratie van docentopvattingen over de aard van natuurwetenschap: Een vragenlijst- en interviewstudie*. Paper presented at the Onderwijs Research Dagen (ORD), the annual meeting of the Flemish Educational Research Association and the Dutch Educational Research Association, Wageningen, the Netherlands.

POSTER AND ROUND-TABLE PRESENTATIONS

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

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

CURRICULUM VITAE

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

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

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

DANKWOORD

Veel personen hebben allemaal op hun eigen manier bijgedragen aan de totstandkoming van dit proefschrift. Daarom dit dankwoord.

In de eerste plaats gaat mijn grote dank uit naar mijn beide promotores Jan van Driel en Nico Verloop. Jan, het overleg met jou had soms meer weg van een 'brainstorm-sessie', waarin je mij op de juiste manier wist te bevragen en kon uitdagen om de volgende denkstap te zetten. Dank voor alle feedback, de prettige samenwerking en de ruimte die je me hebt gegeven om dit onderzoek op mijn eigen manier uit te voeren. Nico, de sessies met jou waren weliswaar minder in aantal, maar zeer verhelderend en waardevol door de gedetailleerde en kritische feedback op mijn stukken. Bedankt!

Zeer veel dank ben ik verschuldigd aan alle natuurkundedocenten, docentopleiders en studenten van de docentenopleiding natuurkunde die hun medewerking hebben verleend aan de deelstudies of betrokken zijn geweest bij de opzet daarvan. Dank voor jullie tijd om de vragenlijsten van mijn onderzoek in te vullen en uit te testen, mee te werken aan een (pilot) interview en/of de inhoudelijke feedback op de instrumenten en de formulering van vragen. Een bijzonder woord van dank aan Wouter Tinbergen, Peter van Tilburg, Lia Noorthoek en Rob Wielenga voor jullie medewerking in het benaderen van natuurkundedocenten voor mijn onderzoek.

Verder gaat mijn dank uit naar Ben Smit, Dirk Wongsopawiro, Hans van Bemmel en wijlen Rien van der Leeden. Jullie hulp en inhoudelijke inbreng in de fase van data-analyse zijn van onschatbare waarde geweest voor de interpretatie van de gegevens en het bepalen van de methode en focus voor vervolgonderzoek. Ben, Dirk en Hans, bedankt! Rien, het maakt me verdrietig dat je de verschijning van dit proefschrift niet meer hebt mogen meemaken.

Dank aan Heather en Kevin Phillips en Ineke Smit voor de correctie van de Engelse taal in dit proefschrift en aan Hans Hulshof voor zijn feedback op de Nederlandse samenvatting en stellingen.

Veel collega's en medeonderzoekers hebben door hun betrokkenheid, vragen en discussies bijgedragen aan de inhoudelijke kwaliteit van dit onderzoek en de implicaties. In dit kader wil ik de leden van de onderzoeksgroep van het ICLON, de collega's van het bèta-team, de docentopleiders bij de afdeling VO en de collega's van de vierde verdieping bedanken voor alle constructieve feedback, interesse voor mijn onderzoek, de positieve werksfeer en de wijze waarop ze mij inzicht hebben gegeven in de uitoefening van het vak van docent(opleider). Verder gaat een woord van dank uit naar de collega's en medeonderzoekers werkzaam bij de afdeling Onderwijskunde van de Universiteit Twente. Bedankt voor de inhoudelijke discussies die mij met name hebben geïnspireerd bij het schrijven van het slothoofdstuk. In het bijzonder wil ik Joke Voogt en Susan McKenney bedanken voor de tijd die ik heb gekregen om in de laatste fase mijn proefschrift af te ronden.

A special thanks to my co-workers and friends of the Graduate School of Education at UC Berkeley (CA, USA) for making my 6-week visiting student scholarship (2009) such a wonderful and inspiring experience! Thanks to professors Kathleen Metz, Alan Schoenfeld, and Andrea diSessa, the late associate professor Randi Engle, and to Kate, Heeju Jang, Janet Casperson, and Xenia Meyer for the inspiring conversations about the topic of research and for making my journey such a wonderful learning experience! Randi, I enjoyed your video analysis research group so much and I feel very sad about the fact that you passed away.

Ten slotte een woord van dank aan mijn familie en vrienden. Jullie hebben voor de nodige afleiding en humor gezorgd, waardoor ik werk en privé in balans kan houden. Dank aan mijn ouders, broers, (schoon)zus en zwager voor jullie betrokkenheid, steun en feedback. Dank aan mijn vrienden, John & Heidi, Jesse & Marlies, Jaap & Mirjam, Dirk, Mariska, Christel en Klaas voor jullie vriendschap en meeleven. And last but not least, thanks to my friends Wu Wei, Maria João, and Arijaan for such a wonderful friendship. Een ieder die op welke manier dan ook heeft bijgedragen aan de totstandkoming van dit proefschrift: BEDANKT!

Nelleke Belo
Enschede, februari 2013

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Belo, N.A.H. (2013). *Engaging students in the study of physics: An investigation of physics teachers' belief systems about teaching and learning physics*.