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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

Chapter 2

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

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

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

ABSTRACT

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

2.1 INTRODUCTION

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

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

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

2.2 LITERATURE REVIEW

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

2.2.1 Beliefs about 'what' students are learning

General goals of science education

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

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

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

2.2.2 Beliefs about 'how' students are learning

Conceptions of learning in general

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

The regulation of students' learning processes

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

Teaching procedures to enhance students' comprehension of content

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

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

Student engagement and motivation

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

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

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

2.3 RESEARCH QUESTIONS

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

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

2.4 METHOD

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

2.4.1 Data collection

Sample

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

Instrument

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

Procedure

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

2.4.2 Data analysis

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

Selection of interview fragments for analysis

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

Coding and interrater agreement

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

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

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

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

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

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

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

2.5 RESULTS

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

2.5.1 Learning physics

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.5.2 Doing physics

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.5.3 Learning about physics

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

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

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

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

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

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

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

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

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

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

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

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

2.6 CONCLUSIONS AND DISCUSSION

2.6.1 Main conclusions

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

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

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

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

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

2.6.2 Discussion

Limitations of the present study

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

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

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

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

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

Beliefs related to the goal of 'Learning about physics'

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

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

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

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

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

Implications for secondary physics education

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

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