Teacher knowledge and lesson design

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Understanding and supporting biology teachers' decision-making while designing context-based lessons

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De zon maakt bloemen, warmte, hei,
de zee maakt stil - wat maken wij?

Leo Vroman

Kruim

Wat heel is, kunnen wij niet zien, het is
te groot, het past ons niet en niet
in onze hoofden

Maar wat aan mootjes, haksel is, verkiezeld,
kruim, gepureerd, verstoven of ontbonden –

Al het verdeelde zit voorgoed in ons.

Eva Gerlach

Voor Eelco

Table of contents

Chapter 1

General Introduction

1

1.1 Introduction

All over the world, secondary school science curricula are frequently being updated, reformed and revised. Likewise, Dutch secondary school biology curricula have recently undergone an innovation which was based upon a context-based approach. The implementation of reform ideas at classroom level will generally differ from what policy makers originally envisioned (Fullan, 2007; Janssen, Westbroek, Doyle & Van Driel, 2013; Van den Akker, 1998). Whatever the aims of the innovation, the teachers who teach the curriculum are key to the outcomes (Fullan, 2007). Teachers interpret and appreciate new ideas while deciding whether and how to use them when designing, teaching, and reflecting upon their lessons. In this entire process, teachers' practical knowledge (defined as the cognitions that underlie teachers' actions (Meijer, 1999)) plays a central role. When studying teachers' practical knowledge, two important problems arise: first, the knowledge of teachers often remains largely implicit (van Driel, Beijaard, & Verloop, 2001), and even when research tools are used to elicit aspects of a teacher's knowledge, these often poorly explain the decisions teachers make when designing and teaching lessons (Borko, Roberts, & Shavelson, 2008; Fives & Buehl, 2012; Mathijsen, 2007). A second problem is that, as Kennedy put it, "educational research is at a stage in which we have strong theories of student learning, but we do not have well-developed ideas about teacher learning, nor about how to help teachers incorporate new ideas into their ongoing systems of practice" (Kennedy, 2016a, p. 29).

The aim of this thesis is to clarify the relation between teacher knowledge and the decisions they make while designing innovative lessons, in order to be able to effectively support teacher professional development in the context of curriculum reform. The reason why the focus will predominantly be on the process in which teachers design their lessons is that during this design process teachers make important decisions about the content and pedagogies of these lessons. The lesson design process also offers important opportunities to support teacher learning, for when designing lessons, teachers simultaneously use and create their knowledge (Aikenhead, 1984; Hashweh, 2005; Sanchez & Valcarcel, 1999). Before going more deeply into current research about teacher knowledge and their design of innovative lessons, I will first describe the background and implementation process of the context-based reform in the Netherlands.

1.2 Context-based biology teaching and learning

This research took place during a reform of the secondary school biology curricula. The aim of this innovation was to make the biology curriculum more relevant, more up-to-date and more coherent through the use of real-world contexts in class, a context being defined as

an authentic scientific, professional or life-world practice (Boersma, Kamp, Van den Oever, & Schalk, 2010). In the Dutch context, the terms "concept-context approach" (*concept-contextbenadering*) or "context-concept approach" are used to describe the pedagogy being promoted, depending on whether the speaker or writer wishes to stress the importance of the biological concepts or the importance of the context in which those concepts are used. However, because this thesis is composed of a collection of research articles which were written for an international audience, we have chosen to use the term "context-based education", with which many international scholars of science education are familiar (Bennett, Lubben, & Hogarth, 2007; Gilbert, 2006; Sevian, Dori, & Parchmann, 2018).

The movement towards more context-based approaches in secondary science education in The Netherlands has a long history, which goes back to the 1970s (Kuiper, 2009). This movement initially took place in physics, and later also in chemistry classes, in cooperation with teachers of several experimental schools. In biology education, there had been no large-scale experiments such as in physics and chemistry classes. Nonetheless, there was considerable dissatisfaction about the biology curriculum, and in 2003, the Royal Academy of Arts and Sciences concluded in an influential report that the biology curricula suffered from a lack of relevance, a lack of coherence and an overload of biological concepts (KNAW, 2003). This report, together with similar analyses in the other science subjects, was the onset of the innovation process in science education, for which the context-based teaching approach was chosen as a leading principle. The innovation committees that were installed chose to involve a diversity of teachers in the process of curriculum innovation. In biology education, seven "biology development schools" (BOS) played an important role, in which teachers in cooperation with educational researchers developed and evaluated teaching and learning materials (Folmer, Ottevanger, & Bruning, & Kuiper, 2011). Their experiences were used to design experimental context-based syllabi and central examinations, which in turn informed the design of new lesson materials. At the same time, at many different places in the country, biology teachers experimented with the context-based teaching approach, and shared their experiences for instance during discussions at conferences and through publications. In 2013, the new context-based examination programs were officially launched. Data collection for our research took place from 2008 to 2012, that is, during the developmental phase of the innovation process. In our research, we focused on teachers who were not involved with the programs on the biology development schools, with the exception of one teacher ("David"), who participated in our first study, reported in chapter two.

1.3 The importance of teachers' lesson design decisions in the context of curriculum reform

In the process of curriculum reform, the decisions teachers take while designing their lessons are critical (Davis, Janssen, & Van Driel, 2016; Fullan, 1991, 2007; Randi & Corno, 1997). Lesson design, in this thesis, is defined as all activities teachers undertake when planning and preparing their lessons, which can include adaptation of existing materials and/or the development of new teaching and learning materials from scratch. Designing lessons takes place in a cyclical process of planning, implementation and evaluation, in which goals and activities are continuously revised (Yinger & Hendricks-Lee, 1994). Sometimes, teachers need to design their own teaching materials, because high quality reform-based materials for teaching and learning are lacking. Even if relevant and high quality materials are available, teachers' design decisions when using such materials can lead to crucial changes, which can either lead to a weakening or a strengthening of the reform ideas. When Van Berkel (2005) studied the development and implementation of a context-based chemistry method in Great Britain, he discovered that the changes teachers made resulted in lessons which were less context-based, because teachers added an explanation of the concepts before having students work on context-based activities. A related well-known phenomenon is the tendency many teachers have to reduce the cognitive demand of student tasks for students (Stein, Remillard, & Smith, 2007). On the other hand, teachers will strengthen reform ideas when redesigning existing materials to better accommodate their students' needs (Wallace & Priestley, 2017) or to respond to the changing interests of themselves and their students, and to current developments in society and biological science (George & Lubben, 2002).

Whereas teachers always design lessons, designing innovative lessons is more challenging then routinely designing lessons of the kind that they feel familiar with. Former research shows, for instance, that teachers consider it difficult to translate a context into meaningful learning materials and to guide students' learning processes while they work on context-based activities (De Putter-Smits, 2012; Stolk, Bulte, de Jong, & Pilot, 2009). Even for experienced educational designers, who have substantially more time available for the design of curriculum materials than the average science teacher, the design of context-based lessons is problematic, especially when it comes to the alignment of curriculum standards, learning activities and central questions within the contexts (Krajcik, McNeill, & Reiser, 2008). Innovative lesson design can be an important learning activity for teachers in itself (Hashweh, 2005; Sanchez & Valcarcel, 1999), whether existing reform materials are used (Davis, Beyer, Forbes, & Stevens, 2011) or new materials are developed (Sanchez & Valcarcel, 1999). It is to be expected, however, that teachers will need extra support in the process. Before we can decide what kind of support to offer teachers, we first need to understand more about how teachers think and act when designing and enacting their lessons.

1.4 An historical overview of thinking about teacher thinking and their actions

It is a persistent problem that we lack grounded and tested theories about how we can effectively support teachers to integrate new ideas into their systems of practice, despite that many before have studied teachers' cognitions and their actions, and proposed ways to support teacher learning. In the history of the research on teacher learning one can recognize a pendulum movement in which the focus shifted from teachers' actions to their cognitions and back to their actions, while the connection between teacher knowledge and their actions often remained understudied (Borko et al., 2008). In the 1960s and 1970s, the focus of educational researchers was largely on what effective teachers actually *do* in class, such as waiting a few seconds after posing a question in order to allow students to think of an answer or using predictable signals to get students' attention. The idea was that teachers could be trained to demonstrate such behaviors in order to become effective teachers. While this line of reasoning, often called process-product research, is today still very present in teacher education, in the 1980s this line of research was criticized by Shulman for disregarding the importance of teachers' knowledge and beliefs, and of the content matter of what is being taught and learned (Shulman, 1986b, 1987). What effective teachers do, he argued, depends on what those teachers know and believe about the content matter, general learning strategies, about the curriculum, student characteristics and thinking, possible representations of content matter and assessment. Since then, many have dedicated their research work to mapping and categorizing the special knowledge teachers need to teach (Kennedy, 2016b). Less attention was paid to teachers' actions in everyday classroom practices, and to the connection between teacher knowledge and their actions in the classroom (Borko et al., 2008). More recently, attention has been redirected towards teachers' actions. This time, researchers do not look at isolated actions such as posing questions, but to more complex practices, called "core practices", within school contexts, such as "eliciting student thinking" or "pressing students for evidence-based explanations" (McDonald, Kazemi, & Kavanagh, 2013a; Windschitl, Thompson, Braaten, & Stroupe, 2012). The idea is that both novice and experienced teachers can be trained to effectively perform such practices. Kennedy (2016b) warns that too much attention for the training in core practices might again neglect underlying beliefs, and in particular, underlying goals that teachers hold. Such studies might delusively convey the message that for each learning objective, one "expert" strategy can be identified, while in reality the best strategy depends on the context and the teachers' and students' specific beliefs, needs and abilities. In our research, we will try to synthesize the insights from both more knowledge-oriented and action-oriented research lines. We will do this by adopting a perspective that has been tried and tested before, that of the teacher as decision maker.

1

In the early 1970s, three influential scholars independently concluded that decision-making was central to teaching and to understanding teaching practices (Bishop, 1976; Shavelson, 1973; Shulman & Elstein, 1975). As Shavelson (1973, p. iii) put it: "the basic teaching skill is decision making. What distinguishes the exceptional teacher from his or her colleagues is not the ability to ask, say, a higher-order question, but the ability to decide when to ask such a question" (underlining in original). Most of the research by Shavelson, Bishop and colleagues was focused on the decisions teachers make while teaching, but it also included decisions teachers make while planning their lessons. Such lesson planning studies were mostly linked to the nature and sequence of teacher's decisions while planning their lessons, disregarding the *content* of those decisions. Information was collected, for instance, about whether and when teachers thought about learning goals, but not what those learning goals were. Still, these descriptive studies into lesson planning, in which thinking aloud methods were often used, yielded valuable insights. First, they showed that teachers' planning behaviors deviated from what is prescribed by rational planning models, and that such models seldom effectively support teachers' planning processes (Visscher-Voerman, Gustafson, & Plomp, 1999). Instead of starting by formulating learning objectives, many teachers start their design by selecting activities that have proven to be successful in past classroom situations (Clark & Peterson, 1986; Moallem, 1998). Second, teachers generally do not rationally consider alternative approaches but rely on routines and rules-of-thumb that have proven to be successful in past experiences (Schön, 1983; Shavelson & Stern, 1981). Other studies have shown that teachers, when designing innovative lessons, will not simply add reform goals and pedagogies to their existing teaching knowledge and repertoires. While reform ideas often have student learning as their sole goal, teachers need to find solutions that are practical within their own classrooms, that is, solutions that are instrumental (include procedures to reach the proposed goals), congruent with their perceptions of their own situation, and cost-effective (Doyle & Ponder, 1977; Janssen, Westbroek, Doyle, & Van Driel, 2013). The process of lesson design offers important possibilities to study this process in which teachers integrate new conceptions within their existing systems of knowledge and beliefs in ways that are practical within their own contexts. The relation between teacher knowledge and their design of lessons, however, has been remarkably understudied (Hashweh, 2005, 2013).

1.5 Research questions

The overall research questions in this thesis are:

1. What decisions do biology teachers make when designing context-based lessons for their own classroom practice, and how do these relate to their practical knowledge?
2. What are characteristics of an effective professional development strategy to support biology teachers when they design context-based lessons for their own classroom practice?

According to Clark & Peterson (1986), the lesson design process encompasses decisions teachers take and activities they perform before teaching (consisting mainly of lesson planning and organizing activities), decisions taken during teaching and decisions taken after teaching. The main focus in this thesis will be on the pre-lesson decisions teachers make when they design their lessons.

1.6 Thesis outline

Economist Victor Fuchs once described a social scientist as somebody who looks for something that works in practice, and then wonders if it will work in theory (Fuchs in personal conversations with Bernard Nelson, cited by Shulman & Shulman (2004)). I, being a biologist who had to learn to think as a social scientist, recognize this process in the journey we[1] went while performing the research I report in this thesis. This thesis, then, can be read as a report of how our understanding about the relation between teacher practical knowledge and their design of innovative lessons developed throughout this journey. While we adapted and developed methods to talk with teachers about their practical knowledge, and while we designed and evaluated a strategy to support teachers in this process of innovative lesson design, we developed and refined our theoretical frameworks. Figure 1.1 gives an overview over the studies that were conducted. The studies reported in chapters 2, 3 and 4 were set up to answer the first main research question, while the study reported in chapter 5 was aimed at answering the second main research question. Chapters 2 and 3 were based upon six case studies of teachers who designed and implemented context-based lessons for their own classroom practice without the intervention of professional development activities. The studies reported in chapters 4 and 5 were situated in the context

[1] This research, like all research, has not been done alone. I went the journey together with my advisors, with my colleagues and friends with whom I discussed theories and findings, and of course with the teachers who participated in the studies.

of a professional development program for 12 biology teachers who wished to learn to design context-based lessons for one of their own classes.

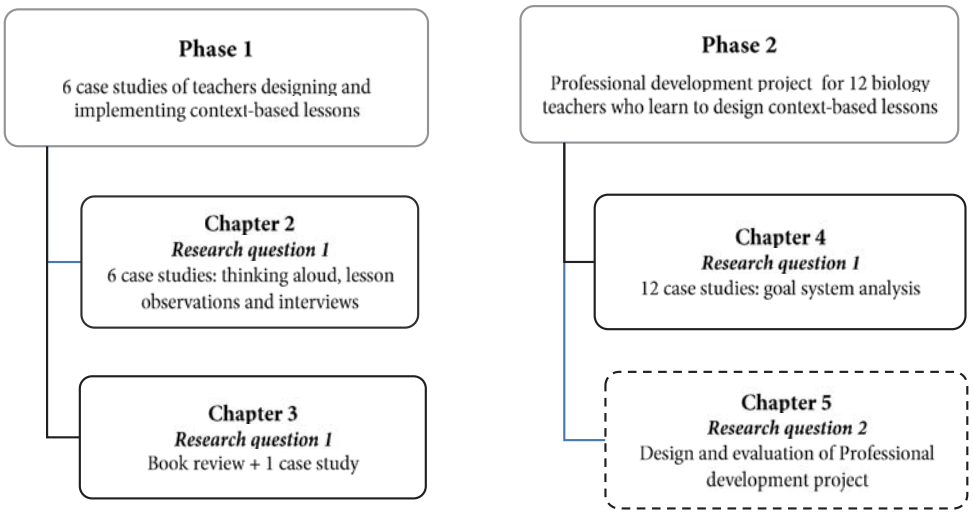

Figure 1.1 Overview over the studies reported in this thesis

The journey started with an explorative study in which we wished to learn what biology teachers do and think when asked to design innovative context-based lessons for their own classroom practice, and more specifically, what rules-of-thumb they use when designing their lessons **(chapter 2)**. The research questions in this study were (1) What rules-of-thumb do biology teachers use when designing context-based lessons for their own educational practice? and (2) How do these personal rules-of-thumb relate to the formal innovative goals and lesson characteristics? Six in-service biology teachers with a variation of backgrounds and work contexts were asked to design context-based lessons for their own classroom practice, while thinking aloud. The implementation of the lessons was studied, and pre- and post-lesson interviews were conducted.

We were not the first to point at the importance of rules-of-thumb as part of practitioners' practical knowledge. Rules-of-thumb play, for instance, an important role in the work of Donald Schön. In c**hapter 3** I therefore explore how Schön's most influential work, his book *The Reflective Practitioner* (1983), could forward our understanding of the way teachers use their knowledge when designing lessons. The chapter has the format of a book review, which is combined with a short case study describing how one biology teacher uses his practical knowledge when designing a context-based lesson. This case study displays both the merits and limits of using Schön's language, in which the concepts *rules*, *types* and

appreciations play a central role, when analyzing the process in which a teacher designs his lessons. One of the main aspects deserving further attention will be the relations between and interdependencies of a teachers' rules, and the relation between rules and appreciations. Rules and appreciations both are strongly connected to a practitioner's goals. Someone's rules and goals, including their interconnections, can be represented in the form of a goal system (Carver & Scheier, 2001; Shah & Kruglanski, 2008). Goal system theory might be a valuable addition to Schön's perspective of the reflective practitioner, and might enable us to do justice to both the nature of a teacher's knowledge use when designing lessons and to the interdependencies of a teacher's rules and goals.

In **chapter 4** these ideas are further developed in an empirical study which took place in the context of a professional development project for biology teachers who wished to learn to design context-based lessons for their own classroom practice. The aim of this study was, to see in which way goal system theory could be used to explain and comprehend individual teachers' understanding and implementation of an innovative context-based curriculum. Twelve teachers' goal systems were constructed using the laddering interview technique (Fransella, 2005; Reynolds & Gutman, 1988). Analysis was specifically focused on *core goals* (defined as goals which have two or more links with lower or higher goals within the same system) and *negative links* (in which existing goals counteract the attainment of higher level goals) within a goal system, and how these are related to a teacher's interpretation of the context-based reform.

In the study which is reported in **chapter 5**, the second main research question was taken up, namely: "what are characteristics of an effective professional development strategy to support biology teachers when they design context-based lessons for their own classroom practice?" We were specifically interested to learn how we could effectively build upon teachers' existing goals and concerns, and how and to what extent design tools, heuristics and examples, in the form of exemplar curriculum materials and model lessons, might support teachers in their design of innovative context-based lessons for their own classroom practice. The research took place in the context of the same PD project as the research reported in chapter 4, and the same 12 teachers participated. A professional development strategy was developed, based upon existing literature and on the findings from the previous chapters of this thesis. Data from interviews, thinking aloud protocols, lesson plans, lesson recordings and registration of meetings were used to refine the professional development strategy and to give specific recommendations for future projects.

In **Chapter 6**, all findings are summarized and discussed in relation to the two main research questions and are situated in literature. Implications for research, for curriculum reform and for the education and professional development of teachers are explored.

1.7 The Dudoc Program

This research was part of and funded by the Dudoc Program, a program which was meant to give science teachers the opportunity to do educational research and thus make the teaching profession more attractive, widening career perspectives. It also aimed at narrowing the gap between research and practice at schools, bringing the perspective of the practicing teacher to academic research groups. Another aim of the Dudoc Program was to support the innovation of the secondary school science curricula from a scientific perspective. The Dudoc Program enabled me to spend two days per week to perform my PhD studies, alongside my job as a secondary school biology teacher. All Dudoc teachers/researchers formed a research community and regularly met for workshops and seminars (Bakx, Bakker, Koopman, & Beijaard, 2016; Knippels, Goedhart, & Plomp, 2008).

Chapter 2

Biology teachers designing context-based lessons for their classroom practice – the importance of rules-of-thumb

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Abstract

In science education in the Netherlands new, context-based, curricula are being developed. As in any innovation, the outcome will largely depend on the teachers who design and implement lessons. Central to the study presented here is the idea that teachers, when designing lessons, use rules-of-thumb: notions of what a lesson should look like if certain classroom outcomes are to be reached. Our study aimed at (1) identifying the rules-of-thumb biology teachers use when designing context-based lessons for their own classroom practice, and (2) assessing how these personal rules-of-thumb relate to formal innovative goals and lesson characteristics. Six biology teachers with varying backgrounds designed and implemented a lesson or series of lessons for their own practice, while thinking aloud. We interviewed the teachers, and observed their lessons. Our results suggest that rules-of-thumb, which differed substantially among the teachers, indeed to a great extent guide the decisions teachers make when designing (innovative) lessons. These rules-of-thumb were often strongly associated with intended lesson outcomes. Also, teachers' personal rules-of-thumb were more powerful in determining the lesson design than formal innovative goals and lesson characteristics. The results of this study encourage more research into how rules-of-thumb reflect teachers' practical knowledge, for which suggestions are made.

2.1 Introduction

There is an international trend in science education towards context-based approaches. Teaching concepts in relationship to real-world contexts is expected to make science education more meaningful, relevant and motivating for students (Gilbert, 2006). In biology education in the Netherlands an innovation process towards context-based education is currently taking place (Boersma *et al*, 2007). As in any innovation the outcome will largely depend on the teachers implementing it (Fullan, 2007; van Driel et al., 2001).

Teachers generally do not implement an innovation exactly the way it was originally envisioned and described in curriculum documents (Fullan, 2007). Research has shown that when teachers interpret an innovation their practical knowledge, which is an integration of experiential knowledge, formal knowledge and personal beliefs acts as a filter (Levin & He, 2008; van Driel et al., 2001). Moreover, knowing that innovations are often poorly translated into teaching materials (Van Berkel, 2005), teachers frequently need to design innovative lessons themselves. Although many authors have pointed to the importance of studying teachers' instructional design in order to understand how practical knowledge informs instructional decision-making (Clark & Dunn, 1991; Hashweh, 2005; Sanchez & Valcarcel, 1999), this relationship has scarcely been subject to research (Hashweh, 2005). Therefore, in this study we explore the role of teachers' practical knowledge in their design of innovative context-based lessons for their own classroom practice.

2.2 Theory

2.2.1 Context-based biology education

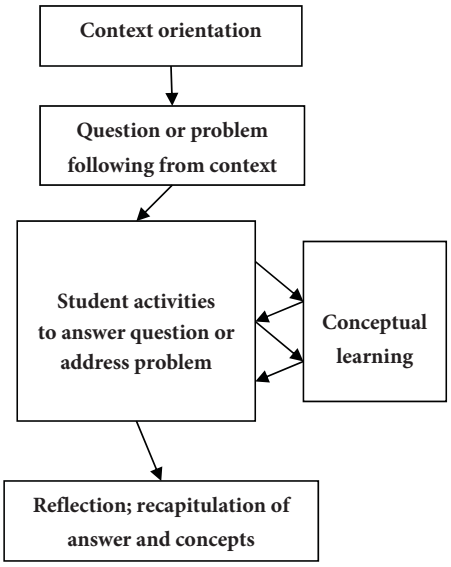
Context-based education is not new. It has been propagated in different parts of the world, in slightly different forms and with different purposes, often in response to alleged failures of the traditional science curriculum (Aikenhead, 2007; Gilbert, 2006). Likewise, context-based education is seen as a possible answer to the problems in biology education in The Netherlands that were identified by the Royal Netherlands Academy of Arts and Sciences in their 2003 report (KNAW, 2003): a lack of relevance (from the viewpoint of both students and of science and society), a lack of coherence (between biological concepts and between concepts and contexts), and an overload of biological concepts in the curriculum.

When reviewing the international literature on context-based education, one has to conclude that besides providing an answer to these problems there are many other objectives to be obtained by context-based education. Most importantly, context-based education is expected to improve students' understanding: contexts are thought to trigger students' preconceptions, which are the starting point for meaningful learning (Scott, Asoko, &

Leach, 2007). This is further stimulated by the use of questions and problems from real-world contexts as starting points for developing a 'need' to learn about scientific concepts (Bulte, Westbroek, de Jong, & Pilot, 2006). Second, context-based education is thought to increase coherence within curricula, because various concepts come together within contexts and reappear in other contexts (Gilbert, 2006; Pilot & Bulte, 2006). Third, context-based education is expected to increase student motivation more effectively than more traditional educational approaches, and make students feel more positive about science (Bennett et al., 2007). Context-based education is also used to change the educational emphasis from learning scientific "facts" to involving students in scientific activities such as argumentation, modelling, and designing (Krajcik et al., 2008), and more in general of increasing the relevance of the science curriculum by embedding concepts within relevant contexts and using relevant contexts to select the scientific concepts and skills to be learnt (Boersma et al., 2007).

In the same way as there are various, often related, reasons for using contexts in science education, there are many different ideas about how to define "context" in education and what a "context-based lesson" should look like. A "context" has been alternately described as a theme, issue, story, topic, situation, practice, application and problem (Bennett, Grasel, Parchmann, & Waddington, 2005; Goedhart, 2004; Pilot & Bulte, 2006). Of these, the interpretation used most frequently is that of a context as a "situation". The *type* of situation chosen also varies. Some authors only select situations that are of personal relevance to students (Taasoobshirazi & Carr, 2008), or have societal relevance (Zeidler, Sadler, Simmons, & Howes, 2005), whereas others include all contexts that students may encounter in their personal or future professional life, or may help them understand how science "works" (Aikenhead, 2007). For our purposes we have chosen to define a context as *a realistic situation from students' own lives, from society or from professional or scientific practices*.

Although opinions on the definitions and goals of context-based education differ, there seem to be some basic characteristics of context-based lessons that many people agree upon, which in this study will be called the *formal design principles* (Figure 2.1). A context-based lesson or lesson sequence typically starts with an introductory phase, during which students can imagine themselves being part of the situation (Bennett et al., 2007). From this situation a question or problem arises logically. Students answer this question by performing learning activities, meanwhile gaining insight into the biological concepts that are needed to answer the question or solving the problem (Bennett et al., 2007; Bulte et al., 2006; Glynn & Koballa, 2005; Kortland, 2007). In the end reflection on the process takes place, the answers are summarized and explicit attention is given to the biological concepts used. This procedure is expected to enable transfer of these concepts to new contexts (recontextualization; Van Oers, 1998).



Formal design principles for context-based biology education

1. The lesson (sequence) should start with an **introduction to the context**, which is a realistic situation from students' life-world, from society, or from professional or scientific practices. This introduction ensures that students imagine themselves being part of that situation.

2. From the introduction, a **question or problem** should logically follow. This question or problem can be posed by the teacher, the students or both.

3. The **student activities** should be aimed at answering the central question or solving the problem.

4. In the lessons students should learn to understand one or more **biological concepts**.

5. The **concepts** being learnt should be **necessary** to answer the question or solve the problem.

6. In the end, students and teacher should **reflect on the answer/solution**.

7. In the end, relevant biological concepts are **summarized** (decontextualized) in order to facilitate recontextualization.

Figure 2.1 Formal design principles

2.2.2 Teachers' personal rules-of-thumb

Many authors have pointed out that teachers generally do not implement an innovation in the way it was originally envisioned. Innovations are interpreted, with teachers' personal practical knowledge playing an important role. 'Practical knowledge' is defined as the cognitions that underlie teachers' actions (Meijer, 1999). Hashweh (2005) informs us that this practical knowledge 'results initially, and most importantly, from teacher planning, which is essentially a design process' (p. 278). He adds that the relation between lesson design and a teacher's practical knowledge is a reciprocal one: teachers draw on their knowledge when deciding on instructional goals and strategies. Still, as yet little research has been conducted on the manner in which practical knowledge informs teachers' decision-making during lesson planning.

We might learn from descriptive studies into teacher lesson planning that have been carried out in the past. Until the 1970s the main aim of these studies was to describe teacher behaviour and to assess whether teachers follow formal planning models – the conclusion was that they usually don't (Yinger & Hendricks-Lee, 1994). From the 1970s onward, attention shifted to teachers' cognitions. Lesson planning was considered a process of either solving problems or decision-making, in which teachers generate alternatives and choose between them (Shavelson, 1973). This perspective has been criticized, because it underestimates the role of routines and the influence of classroom materials (Clark & Dunn, 1991; Shavelson & Stern, 1981). The image of the teacher as a rational decision maker evolved into the image

of the *reasonable* decision maker, who makes judgments and decisions in a complex and uncertain environment. Instead of balancing multiple alternatives when designing their lessons, teachers seem to be guided by a limited set of rules-of-thumb developed during the process of planning, teaching and reflecting. Such rules-of-thumb are defined as prescriptive notions of advisable lesson characteristics, most often related to some intended outcomes in student understanding, student behaviour, student and teacher emotions and lesson organization (Elbaz, 1983; Feldman, 2000; Janssen, Veldman, & Van Tartwijk, 2008; Peters & Beijaard, 1983).

This study set out to explore six biology teachers' decision-making processes when designing innovative context-based biology lessons for their own educational practice. We expected the outcome of these processes to be determined by both teachers' personal rules-of-thumb and their appreciation of the innovative goals and lesson characteristics. This has led to the following research questions:

1. What rules-of-thumb do biology teachers use when designing context-based lessons for their own educational practice?
2. How do these personal rules-of-thumb relate to the formal innovative goals and lesson characteristics?

In other words, we wished to explore the applicability of the concept of rules-of-thumb in a study of innovative lesson design by teachers, while at the same time learning how teachers interpret the idea of context-based biology education when designing lessons.

2.3 Methods

2.3.1 Selection of participants

Because the context-based innovation of the Dutch biology curriculum is meant to be implemented by teachers of varying levels of experience and with different teaching styles, and on different grade levels, we aimed to include a variety of secondary school biology teachers teaching a range of grade levels at different school types in this study. We sought advice from two experts with a wide network of biology teachers, which resulted in our contacting fourteen biology teachers. Six of them agreed to participate; they all teach at different Dutch city schools. Table 2.1 summarizes participant characteristics. Both David and Vera (not their real names) are experienced designers of context-based lessons: David because he had already been involved in the design of an experimental context-based curriculum for three years and Vera because she had been using contexts in her lessons for several years, independently from the current innovation in biology education. None

of the teachers had, before the start of the study, experienced any professional development activities aimed at designing or implementing context-based biology education, with the exception of David, who had been participating in a teacher design team for three years, in which he developed context-based lesson sequences. This design team was made up by two teachers and received advice in meetings with other design teams and two educational researchers.

Table 2.1 Participant characteristics

Teacher	Kate	Richard	Marion	Thomas	David	Vera
Teaching experience (years)	8	6	13	1	22	4
Experience in designing context-based lessons	None	None	Minor	None	3 years	3 years
Grade level*	pue	gse	pue	gse	pue	pve
Upper/lower secondary education	Lower	Upper	Upper	Lower	Upper	Lower

* pue = pre-university education, gse = general secondary education, pve = pre-vocational education

2.3.2 Data collection

We asked every teacher to design a context-based lesson or short lesson sequence of three lessons at most for one of their own classes. Given the design of this study we did not want teachers to design large lesson modules and sophisticated materials. Rather, we wished to observe teachers' day-to-day design activities, the only difference being that this time they would follow a context-based approach. During the implementation phase of the innovative biology curriculum in the Netherlands teachers will not be obliged to follow a professional development programme. An 'average' Dutch biology teacher is expected to learn about the context-based approach in some way or another, but a majority of teachers is not going to follow an extensive professional development programme. Hence, we did not train the teachers in designing context-based lessons, but only informed them about the definition of context-based education and the formal design principles used in this study (figure2.1), and the general aims of context-based education: increasing relevance, student understanding, conceptual coherence and student motivation. This was done by means of a short note (1 A4) and a very short oral introduction during the first interview. Additionally, we provided the teachers with a modest literature package that represented the literature about context-based education that was easily available to teachers at that moment: the 2007 report of the Dutch Biology Education Innovation Committee (CVBO) (Boersma et al., 2007), and five articles from Dutch science education journals (Lijnse, 2007; Schalk & De Hullu, 2007; Van den Oever, 2007; Vermaat, 2007; Wolter & Van Woerkom, 2007).

After a short, structured interview, intended to gather information about the teacher's background, teaching experience and knowledge and beliefs concerning context-based education, teacher and researcher together decided for which class and date to design a lesson, on the basis of two criteria: (1) ecological validity: the teachers designed a lesson that they would normally also have been planning at that moment. For Kate, Richard, Thomas and Vera, this meant they designed a lesson they planned to teach one or a few days later, because they usually plan their lessons only a short time ahead, while David and Marion designed a lesson they planned to teach a month later, because they usually plan their lessons at the beginning of a new term; and (2) teachers' preferences: sometimes teachers had specific reasons for choosing a particular class or moment, for example because the subject was considered difficult and they hoped the new approach would lead to better student understanding.

Immediately after this interview participants designed their context-based lesson, while thinking aloud. We asked the teachers to use the formal design principles (figure 2.1) as a starting point. They were free to use all the materials they wanted. The teachers designed their lesson in the same surroundings as where they would normally design their lessons (that is: at school, in an office or at home) and were instructed to use the same procedures they would normally use. The design activities the teachers undertook were manifold: studying the school book, searching the internet (fora, encyclopaedic sites, news sites, scientific articles, video material), searching own databases, brainstorming on a piece of paper, specifying learning goals, envisioning student activities in the classroom, elaborating student worksheets, arranging practical necessities such as making classroom reservations, etcetera. The amount of time spent on designing was not limited by the researcher. In practice, the entire design session lasted between 40 and 70 minutes.

During the lesson design process, the first author was present. She generally did not intervene, except for asking 'what are you thinking right now?' The teachers in our study reported that they experienced the design process while thinking aloud as similar to the natural situation, although Richard said he now spent slightly more time designing the lesson than he would normally do. Both Thomas and Marion said the situation felt slightly uncomfortable, although they did not think this influenced their thinking processes very much. Following the thinking-aloud session, we asked the teachers to reflect on the design process, to clarify decisions made, and to explain what factors hindered or promoted the design of the lesson. Of all thinking-aloud sessions and interviews audio and video recordings were made, and all interviews and thinking-aloud protocols were typed out verbatim.

Following Clark and Peterson (1986) we understand the lesson design process as a cyclic process of planning, implementation and reflection. This means that we expected design decisions not only to be taken during the thinking aloud session, which resulted in a lesson

plan, but also between the thinking aloud session and the implementation of the lesson and during the implementation of the lesson. All teachers had drawn up the basic structure of the lesson within the thinking-aloud session, but most teachers indeed also performed some supplementary design activities between the session and the implementation of the lesson in the classroom, such as drawing up student assignments in more detail and making practical arrangements. The teachers kept notes of all these activities. The lesson itself was observed and videotaped. During the observations of the lessons, the researchers created a description of the lesson, in which both students' and teacher's activities were noted as well as the time at which they were taking place. Following it, an interview was held in which the initial findings were presented to the teacher, and the teachers were asked to further clarify the decisions they had made.

We asked every teacher to design a context-based lesson or short lesson sequence of three lessons at most for one of their own classes. Given the design of this study we did not want teachers to design large lesson modules and sophisticated materials. Rather, we wished to observe teachers' day-to-day design activities, the only difference being that this time they would follow a context-based approach. During the implementation phase of the innovative biology curriculum in the Netherlands teachers will not be obliged to follow a professional development programme. An 'average' Dutch biology teacher is expected to learn about the context-based approach in some way or another, but a majority of teachers is not going to follow an extensive professional development programme. Hence, we did not train the teachers in designing context-based lessons, but only informed them about the definition of context-based education and the formal design principles used in this study (figure 2.1), and the general aims of context-based education: increasing relevance, student understanding, conceptual coherence and student motivation. This was done by means of a short note (1 A4) and a very short oral introduction during the first interview. Additionally, we provided the teachers with a modest literature package that represented the literature about context-based education that was easily available to teachers at that moment: the 2007 report of the Dutch Biology Education Innovation Committee (CVBO) (Boersma et al., 2007), and five articles from Dutch science education journals (Lijnse, 2007; Schalk & De Hullu, 2007; Van den Oever, 2007; Vermaat, 2007; Wolter & Van Woerkom, 2007).

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as the time at which they were taking place. Following it, an interview was held in which the initial findings were presented to the teacher, and the teachers were asked to further clarify the decisions they had made.

2.3.3 Data analysis

The first step in the analysis was to identify all decisions made by the teachers during the design process. Design decisions could be diverse, e.g., choice of student activities ('I want to use a creative activity'), choice of organisation ('this time, students don't work in groups, but individually'), or a choice not to do something that had been considered ('I don't choose the holiday context, because…' (Kate)). Design decisions taken before the lesson could easily be identified using the protocols and teachers' notes. Decisions taken during the lesson were identified by comparing the teachers' own lesson plans with the summary of the implemented lesson. Discrepancies could be traced back to decisions made just before or during the lesson, which were confirmed or explained by the teachers during the interview following the lesson.

Every decision was linked to the reasons that particular teacher gave for making that choice. Often, these reasons would be obvious from the thinking-aloud protocol (e.g. 'So, that's playing blind man's buff, just to let them experience it, that is just a funny intro, that will be fun' (Thomas)). If the reason for a certain decision was unclear, we asked the teacher for clarification immediately after the thinking-aloud session. Based on this information, the first author drew up a summary of decisions and reasons for each of the six teachers. As a first member check, we presented this summary to the teachers during the post-lesson interview, and asked them to confirm and/or adapt it. No major adaptations appeared necessary. This process resulted in a *decision summary*, an example of which is given in Appendix 1. The decision summaries were used by two researchers independently from each other to identify all personal rules-of-thumb and related intended outcomes that influenced the design process. They tried to keep as close to the teacher's own phrasing as possible. There were some minor differences between the two researchers, which could all be easily resolved through discussion. Ultimately, we used a second member check to validate the findings: we sent the tables of rules-of-thumb and intended outcomes, plus the narratives as they appear in the *Results* section of this paper, to the teachers, who confirmed that their personal reasoning had been correctly and recognizably represented in the text and Tables. One teacher asked us to rephrase one rule-of-thumb, which we did, after reviewing the original data.

In short, we tried to validate the data by triangulation of data source and method (interviews, thinking-aloud protocols, video analyses), by triangulation of researchers, and by using member checks (Miles & Huberman, 1994). We tried to optimize the ecological validity of the findings by visiting the teachers in their own school environment and asking

them to design and implement a lesson in the way they would normally do it. The validity of the rules-of-thumb that will be presented in the next section may be limited to the particular levels and subjects of those lessons. However, teachers' phrasings suggest a more general validity, as was confirmed by their concluding email messages (e.g. Vera: 'You have understood and represented me and my ideas about teaching very well.')

2.4 Results

In this section we will describe the individual teachers' decision-making processes and link these to their personal rules-of-thumb and, if the link could be established from the data, intended lesson outcomes associated with these rules-of-thumb (table 2.2). In the representation of the teachers' reasoning and rules-of-thumb in this article we have kept as close to the teachers' own phrasings as possible. As a consequence, the rules-of-thumb as they appear in this study are dissimilar in shape and level of abstraction.

2.4.1 Kate (pre-university education, 12/13 years old): Biodiversity in a park

During the first interview it was immediately obvious that during her years of teaching experience Kate had given a lot of thought to her educational goals. She made extensive use of personal rules-of-thumb when designing the lesson (table 2.2). The intended outcome for most of these principles comes down to one thing: better student understanding of biological concepts. During the post-lesson interview Kate formulated the ultimate goal of her lessons: she wants her students to be able to recognize biology in the real world while thinking like a biologist, not like a park designer or a doctor: 'In my lesson you [the student] are a biologist, you think like a biologist'. At the same time, she considered the emotional well-being of her students, again in order to facilitate learning: 'When the group atmosphere is good and students believe they can succeed, they learn best'. This is also the source of most of her rules-of-thumb: these all are ideas of what lessons should look like, in order to further student understanding in the best way possible. One example is to start from the biological concepts, not from a context, 'because otherwise they cannot know from what angle to think; it is about biology, not about economy. From an economic point of view dog dirt on the lawn might also be a problem, but then you should find a different solution'. Contexts, in Kate's opinion, first of all serve to give meaning to concepts by triggering preconceptions and helping students understand what the concept means in their own situation, thus enabling conceptual development from a constructivist point of view, and eventually application of the concepts in reality.

Kate's lesson started with a question central to biology, namely: *What does an animal need to be able to survive and reproduce?* Kate aimed to have students understand the

meaning of this question by letting them draw their own house and identify elements of their surroundings they really need, like food, safety, a pleasant room temperature, etc. This is what Kate called the main "context" of her context-based lesson. After drawing their own house, students drew the "house" of an animal they knew from a recent park visit. For this purpose, Kate had prepared 27 different biographies of the animals involved. She had also brought a map of an imaginary park that students could use to find a home for "their" animals. This moment in the lesson led to emotional scenes: 'There is no place my frog can live! There is no pond in the park!' After deliberation, the teacher and students resolved this by adapting the park in such a way that every animal could have its place in it. During the lesson, the students regularly referred to their textbooks so that they could link classroom activities to the concepts used in the book: habitat, nature development and biodiversity.

During the interview following the lesson, Kate recalled that some students had found it very difficult to understand why they had to draw their own house. We came to discuss the fact that the lesson could have taken another shape, more in line with the formal principles, according to which the design of a park would have been the start of the lesson and students would have had the role of park designers. The question then would have been something like: "how can we make a park where many animals can find what they need to survive and reproduce?" Kate clearly showed her disapproval of the idea: 'When you ask them to design a park, I feel you are cheating them… because they will never be permitted to design a park for real… that is no good. The question is even, if somebody says: "student, help me design this park", if that will be taken seriously... I'm afraid it will not. I do not want to do that to them… It almost makes me sad.'

The basic structure of the lesson was finished within the thinking-aloud session, but making the lesson took Kate eight hours in all, which she mainly spent on writing the biographies, making the student worksheets and drawing the park map. Kate was very satisfied with the resulting lesson; it was quite different from her regular lessons, which usually start with her writing a definition on the board, explaining the definition, giving examples, followed by having the students make exercises from their textbooks.

2.4.2 Richard (upper general secondary education, 15/16 years old): A safari trip

Richard has been a teacher for six years, after working as an IT-specialist for a time. His main concern as a teacher was a lack of student motivation, which he hoped to address through the implementation of context-based education.

When designing the lesson, Richard started by determining the concepts to be learnt: the structure and function of the autonomous nervous system. He then began an internet search using the search terms 'autonomous nervous system' and 'disease'. In this way he gathered many ideas for the context for this lesson: asthma, bowel diseases, prion diseases, and so on. However, he rejected all these ideas, because he thought they would not lead to

the idea that the autonomous nervous system affects all organs at the same time. What is more, he was afraid that using a medical context would give students the impression that things in their body go wrong all the time, while he'd rather have them imagine how well everything is organized inside them. At this point Richard got stuck. He sighed: 'All the time, it's only one organ, and that doesn't fit the material to be learnt. If we wouldn't try so hard to make some context-based thing, I would have stopped a long time ago… What can it be, something that appeals to them and helps them to remember…?'

That is when he thought about his regular way of teaching the subject, using the analogies of the lion (when a lion jumps forward at you, your nervous system is in a state of arousal, and it happens to be a handy mnemonic that a gang<u>lion</u> is a structural characteristic of that system) and a cake-eating event, when the system is in a state of rest. Normally, he simply explains to the students, using these analogies, what the structure of the nervous system is and how it works, after which the students work from their books. He says: 'Well, yeah, of course we could … change the student activity, because, of course, in the end, the context simply is your own body and what it should do in different situations. … And that's how I normally explain it to them, but of course I could do it by not explaining it [but] by stimulating the students to think for themselves about what, in situation 1 and situation 2, the organs should do.'

Now the lesson took shape very quickly: it started with a gripping story about the class being on a safari trip, celebrating the birthday of one of the students, eating cake, when suddenly a lion jumped out while the guide was distracted by the new gadgets on his cell phone. The questions that followed were: "what should your organs be doing in the cake-eating situation? And what should they do when the lion appears on stage?" Without needing more information, the students were able to figure out what the answers to these questions should be, after which the teacher explained how the autonomous nervous system is designed to make sure the organs are in fact doing what the students predicted they should be doing.

Afterwards, Richard thought this was a good context-based lesson, and actually better than his regular ones. He realized that the student activities in this lesson did not at all resemble what you would actually do in the context given (it would be very foolish to ponder on the state of your kidneys while you are being attacked by a lion), but he did not consider that problematic, for the context served to motivate students, stimulate them into action, and give them something to help them remember the concepts. The lesson would not gain in relevance if an understanding of the concepts would really be <u>necessary</u> in some situation or another. According to Richard, conceptual understanding is relevant in itself.

2.4.3 Marion (Pre-university education, 16/17 years old): The age of a fossil shell

Marion is an experienced biology teacher who is also a coach for new teachers at her school. She has long been fascinated by different learning styles, which she repeatedly cites as the rationale behind her main educational principle: the curriculum should include a variety of student activities. The main reason for her to embark on context-based education is to add to the variety of teaching approaches in her repertoire.

Unlike the protocols of the other teachers, there is not much practical reasoning in Marion's thinking-aloud protocol, which is reflected in the limited size of Marion's section in table 2.2. At the beginning of the session Marion produced two possible contexts: one based upon a newspaper article she had read about a fossil shell that had been found, and the other about Lake Victoria. The second option was quickly abandoned, because Marion felt she lacked the biological knowledge needed to elaborate on this example. Marion composed a lesson based upon the newspaper article, while strictly following the formal design principles. She used a television documentary about a palaeontologist's work as an introduction to the context. Then, her students were asked to imagine themselves a palaeontologist who finds a fossil shell in a certain stratum at a certain place in the Netherlands. Using geological information from the internet, the students then inferred what the age of this shell would be.

Marion implemented her lesson in a large class of often poorly motivated 16/17 years olds. She was moderately happy afterwards: her students worked slightly more enthusiastically than usual, but she was not sure whether they had learnt what she would have wanted them to learn.

2.4.4 Thomas (upper general secondary education, 12/13 years old): Vision impairments

Thomas is in his first year of teaching. He is a passionate collector of "amazing biological stories". Anecdotes from newspapers or television shows have a prominent place in his lessons. For Thomas, the main reason for participating in this research was his general willingness to innovate, but from the beginning he had been sceptical towards the assumptions underlying the current innovation. He felt that most of the contexts that feature as examples in official documents would not motivate students to learn and teachers to teach. Thomas considered it very important to give original, fun lessons, with students and teacher sharing their experiences. Most of his regular lessons have the following structure: start with a newspaper article, then give a clear explanation of the concepts to be learnt, after which students make exercises from the book, and end the lesson with an instructive video fragment.

While designing his context-based lesson Thomas spent a lot of time searching for a context that was interesting enough to spend a whole lesson on and at the same time

covered the concepts to be learned. This process quickly frustrated him, because he felt he did not succeed in finding a context for which it would be necessary to understand the function of every part of the eye, which was the concept to be taught in this lesson. Therefore, Thomas changed his strategy and started thinking of an activity that covered the concepts (making a drawing of an eye with a certain defect), which helped him to select a context to fit this activity (making an illustration for a medical handbook). Interestingly enough, Thomas forgot to mention this altogether during the lesson itself, showing that he did not consider this particular context essential to the lesson. The lesson started with a discussion of a newspaper article about colour-blind monkeys, which naturally resulted in a discussion of vision impairments in general, after which students made drawings to illustrate these vision impairments.

Thomas's feelings after the lesson were mixed: he was happy with the interactive discussions, and his students expressed their appreciation for the lesson, but he thought the "main activity" of drawing the eye was a bit boring, whereas the students did not understand very well what they were supposed to do and learn.

2.4.5 David (Pre-university education, 15/16 years old): Cell differentiation during embryonic development

David is an enthusiastic biology teacher and teacher educator who has some years' experience in developing context-based lesson sequences. The lesson he designed was part of a larger sequence about love, sex and reproduction. In his long-term plan, already made, he had determined the concepts to be learnt per lesson and the materials he had to offer. In this way it had already been decided that this lesson would cover hox genes and cell differentiation in embryos, and that a film about cell migration in a zebra fish embryo should be shown. During the thinking-aloud session David used many other rules-of-thumb to make up the rest of the lesson, while he explicitly linked every rule to objectives to be reached (see table 2.2). The resulting lesson was built around the central question: *What is happening at cellular level during embryonic development?* Many examples ("contexts") were used to illuminate the answer to this question in different situations. In this case the contexts mainly served to give meaning to the question and concepts, and to show an example of current biological research. The central question and its answer in different contexts were presented by David using lots of visually fascinating examples (scientific research into zebra fish embryo development, causes of growth disorders, a pregnant woman growing a beard, etc.), while the students mainly sat and listened, with the exception of two short moments when the students were asked to answer a question on paper.

Retrospectively, David thought this was a good context-based lesson, because he showed many examples and showed the dynamics of what's going on inside organisms.

2.4.6 Vera (pre-vocational secondary education, 13/14 years old): DNA in a personal context

Vera started her teaching career as a nurse and medical teacher in the Israeli army. After migrating to the Netherlands, she started a beauty salon, which at the time of the study she had for four years been combining with teaching external care and biology at a vocational secondary school.

During the interviews Vera explained that storytelling is a very important ingredient of her lessons. Those stories can sometimes be considered contexts in which biological concepts play a role, and sometimes they merely serve as metaphors, for example when she compares the circulatory system to the railways or the nervous system to a bread factory where orders are given from higher to lower hierarchical levels. Often, she does not prepare her lessons, choosing an improvisational approach instead, responding to the stories students bring to the classroom or the ideas that come into her mind during the lesson.

Vera's main goal for this particular lesson was to have her students realize the societal and personal importance of DNA knowledge. For this reason, Vera chose to start the lesson by telling her students a very personal story in an interactive way. Vera has a son with haemophilia, which is a genetic disease. She told her students how this had been discovered, and asked them what they thought it would mean to her son to have this disease (referring back to another concept domain: circulation). Then she explained that she herself appeared to be the carrier. She asked her students to help her explain what a "carrier" is and what that has to do with DNA and chromosomes. Subsequently, she gave her students a pile of newspaper articles on a wide range of DNA –related topics, and a very open assignment to choose a subject, search the internet and make a PowerPoint presentation about DNA. Vera was the only teacher of the six who did not determine the concepts to be learnt beforehand. She considered it more important for her students to realize the importance of the biological domain of genetics for society and people's personal lives, and left her students fairly free to determine what they wanted to investigate.

Reflecting on her lesson, Vera said it would have been better to have a more structured assignment, but in general she likes her students to have room to decide what and how they want to learn, and have them learn from their own experiences and questions.

Table 2.2 The teachers' rules-of-thumb and intended outcomes

Rule-of-thumb	Intended outcome
Kate	
Start the lesson by giving meaning to the concepts, using students' own daily life	Students learn they are organisms that are part of the science of biology Students are able to give meaning to the concept
Use well-structured assignments	Students think at a higher level
Let students learn the theory first, before applying it in a context	Students acquire the biological thinking tools needed to interpret the context
Use the textbook	Students feel secure, and are able to connect the lesson to the theory in the book
Use creative activities	Students are motivated
Start at organism level	Students learn to think "biologically" by wondering how organisms succeed in staying alive
Use the concepts in multiple situations	Students learn to use the concepts in different situations
Richard	
The context matches the entire concept	Students get an idea of the concept as a whole
Use a simple context	Students easily understand and remember the context
If we are talking about the human body the focus is on processes in students' own bodies	Students imagine how their own bodies work
Do not use medical contexts	Attention is concentrated on the positive facts: the beauty of the complexity of the body when it goes right, instead of wrong.
Use an appealing context	Students pay attention to the lesson
Give students examples that help them to remember facts	Students remember the facts they learn
Use a variety of student activities	Students' concentration levels are high
Have students find out the facts themselves	Students acquire lasting knowledge
The teacher gives a structured overview of the biological concepts	This helps students to build a conceptual network
Marion	
Use a context that students can relate to	Students give meaning to the concepts Students remember the concepts
Use a variety of student activities	Students are motivated Students are active
Use structured assignments	
Use the media (television, internet)	
Thomas	
Concepts should be presented in a structured fashion. The context should neatly fit the concepts: avoid contexts in which too many biological concepts play a role	Students understand the concepts
The context appeals to teacher and students	Both students and teacher are having a good time

Rule-of-thumb	Intended outcome
The student activities are "fun" to do	Students have fun
The use of clichés is avoided	
Students have the opportunity to move around during the lesson	
There is room for students to make their own contribution to the lesson	
Use newspaper articles	Students see the relevance of biology to daily life
Use video material	Students enjoy class
David	
Use a context that fits the concepts to be learnt	Items from the examination programme are covered
Use examples from current biology	Students get a picture of real, state-of-the-art biology
Start with a context that surprises and involves students	Students are involved
Start with a human context, at the organism level	Preconceptions are triggered
Show somatic disorders	Students wonder how they ended up whole and healthy
Give students access to inspiring materials, even if it means there is less time for students to ask questions	
Move up and down organization levels (organism-organ-cell-molecule)	Students learn to move up and down organization levels
Make connections with other biological themes	Students build up coherent conceptual networks
Share personal experiences	Students recognize the importance of "life skills"
Use Binas (a handbook with biological figures)	Students' skills in using Binas are developed
Use historical contexts	Students realize how their current knowledge determines the way they view the world
Vera	
Tell gripping stories, with the teacher really putting herself into the situation	Offer students something to help them remember what they learn
Do not take the textbook as basis	Boredom is avoided
Use examples from students' daily life	Students acquire a meaningful understanding of the concepts
Emphasize solutions instead of problems	Students learn to think positively
Create room for improvisation and for students to contribute to the lesson	Students' attention will not flag The concepts are linked to real situations that are important to students at that moment If students investigate what they are interested in they will learn better
Use newspaper articles	Students recognize and understand biological concepts they encounter in the media
Use students' activities that force them to higher-level thinking	

2.5 Discussion

We will start our discussion by addressing the two aims we had set for this study: describing the rules-of-thumb the teachers use when they design context-based lessons, and relating these personal rules-of-thumb to the formal goals and lesson characteristics of the new context-based biology curriculum in the Netherlands. After that we will reflect on the usefulness of the concept of rules-of-thumb in the study of teacher knowledge and its relation to other conceptualizations of teacher knowledge. In conclusion, we will derive some implications for curriculum innovation and the professional development of teachers.

2.5.1 Teachers' use of rules-of-thumb when they design context-based lessons

The rules-of-thumb the individual teachers used when designing their context-based lessons have been summarized in the Results section. As will later be discussed in more depth, teachers' rules-of-thumb are personal and are likely to be linked to specific classes, subjects and contexts. Still, it is both possible and interesting to have a look at the whole of rules-of-thumb used by the teachers in this study, which are related to the choice of concepts, context and activities, respectively. All the teachers appeared to follow roughly the same process when designing the lesson: first, the concepts were determined, after which was decided which context to use, and as a last step the students' activities were developed. For all teachers, the unit plan they had made at the beginning of the term defined the concepts to be taken as starting points in the design of the lesson, which is in accordance with the observation by Clark and Peterson (1986) that unit planning was considered the most important type of planning by teachers, followed by weekly and daily planning. Only after the concepts to be learnt had been established, attention was given to possible contexts for the lesson(s). The exception here was Vera, who was not very strict in her longer-term planning. All teachers stressed that the context chosen should be appealing, in order to motivate students for the lesson. Two teachers (Richard, Marion) aimed at having one overall context for the lesson, while the other teachers had their students shift between different contexts. For three teachers (Richard, Marion and Thomas) it was essential for the context(s) not to be too complicated, for characteristics of the context were not to distract their students from learning the concepts they should learn, while the other three teachers considered both the concepts and context-specific information to be interesting and instructive. It would have been logical and in line with the innovation if the next step for the teachers would have been to design student activities to match the context, but often, teachers had other, conflicting, rules that determined the form the student activities should take, such as using activities that motivate students, that proved to be successful in former lessons, or that have students reinvent the concepts themselves, as will be elaborated in more depth in the following section.

Many rules-of-thumb used by the teachers seem to be strongly related to the nature of their educational aims: whether that be conceptual learning (Kate, David, Marion), factual learning (Richard, Thomas), affective aims such as attaining positive feelings towards biology or wonder about nature (Richard, David, Thomas) and personal and societal aims (Vera).

2.5.2 Relation between teachers' rules-of-thumb and formal design principles

While all six teachers succeeded in designing a context-based lesson according to their own standards, most chose not to adopt the formal design principles completely. We will try to explain this by exploring the teachers' intended outcomes for the lessons, and the rules-of-thumb they employed to generate these outcomes.

According to the formal principles the use of real-life situations in biology education is thought to increase relevance, student understanding, coherence and student motivation. Teachers' reasoning in this study showed that their personal rules-of-thumb conflicted with these ideas in several ways. First and most importantly, it was thought that a context which is too specific and realistic would not motivate students to learn, while increasing student motivation was the teachers' foremost reason for using a context-based approach. One reason cited is that using such contexts would decrease the relevance of the curriculum in the eyes of the students: 'Why should I know what a mussel grower needs to know? I will never be a mussel grower!' (Thomas). Most teachers in this study did not use the context-based approach to increase the relevance of the curriculum, because they consider that covering the examination standards is relevant in itself. Vera was the only one who used her contexts to select concepts to be learnt, in order to increase the relevance of these concepts for students.

Interestingly, only David and Vera, who were the two teachers most experienced in designing and enacting context-based lessons, said they chose their contexts in such a way as to allow making connections between different biological themes or between different lessons, in order to help their students develop their understanding of the coherence between various biological themes. Vera's haemophilia context, for example, connected genetics with circulation. In contrast, Thomas and Richard explicitly tried to avoid such contexts, saying concepts should be put into a clear framework, and that they wished to prevent possible confusion caused by using concepts from different domains within one context.

In summary, the teachers in this study did not feel that the use of authentic, complex contexts would help them work towards the outcomes they intended their lessons to have. Kate even said that using authentic activities would mean fooling students: they will never do activities such as designing a park for real. The only real thing is the test in the end. Marion thought it would be impossible for students to learn from activities that resemble

what people do in real-world contexts. A palaeontologist, for example, already has the knowledge the students still have to acquire, so that a palaeontologist's questions and activities necessarily have to be essentially different from the questions and activities of students learning in a palaeontology context.

With regards to the *structure* of the lessons, two main dissimilarities with the formal design principles catch the eye. First, four teachers chose to employ multiple contexts within one lesson or lesson sequence, ranging from three (Kate and Thomas) to six or more (David and Vera), instead of focusing on just one. Although in none of the cases this was an explicit rule-of-thumb, we can understand why these teachers chose to use multiple contexts within one lesson when we look at the intended lesson outcomes. David wanted to show the general applicability of a biological idea to his students, and to amaze them by using a large variety of stories and images. Vera wanted to make biology relevant for students themselves, so she let her students choose their own contexts, apart from the context that was personally relevant to her. Thomas wanted to enjoy himself while having his students enjoy themselves, and, as he said, both he and his students liked to exchange tall stories, the more the better. Kate, on the other hand, led her students through different contexts at different organizational levels to deeper conceptual understanding. A second difference with the formal lesson structure is that not every teacher started the lesson with a vivid introduction to the context. In this regard Kate and David had a comparable strategy: they began with highlighting a question central to biology, after which they illustrated the answer to this question by using different contexts. Kate explicitly stepped away from the principle that the students' learning process should start from a context and then proceed towards an abstract concept that can be applied in a new context, because she thought that students first need to have the tools (concepts) needed to approach a situation from a biological perspective.

In conclusion, when designing context-based lessons the teachers in this study mainly aimed at activating and motivating students, which is in accordance with the findings by Platteel (2010) in her study of eleven Dutch native language (L1) teachers who designed context-based lessons. Our teachers also, though to a lesser extent, aimed at enlarging conceptual understanding. Only the experienced designers of context-based lessons (David & Vera) aimed at increasing the relevance of their teaching, enhancing conceptual coherence, and having students learn about specific contexts and specific ways of thinking and acting while stimulating their personal development.

2.5.3 Teachers' practical knowledge and their use of rules-of-thumb

The descriptive studies into lesson design by teachers in the 1970s have made clear that teachers' decision-making during lesson design should not be considered a process of generating and rationally weighing alternatives (Shavelson & Stern, 1981). Our study

offers an alternative by suggesting that biology teachers' practical knowledge guides their educational decision-making during lesson design via the use of personal rules-of-thumb. This finding is in line with conclusions from more general research into decision-making in realistic settings, of which a main representative is Gigerenzer (Gigerenzer, 2008; Gigerenzer & Goldstein, 1996). Following Simon (1972), Gigerenzer stresses the fact that people's rationality is bounded, which means that our decision-making is constrained by the availability of time and means and by the limitations of our information processing capacity. Under these circumstances decision-making is greatly influenced by heuristics (rules-of-thumb), for which Gigerenzer gives examples from different fields such as sports and medicine. Our study suggests that rules-of-thumb play a similar role in educational decision-making by teachers, and that these rules-of-thumb can be viewed as that part of teachers' practical knowledge that has a direct effect on educational decision-making.

One characteristic of such "rules-of-thumb" deserves further attention. The rules-of-thumb used by the teachers in this study appeared to be strongly related to intended lesson outcomes and broader teaching goals, as we discussed before. David wanted to include many different contexts in his lesson, because he aimed at showing the general applicability of a biological idea, and Vera used personal stories in her lesson because she wanted her students to understand the relevance of biology to their personal lives. Similarly, many rules-of-thumb (such as 'start the lesson by giving meaning to the concepts, using material from students' own lives' (Kate)) could be split up into different levels, one an outcome of the other. If we take this a little further, it is conceivable that the whole of teachers' rules-of-thumb, related to particular classes and subjects, can be represented by a hierarchy of rules, with the intended outcomes and broader goals at the top and the means at the bottom. These rules-of-thumb, on different levels of abstraction, would be linked together through the questions of 'how' to reach a goal, or 'why' to do something a certain way. (Carver & Scheier, 2001; Kruglanski, Shah, Fishbach, Chun, & Sleeth-Keppler, 2005)

Now, the question is how these rules-of-thumb relate to other conceptualisations of teacher practical knowledge. We will argue that rules-of-thumb are that part of a teacher's practical knowledge that directly guides this teacher's decisions. We believe that in order to study the dialectical relations between teachers knowledge and teacher planning, for which Hashweh (2005) did an urgent appeal, one should focus on that part of a teacher's knowledge that directly guides a teacher's actions. This does not mean that a teacher's knowledge does not encompass more. A teacher's rules-of-thumb are part of, and influenced by, a larger knowledge base of teaching. Since the mid-80s, many studies have been dedicated to the unravelling of the composites of this knowledge base of teaching. In the field of science education, many of such studies focused on studying teachers' Pedagogical Content Knowledge (PCK). The concept of PCK has been introduced by Shulman (Shulman, 1986b, 1987) as an element of the knowledge base of teaching (which, apart from PCK,

includes content knowledge, general pedagogical knowledge, curriculum knowledge, knowledge of learners, knowledge of educational contexts and knowledge of educational ends). In Shulman's words, PCK "represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). In many studies PCK is identified as consisting of different subcategories of knowledge (e.g. (Magnusson, Krajcik, & Borko, 1999), and many studies aim at recovering the content of these subcategories in the study of particular teachers. The study of PCK in this manner can be valuable to identify common patterns in the practical knowledge of individual teachers, which may help furthering our understanding of teacher knowledge and building a framework for helping teachers to develop their pedagogical repertoire. Teachers, however, use all the components of their knowledge in an integrated fashion when planning and implementing their lessons (Abell, 2008). As our study shows, when teachers explain why they take certain decisions when planning their lessons, they do this by using rules-of-thumb: rules that integrate parts of their pedagogical content knowledge that are relevant for that specific moment, those specific students, that specific topic, that specific context in which they design their lesson.

A teacher's practical knowledge is known to be person- and context-bound (van Driel et al., 2001), and this is particularly true for the sets of rules-of-thumb that we identified in this study. A particular context will trigger particular rules-of-thumb. Also, contextual conditions can be translated into rules-of-thumb. An example is the frequently occurring rule to use a context that matches the concepts to be learnt, as dictated by the longer-term plan. This automatically points to a possible limitation of this study: Although the teachers confirmed they recognized themselves and their teaching styles in our case descriptions and in the rules-of-thumb we identified, we do not know to what extent these subsets of rules-of-thumb are representative for these teachers' practice. What's more, the teachers in this study have been asked to design an innovative lesson, with the exception of David and Vera, who were already used to designing context-based lessons. We have not studied which rules-of-thumb the other four teachers use on a regular basis, which of those would be easily replaced by formal design principles, and which are most resistant to change. Follow-up studies are needed to answer these questions. Following teachers through the design of a greater number of more diversified lessons would enable us to increase the validity of the outcomes, and possibly to construct a more complete system of hierarchically related rules-of-thumb, after which questions about the stability, coherence and diversity of such systems could be addressed.

2.5.4 Implications for curriculum innovation

In this study teachers have designed lessons in the context of a curriculum innovation. It has long been known that teachers generally do not implement an innovative curriculum in exactly the way it had originally been envisioned, and that their interpretations and adaptations are crucial in determining how an innovation is enacted in the classroom (Van den Akker, 2003; van Driel et al., 2001). Therefore, it has been strongly recommended to take teachers' knowledge and beliefs into account when innovating a curriculum (Borko & Putnam, 1996; Fullan, 2007). This is, however, not straightforward. We know that the relation between teacher cognitions and teacher behaviour is not always consistent (Mathijsen, 2007). Teacher practical knowledge is also known to remain largely implicit (van Driel et al., 2001). It is therefore needed to elicit that part of knowledge that actually guides teachers' actions. Focusing on teachers' rules of thumb by studying their lesson design processes seems to be promising, not only because rules-of-thumb appear to be strongly consistent with teachers' actions, but also because it is expected that an important part of the interpretation and translation of innovative ideas takes place during the design of lessons (Hashweh, 2005).

The results of our study indicate that a teacher's objectives, through the use of rules-of-thumb, determine which formal design principles are adopted and which are not. Teachers' aim of motivating students, for example, conflicted, in their opinion, with the formal principle of using authentic contexts, and the aims of covering the concepts as stated in the longer-term plan and presenting the concepts within a clear framework conflicted with the formal ideal of making connections between different biological themes within one context.

Our findings could have been influenced by the fact that the teachers had not received any professional support in designing context-based lessons, apart from the experiences some of them had before the start of this study. Although this was a conscious choice, related to the aims of this study (many teachers in The Netherlands will not receive professional support in designing context-based lessons and are nonetheless expected to enact the new curriculum in future), it will certainly have had its effect on the outcomes, and we encourage the development of professional development programs to support biology teachers in their design of context-based lessons. How, then, could the findings of this study inform the design of such programs?

We would recommend such a design to build upon knowledge and beliefs of the teachers who participate (Verloop, Van Driel, & Meijer, 2001). This could be achieved by having the teachers design a lesson while thinking aloud, which will help to make their current rules-of-thumb explicit, and to repeat this in several cycles of design, implementation and reflection. A first group meeting could be dedicated to an explicit discussion of the participants' personal rules-of-thumb in the perspective of the formal objectives and design principles, where the main focus should be the objectives, because these appeared to be very influential.

Such a discussion could be facilitated by the use of illustrative curriculum materials. Later in the program, when teachers are working on the design and implementation of lessons, rules of thumb or heuristics could be regularly identified and referred to. If a teacher chooses not to implement certain innovative principles, this could have different causes: the teacher does not have the same objectives as those underlying the innovation (after which a further discussion of the importance of different educative goals is to follow), the teacher does not believe that innovative principles will lead to the proposed objectives, or the teacher does not believe to be able to implement the principles as proposed. In those cases, the teachers could be supported on demand by providing them with tools, having them exchange good practices and providing them with further exemplary teaching materials.

Chapter 3

Teachers' Educational Design as a Process of Reflection-in-Action

The lessons we can learn from Donald Schön's* The Reflective Practitioner *when studying the professional practice of teachers as educational designers

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Abstract

This chapter combines a review of Donald Schön's *The Reflective Practitioner* (1983), with an analysis of the lesson design process of Richard, one of the teachers who participated to the study which was described in chapter 2. The question is asked how Schön's concept of reflective practice could be used to further clarify the relation between a teacher's practical knowledge and the decisions he takes while designing innovative lessons. Schön argues that a practitioner's practical knowledge, or knowledge-in-action, is applied, tested, and developed during the process of reflection-in-action, which is essentially a design process. During the process, a practitioner's knowledge takes the form of *rules, types* (images of past situations, that help to recognize and understand the current situation), and *appreciative systems* (which determine how a practitioner assesses expected outcomes of design moves). We used these concepts to analyse the lesson design process of Richard, one of the teachers who took part in the study described in chapter two. Richard, an experienced biology teacher, designed a context-based lesson for his own students while thinking aloud. Richard's case shows how his knowledge-in-action became activated and transformed during reflection-in-action while preparing his lesson. Framing Richard's decision process as a process of reflection-in-action clarifies the relation between his knowledge and his design of this lesson. This perspective helps to understand why teachers, in general, and Richard in particular, tend not to implement innovations in the exact way they were envisioned. We identify rules, types and appreciations, as active entities of Richard's knowledge. Further analysis will also reveal that Richard's rules are hierarchically related, and that his decision-making during the design of the lesson can be represented as a trajectory through his personal hierarchical system of rules and goals. Goals that are higher in the hierarchical system give a new meaning to Schön's concept of "appreciative systems", a concept which in Schön's book was rather vaguely defined. Therefore, we postulate that the use of hierarchical goal systems could add to Schön's understandings of reflective practice by understanding better how rules, types, and appreciations influence decision-making and are interrelated.

3.1 Introduction

The world of educational research is a strange one for a teacher to enter. This was very true for me as a biology teacher, having my origins in the "harder" sciences and trained to measure trees, not people. Naively, when I started my PhD study I expected to find a clear set of methods for investigating teacher knowledge and behavior. What a shock to find myself in this hazy environment full of conceptualizations and constructs, overlapping but disconnected, with names such as beliefs, intentions, cognitions, principles, orientations, and knowledge that could be formal, situated, personal, or practical. I was interested in knowing what teachers do when designing lessons, how this relates to their knowledge base, and how lesson design can be learnt, which seem to be straightforward questions, but satisfying answers proved difficult to find. A study of the literature taught me that until the 1970s the main aim of studies on teacher planning was to describe teacher behavior and to assess whether teachers follow formal planning models. The conclusion was that they usually do not plan according to goal-oriented models (Yinger & Hendricks-Lee, 1994). From the 1970s onward, attention shifted to teachers' cognitions. Lesson planning was considered a process of either solving problems or of decision-making, with teachers generating alternatives and choosing between them (Shavelson, 1973). Later, Shavelson himself criticized this perspective because it underestimated the role of routines and the influence of classroom materials (Clark & Dunn, 1991; Shavelson & Stern, 1981). More recently Maher Hashweh, who has played an important role in developing the concept of *Pedagogical Content Knowledge*, could not but observe that there is still limited knowledge on the interplay between teacher knowledge and educational design (Hashweh, 2005), that is to say: we lack answers to the questions about how teachers' knowledge develops during the design of lessons, and how this knowledge guides the design process.

While searching the literature for answers every once in a while I ran into quotations from the influential book *The Reflective Practitioner* by Donald Schön (1983), in which I recognized my own experiences as a teacher. Could Schön's ideas help me understand how teachers know what decisions to make when designing their curriculum, and how they learn throughout this design process? It took a while before I finally started reading the book, mainly because of the negative associations with the word "reflection" I had built up during my year of teacher education, but also because Schön's work is often associated with reflection in the sense of "looking back" on something, and is not often cited in the context of educational design by teachers. Not only did it take me a while to *start* reading the book, it also took me some time to finish it. The book proved not to be that fine collection of crystal-clear sentences like the ones I had read in the quotations of his work by others. I had, I think, the kind of experience described by Donald Schön himself in an article he wrote for *Curriculum Inquiry* in 1992, about him reading Dewey's work: "…I found him muddy

and unintelligible. Later on … I saw that Dewey's was a *generative* muddiness: he was trying to say new things that were bound to seem muddy to anyone trained as I had been in the logical empiricism fashionable at the time" (Schön, 1992). In spite of this, I found many interesting parallels between Schön's ideas and the things I myself had discovered when studying teachers' design of lessons. The aim of the review presented here is not to give a detailed summary of the book, as there have been enough of that kind since 1983, but to see if the book still tells us "new things" (to use Schön's words) that can aid the study of teachers as educational designers.

3.2 The Reflective Practitioner

Donald Schön was Ford Professor of Planning and Education at the Massachusetts Institute of Technology from 1972 until his death in 1997. He was inspired by the work of John Dewey, about whose theory of inquiry Schön wrote his doctoral thesis. As Schmidt (2000) notes, Schön was not only an inspiring lecturer, advisor, and musician, but also a very productive author. His sixth book, *The Reflective Practitioner* (1983) has become his best-known work, together with its sequel, *Educating the Reflective Practitioner* (1987). *The Reflective Practitioner* is considered of particular importance because it was the first one in which he comprehensively unfolded his overall epistemology of professional practice, based on the concepts of knowledge-in-action and reflection-in-action. In 1983 the book was innovative in two aspects. First, it represented a recognition of the importance of practitioners' special kind of knowing. Second, it gave an enlightening view of how we, real people, solve problems in the real world and how we simultaneously apply and create our knowledge in the process.

The book starts with a critical discussion of the view of professional knowledge dominant at the time (and in many regards prevailing still): the paradigm of Technical Rationality. According to this view valid, research-based knowledge is solely generated by academics, only to be applied by practitioners as they solve well-defined problems. This view, as Schön argues, can no longer be maintained. In real life, problems are usually not so well-defined that they can be solved by the straightforward application of academic knowledge. Instead, practitioners constantly need to define the problems by naming the things they will concentrate on and framing the context in which they will attend to them. The world is governed not by academic, formal knowledge, but by the knowing-in-action and reflection-in-action of practitioners. Their knowing-in-action is revealed by everyday routines of action. This is a type of knowing practitioners will not readily be able to explicate. Also, practitioners think about what they are doing while doing it in the process of reflection-in-action. Schön draws on his own experiences as a jazz pianist and clarinetist

when he illuminates the process of reflection-in-action in his portrayal of a jazz musician in the midst of improvisation, responding to the musical moves of a colleague. We can also think of a teacher in the midst of action responding to a student's unexpected behavior. Reflection-in-action is about "finding your groove": "studying those winning habits and trying to repeat them every time you perform" (p. 54). Then, there is also such a thing as reflection-on-action, a term that is reserved for the looking back one does after the situation when new insights, although they can be very useful, can no longer have any influence.

After the introduction of his main concepts Schön sets out to describe the knowledge-in-action, reflection-in-action, and reflection-on-action of different practitioners: an architect, a psychotherapist, a civil engineer, a town planner and a manager. During his rich descriptions of these different cases, in which the processes of reflection-in-action and reflection-on-action seem to take many different forms, it becomes obvious that, however appealing the image of the reflective practitioner, it may be rather difficult to distinguish between the different processes in practice. Eraut (1995) even concludes that "most of his examples fail to provide evidence of reflection-in-action. … Indeed it is difficult to distinguish reflection-in-action from reflection-on-action" (p. 9).

Schön ends his book with a chapter in which suggestions are made for the education of professionals and for the organization of professional institutions, in order to create places where conversations between professionals and clients, between managers and their employees, and between colleagues can take the form of reflective conversations in which professional knowledge is explicated and developed. Although Schön gives a clear presentation of his model in which a practitioner's knowledge is simultaneously used and created during the process of reflection-in-action, he does not describe what this knowledge is, exactly. Still, during his elaborate descriptions of the process of reflection-in-action it becomes clear that a practitioner's knowledge base consists of at least three entities: (1) images of past situations, or *types*: prototypical buildings or parts of buildings in the case of an architect, or former lessons or lesson elements or structures in the case of a teacher; (2) theories-in-action, consisting of *rules*, often linked to types: again, an architect might feel that a cathedral (type) must always have a cross shape or a teacher could be convinced that a lesson with a particular group of students should always start with a personal story; and (3) *appreciative systems*. In his discussion of appreciative systems Schön compares the normative scientific hypothesis-based method of experimenting to reflection-in-action, which is also a way of experimenting: "when someone reflects-in-action, he becomes a researcher in the practice context" (p. 68). Whereas in scientific experimentation the objective is to discriminate between competing hypotheses, in the experimental process of reflection-in-action the objective is to change a situation into one that the practitioner likes better. This is done through taking actions or, as Schön often calls it, making moves, which can be either imaginative or real. The moves and underlying rules are *affirmed* if a practitioner

likes what she gets, which is not necessarily the same thing as getting what she expected. Both the assessment of the initial situation and whether or not a move will be affirmed are determined by a practitioner's appreciative system, including personal experience, values, and beliefs, while the process in turn influences a practitioner's appreciations.

Many of Schön's ideas fell on fertile ground, not only because the book put forward the right things at the right time, when people had begun to feel uncomfortable with the dominant positivist approach to knowledge, but also because of Schön's persuasive writing style and abundant use of examples. The concept of knowing-in-action has largely influenced our way of thinking about what teachers know and how they know it (Fenstermacher, 1994). Munby and Russell did important work building upon the conceptualizations of Schön, for example by elaborating on the role of metaphors (Munby & Russell, 1990). Reflection-on-action has become a basic concept in teacher education and research on teaching worldwide (Korthagen, Kessels, Koster, & Lagerwerf, 2001; Lyons, 2010).

Along with the embracement of his concepts came the criticism. Remarks have been made, for example, about Schön's favorite example of reflection-in-action. This example, that has become almost mythical, is situated in a design studio where a master architect, Quist, coaches a student, Petra, working on the design of a school on a difficult terrain. In chosing this practice to illustrate his concepts Schön chose a situation in which the practitioners have the time and some distance to make virtual moves by means of a sketch book and to contemplate on them (Carlgren, 1999; Eraut, 1995). This situation is not only different from a normal design situation, but also considerably different from the situation of a teacher in a classroom, who needs to act and think at the same time, who cannot "sketch and erase" , try something and rewind the time to try something else. Teachers don't spend all their time in front of classrooms, however. There are important instances where a teacher's practice resembles that of the work in a design studio, and the design of lessons is one of them.

3.3 Reflection-in-action in lesson design

Considering the fact that the process of reflection-in-action has been described as essentially a design process, in which knowledge-in-action is applied, tested and developed with the aim of finding satisfying answers to more or less problematic situations (Schön, 1983, 1992), using Schön's image of the reflective practitioner when studying the interplay between teacher knowledge and teachers' daily lesson design seems to be a promising undertaking. Let us therefore try to put Schön's ideas about reflection-in-action into practice in the context of lesson design. For simplicity's sake I will focus on the three elements of practical

knowledge[2] described before: types, rules and appreciations. In a recent study six biology teachers designed lessons while thinking aloud (Wieringa, Janssen, & Van Driel, 2009). As Schön would have predicted, the design problems (intended outcomes for the lesson, etc.) and possible solutions were not clear from the beginning, but instead were constantly defined and redefined during the process of designing the lesson. Analysis showed that these teachers' knowledge influenced the design process mainly through the application of rules, and secondly through the appreciation of the expected outcomes of design decisions. One teacher, for example, had the rule always to start with a personal story, and then decided to let her students work on the computer, because she expected that this would lead to higher student motivation than having them work on a pencil-and-paper assignment. Types, for example in the form of fragments of former lessons, also played a role, as Richard's case will demonstrate.

Richard is an experienced biology teacher, and one of the teachers who participated in the afore-mentioned study. The study took place in the context of a (still ongoing) reform of the biology curriculum in The Netherlands, aimed at making the curriculum more relevant and more coherent. As a part of this reform, teachers are stimulated to use realistic situations from students' own lives, from society or from professional or scientific practices when introducing biological concepts to their students. Richard had not been trained to use this so-called context-based approach to teach and to design his lessons, but he had heard about it and wanted to give the approach a try to address his main concern: a lack of student motivation. He chose to design a lesson about the central nervous system for a group of 16- to 17-year-olds, to be implemented the week after.

Figure 3.1 gives a representation of the rules, types and appreciations used by Richard during the design of his lesson. This figure, although it is only a fragment of a larger whole, provides a diagram of Richard's knowing-in-action and how this changed during reflection-in-action. Richard started by checking the year plan and determining the concepts to be learnt: the structure and function of the two parts of the autonomic nervous system, namely, the part that controls the bodily functions in situations of stress, and the part that does the same for situations of relaxation. These we could call his most important rules: the lesson should cover the concepts as stated in the year plan (rule 1), and hence he would need a context that covered the entire concept (rule 2). He then searched the internet for situations in which people use knowledge about the autonomic nervous system, which automatically led him to medical contexts (rule 3), such as asthma and bowel diseases: diseases that might be caused by a disturbance of the equilibrium between the two parts

[2] I use the term "practical knowledge" to refer to the knowledge teachers themselves generate as a result of their experiences as teachers and their reflections on these experiences Fenstermacher, G. (1994). The knower and the known: The nature of knowledge in research on teaching. *Review of Research in Education, 20*(1), 3-56.

of the nervous system. This is when Richard realized that such situations would not cover the concepts as planned in his yearly plan: he found it particularly important that students would realize that one part of the nervous system intervenes all the organs simultaneously, while in the asthma context for example only the lungs have a part. Also, Richard feared that using a medical context would give students the erroneous impression that things go wrong in their body all the time. He became quite frustrated at this point, sighing "if we wouldn't try so hard to make some context-based thing, I would have stopped a long time ago…". In Schön's terms, the internet search leading to asthma and bowel diseases could be considered a first experiment as part of Richard's reflection-in-action, which ended with his disapproval of the outcome (his *appreciation*). It led him to the formulation of a new rule, or more probably, an already existing rule that yet had to be make explicit: the lesson should help students to experience the beauty of biology when their body works as it should (rule 4). He further clarified that as a general rule he aimed at leaving his students with a positive image of biology (rule 5). Richard believed that such an experience could be better achieved through the use of a more appealing context, where the body functions as it should (6). He

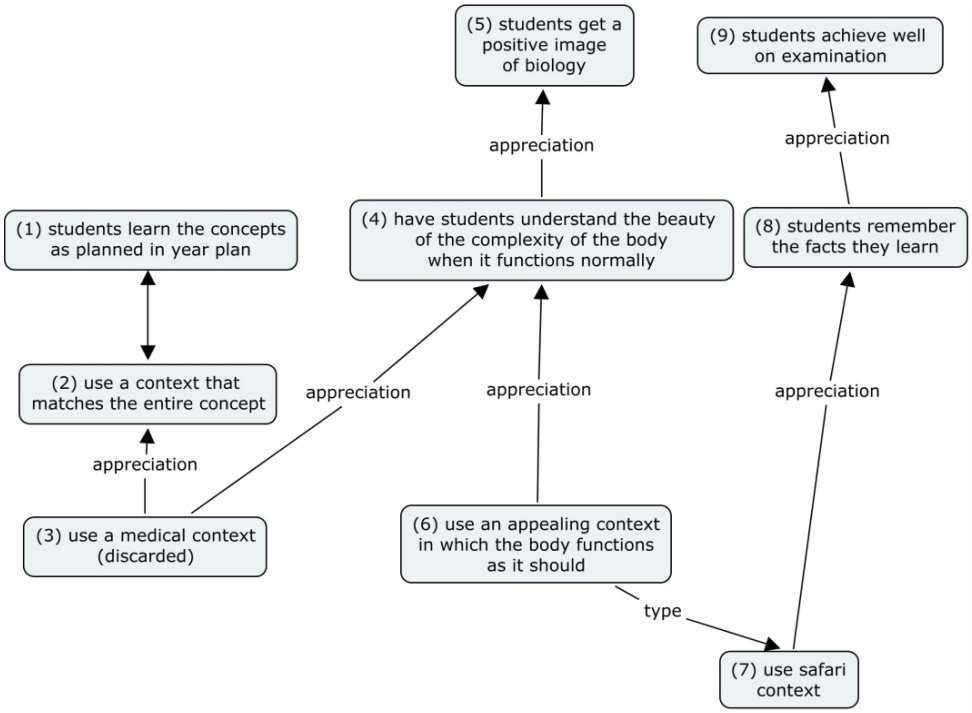


Figure 3.1 Schematic representation of the rules, types and appreciations Richard used while designing a lesson about the central nervous system. Rules are in the boxes, numbers refer to the order in which the rules appeared during the design process, as explained in the text. The arrows indicate the relationship between the different rules, which are defined by either a type or an appreciation. Rules that are positioned at a higher level refer to expected outcomes of the lesson, while rules at a lower level refer to concrete attributes of the lesson.

recalled a fragment of an earlier lesson (a type) in which he used the analogies of a lion (when a lion jumps forward, your nervous system is in a state of arousal) and a cake-eating event, when the system is in a state of rest (rule 7). Richard had been pleased with these analogies (appreciation), because they had helped students to remember the things they learnt (rule 8), which, he hoped, would lead to better grades (rule 9). Now his lesson plan unfolded itself quickly: the lesson would start with a story about the class being on a safari trip together, taking a break, eating cake, when suddenly a lion jumps forward. Then, the students would be asked to predict what the organs would be doing during both the cake-eating- and the lion scenes. This last part of the lesson design process is not included in figure 3.1. Richard was contented with his lesson plan, one that he considered better than his regular ones.

The example the elements of reflection-in-action are present. We have seen how Richard, while designing, reflects on his rules, performing mental experiments to predict their outcomes, appreciating some and discarding others. In the process, he defines the means and ends of his lesson interactively. From a research point of view, framing Richard's design activities as an example of reflection-in-action seems to clarify the relation between his knowledge and his design of this lesson, and, more particularly, demonstrates how an innovative idea (namely, context-based education) is put into practice by this teacher.

3.4 Conclusions

As argued in the beginning of this review, the relation between teachers' practical knowledge and their educational design has so far remained relatively unexplored. How does rereading Schön's classic help us? To revert to the title of this review: what lessons can we learn from Donald Schön's *The Reflective Practitioner* when studying the professional practice of teachers as educational designers?

I would say there are three main lessons to be learnt. First, reading Donald Schön's book directs the attention to the process of lesson design as a source of knowledge for the teacher, who is in the middle of reflecting-in-action while designing, and as a source of knowledge about a teacher's knowledge for the educational researcher, a promising perspective that has also been advocated by Hashweh (2005). Second, in his book, Schön argues that, in the design process, the problem and possible solutions constantly co-evolve, contrary to a still prevailing view according to which knowledge is something that is generated by researchers and is to be applied in a straightforward manner by teachers when planning their lessons. A "Schön-like" way of looking at educational design helps us understand why teachers tend not to use design models and not to enact innovations exactly the way they were envisioned

(Verloop et al., 2001), and can lead us to a better appreciation of the value of teachers' practical knowledge: knowledge that has been tested in teachers' own specific contexts, with their own groups of students. A third reason why rereading Schön's book can help the study of lesson design by teachers is his introduction of the concepts of "rules", "types" and "appreciations" as entities of practical knowledge (although he might not have liked my phrasing if I say "entities" of knowledge). These are concepts that can be studied, and that we can communicate about.

In summary, it is productive to consider lesson design by teachers as an example of reflection-in-action. There are, however, two aspects deserving more attention than they get in Schön's conceptualization of the reflective practitioner, the first of which is the relationship between "formal" knowledge and a teacher's practical knowledge. Schön, in his enthusiasm to challenge the positivistic thinking from the school of Technical Rationality at times seems to forget that the role of formal academic knowledge is not negligible, however important the role of practical knowledge (Eraut, 1995). This is an important issue in the context of teacher education and professional development, but the matter also calls for our attention when studying Richard's case. Richard learnt about the principles of context-based teaching through a formal publication by the Dutch innovation committee of biology education, and wished to try it in practice, designing a lesson that was different from his regular lessons. It could be expected that formal knowledge somehow finds its way into a teacher's knowledge in action, first by influencing the whole of rules, types and appreciations a teacher uses, and by consecutive rounds of reflection. "Enriching" Schön's concept of knowledge-in-action and reflection-in-action by including formal knowledge in the knowledge base of teaching, giving special attention to the relation between formal and practical knowledge (Verloop et al., 2001).

A second aspect deserving more attention is the mutual relationship between a teacher's rules, and the relationship between rules and appreciations. In Schön's book the exact meaning of "appreciative systems" is somewhat vague; in some of his examples they appear to be very personal, while in others they seem to be part of a larger social system. In any case, appreciative systems determine whether or not the outcome of an experiment, real or virtual, is considered successful. Figure 3.1 shows that in the case of Richard appreciations are linked to certain rules: rules defined at a higher hierarchical level than other rules. Richard's rule "the lesson should help students to experience the beauty of biology" for example caused Richard to reject the asthma context and to embrace the safari context. Hypothetically, all the rules a teacher uses in a certain session of reflection-in-action are hierarchically related. Such an images reminds one of both the concept of goal hierarchies in the field of cognitive psychology (Carver & Scheier, 2001) and the idea of hierarchically related design steps in the field of design research (Kazakçi & Tsoukias, 2003). If this is true, such a hierarchy of rules and its relation to types and appreciative systems deserves further study.

Chapter 4

Using goal systems to make sense of biology teachers' interpretation and implementation of a context-based reform

This chapter is based upon:
Wieringa N., Janssen F.J.J.M. & van Driel J.H. (2013), Het gebruik van doelsystemen om de interpretatie en implementatie van concept-contextonderwijs door biologiedocenten te begrijpen [Using goal systems to understand biology teachers' interpretation and implementation of a context-based reform], *Pedagogische Studiën* 90(3): 37-55.

Abstract

Teachers simultaneously have to meet many diverse goals when planning and teaching lessons. A so-called goal system can be used to represent the hierarchical relationships between teachers' goals and teaching practice. The aim of this study is to explore how goal systems can be used to understand how individual teachers interpret and implement a new, innovative curriculum. Our study is based on twelve biology teachers who participated in a professional development program to design and use context-based lessons. During an initial interview each teacher's goal system was mapped out using the technique of *laddering*. Subsequently, during the professional development program, interviews, lesson plans and thinking aloud protocols were used to gain insight into teachers' interpretation and implementation of this educational innovation. We found that within a goal system, teachers' *core goals* – which are defined as goals with two or more links to either higher or lower ranking goals – strongly influenced teachers' interpretation and implementation. To a slightly lesser extent, negative links – i.e. goals that obstruct or contradict each other- also influenced appeared relevant.

4.1 Introduction

Recently, the Dutch secondary school science curricula have been updated. This reform was inspired by a context-based approach (Boersma et al, 2008) with the aim of becoming more relevant, up to date and coherent. How this innovation is actually implemented in the classroom depends on how teachers design and teach their lessons (Dam, Janssen, & Van Driel, 2013). In general, educational reform is mainly targeted at student learning. However, teachers who design and teach lessons simultaneously have to meet many diverse goals (Doyle & Ponder, 1977; Kennedy, 2002, 2006). Kennedy (2002) found these goals reflect into six areas of concern for teachers: sustaining the flow of the lesson, increasing learners' motivation, teaching the required content, fostering learning, running a well-managed classroom and meeting the teacher's own cognitive and emotional needs. All these areas of special interest come into play when teachers teach a new curriculum, irrespective of whether they make use of ready-made teaching materials or design their own (Davis, Beyer, Forbes, & Stevens, 2011).

It is not yet clear how all these varied goals influence teachers during lesson preparation and execution. We do know, that interviews with teachers about their practice usually do not bring this whole range of considerations to light and also that the relationship is not one on one between what teachers say they want to achieve and their actions (Cochran-Smith & Lytle, 1999; Cohen, 1990; Kang & Wallace, 2004; Mathijsen, 2007). Videotaping of lessons with follow-up questioning about the teacher's decisions has been used in an attempt to gain a better understanding of teachers' goals and practices (Kennedy, 2002; Schoenfeld, 2010). However, this is a time-consuming method which, although it provides a wealth of information about one or a small number of lessons, does not easily allow us to ascertain which of the teachers' goals will actually come into play during the implementation of an innovation.

Psychology has a long tradition of conceptualizing peoples' goals, and also of relating those goals to their conscious or unconscious decisions, for example when making choices about staying in a relationship, choosing a product from the supermarket shelves or while planning lessons (Austin & Vancouver, 1996). It appears that peoples' goals are organised within a hierarchical system. Someone who works out in a gym three times a week might, for example, do so to improve their physical condition, enhance their physique and to meet other people as well. The goal of an improved physique is subordinate to higher level goals such a healthier and longer life. Goals such as looking more attractive and meeting new people are goals which can also be subordinate to alternative higher-level goals (Carver & Scheier, 2001).

This study aims to research if goal systems, based on teachers' individual knowledge and experience, can clarify their understanding and implementation of an innovative

context-based curriculum. This research was carried out during a professional development program which aimed to support biology teachers in their design of context-based lessons for their own classroom practice.

4.2 Theoretical framework

The main inspiration for the use of hierarchical goal systems comes from Carver and Scheier (2001), who again refer to back to Powers' (1973) control-system theory. A goal system consists of different levels of goals: high, intermediate and low. Goals at the highest level usually refer to fundamental aspects of personality, such as being a good, nice or successful person. Intermediate level goals often refer to actions a person must take to achieve those higher goals, such as spending more time with their children in order to be a 'better' parent. Goals at the lowest level describe how such an intermediate level goal can be reach (reading a story to my children every night). Lowest level goals can take the form of *scripts*, a series of actions to be performed in a certain order.

Goal systems usually refer to positive goals, i.e. goals someone wishes to achieve. However, negative goals, i.e. things to avoid, can also be part of a goal system (Carver & Scheier, 2001). A child for example may want to go straight home after school to avoid being punished for tardiness by his/her parents. Goals can also be positively related with one aspect and negatively related with another, for example working out at the gym can improve fitness and physical appearance on the one hand, but time-consuming work-outs can correlate negatively with the wish to spend more time with the children reading bedtime stories and thus being a better parent.

The possibilities goal systems offer to comprehend how teachers' goals relate to their actual teaching have, until recently, received little attention and research. Janssen et al. (2013) have demonstrated that a teacher's goals system does indeed seem to influence their classroom practice. They also present a method to increase tot perceived congruence between a reform ideal and a teacher's goal system, thereby increasing the likelihood of their adopting an innovative method of teaching.

In this study we aim to research in which way or ways a goal system can be used to explain and comprehend individual teachers' understanding and implementation of an innovative curriculum. It is to be expected that some goals are more important than others. Ford (1992) stated that the most influential and motivating goals are those that have the most links to other goals and that these well-linked goals are more resistant to change compared to goals with fewer links. Kruglanski et al. (2013; 2011) have further developed this idea. They describe two variants, the first of which is equifinality. Equifinal goals are ends that can be achieved through different means. For example, to lose weight someone

can work out three times a week, cut out high-calorie foods and ask their partner to remind them of their resolutions. The second variant is multifinality, in which one means can serve different higher-level goals. To return to the example, someone who wishes to lose weight can do so to fit a certain summer dress, to look better and to improve his or her health. Kruglanski et al. (2013) state that people value multifinal and equifinal goals, that is, those which are either linked to multiple higher or lower level goals, higher then goals that are less connected to other goals.

Based on the above, a number of hypotheses can be formulated concerning the relationship between a goals system and the implementation of an educational innovation. Firstly, we expect equifinal and multifinal goals – goals which are more highly linked to other higher or lower level goals – to have the most influence on how a teacher interprets an innovation. We shall refer to these goals as *core goals*. Secondly, we expect that not only positive, but also negative links in teachers' existing goals systems are of influence on their interpretation of the innovation. Negative links presumably cause conflict in a teacher's existing practice. To resolve this conflict a teacher could cherry-pick those innovative elements that fit easily into their existing goals system and teaching practice.

4.3 Methods

4.3.1 Context

This research was carried out in the context of a professional development program designed to help teachers to develop innovative context-based biology lessons. Dutch biology teaching is undergoing a reform, the aim of which is to make biology education more relevant, more up to date and more coherent. To meet these ends, learners need to learn to apply concepts within relevant contexts. In this new curriculum contexts are defined as authentic practices, in which participants carry out certain activities with the aim of meeting goals which are relevant within this practice. Examples of contexts are, for example, the stewardship of a nature reserve; food production; or forensic research (Boersma, Kamp, Van den Oever, & Schalk, 2010). The new curriculum does not specify a way of teaching, i.e. pedagogy, but encourages teachers to (re)design their lessons according to the concept-context approach. The professional development sessions in this research were based on, firstly, a pedagogical framework, which incorporates the innovation principles as described by Boersma et al. (2010), and, secondly, on the experiences of teachers who participated in curriculum development schools (in Dutch: Biologie Ontwikkel Scholen) and whose input influenced the finalized curriculum.

The professional development program was conducted by two teacher educators, one of whom had been a member of the curriculum commission CVBO (In Dutch: Commissie

Vernieuwing Biologie Onderwijs). During the program, participants designed and taught short lesson series based on the new context-based curriculum. They met up with the two teacher educators during five sessions to discuss the new curriculum, to analyse existing examples of context-based lessons and to receive, on a need-to-know basis, specifically designed tools to allow them to design their own context-based lessons. Both the teacher educators and participating teachers themselves presented examples of context-based lessons or series of lessons. During the sessions, participants were encouraged to make use of the available expertise and were given the hands-on opportunity to design context-based lessons and to reflect on their teaching experiences.

Table 4.1 Characteristics and objectives of context-based lessons

Lesson characteristics	Objectives
1. Start with a vivid introduction on the context that ensures students imagine themselves being part of the context and that activates prior knowledge (A,B,C)	A. Students' prior knowledge is activated.
2. The context is a concrete situation from students' life worlds or from professional or scientific practices (C, D,E,F,G)	B. Students feel involved and focused.
3. Within the context multiple biological concepts from different biological domains come together (G)	C. Students feel motivated to learn biology.
4. The teaching unit has a guiding question, which provides a clearly focused problem orientation (H,I)	D. The concepts have relevance within the context.
5. The student activities match the context and guiding question (F,I)	E. The concepts derive their meaning from the context; students learn to understand the importance of biological knowledge within this particular context.
6. Students learn to use key concepts of biology (J)	F. Students learn to develop specific biological skills.
7. Students are stimulated to reflect upon their learning process, their understanding of the biological concepts and the relation between the concepts (G,J)	G. Students learn to understand how different biological concepts are related.
8. Students are presented with multiple contexts in which the same concepts are used (E,J)	H. Students feel a "need-to-know".
	I. The teaching unit is coherent.
	J. Students work on a thorough understanding of biological concepts and are able to use these concepts within a diversity of contexts.

Note The objectives as they have been defined in the right column are in most cases not only objectives, but also means towards higher goals such as conceptual understanding (J). In the PD program, a chart has been used in which the hierarchical relationships between these means and goals had been visualized.

4.3.2 Participants

Fifteen biology teachers from five different schools participated to the program (table 4.2). All had responded to an advert in a national journal for teachers or an email sent to secondary schools in the province of Zuid-Holland. Participants came from schools in Zuid-Holland, Utrecht and Brabant. Three teachers discontinued the program for personal reasons and have been discounted in this research. The results from all twelve remaining participants have been analysed. Due to lack of space, we chose to mainly focus our report on the development of three of them: William, Marion and Nicoline. These three teachers were chosen because they show a wide range of variation in terms of the content of their goals and the nature of the relationships between their goals and their implementation of the new biology curriculum.

Table 4.2 Participants

Teacher	School	Predominantly teaches in grades…	Teaching Experience [years]
Ingrid*	A	1-6 pu/gs	20
Nicoline	A	4-6 pu	23
Jacqueline	B	4-6 pu	3
Norbert	C	4-6 pu/gs	11
Steven	C	1-3 pu/gs	5
Simone	C	1-3 pu/gs	20
Ben	C	4-6 pu/gs	3
Roger	C	4-6 gs	34
Elizabeth	C	4-6 pu	30
Marion	D	4-6 gs	15
Oliver	E	4-6 pu/gs	9
William	E	4-6 pu/gs	31

* Pseudonyms have been used to ensure anonimity

** Grade 1 is the first grade of secondary school, comparable to grade 7 of the English/American system. Average age of pupils is 12/13. pu = pre-university; gs = general secondary education. No pre-vocational education teacher participated in the study.

4.3.3 Data collection and analysis

As an initial step, the goal system of each teacher was constructed during a laddering interview. This interview technique has been commonly used to decipher and elucidate goals and their hierarchical relationships (Fransella, 2005; Grunert & Grunert, 1995; Reynolds & Gutman, 1988). During such an interview, the interviewee is continually asked the following two types of questions: 'why do you do that?', and 'why do you think that that is important?' on the one hand, and 'how do you do that exactly?' on the other. The merits and use of this technique to elucidate teachers' goals systems has been described in detail by Janssen et al. (2013). During the intake interview, participants were requested to describe one of

their recent lessons and to use this lesson to characterize their regular teaching practice. Then, teachers were asked to describe more in detail how they commonly approach certain aspects, such as explaining new content, and why. Each goal a teacher mentioned was written down straight away, and the reasoning behind the goal was unpacked using follow-up questions until no more new information could be extracted. Because goal systems are context-dependant, each teacher was asked to focus on one class or level of learners during the whole professional development program, and to have a 'regular' lesson in this class in mind during the interview. During the interview the hierarchy of goals that make up the goal system was constructed graphically. The annotation of the goals and of their relationships was written down in the teachers' own words. No later adaptations or changes were made to these goal systems, except for some considerations of layout to improve legibility. Teachers were immediately asked to comment on the resulting goal system and were asked questions such as: 'do you think this goal system matches what you really think and do in this class?'; 'is there anything you would wish to add?'; 'do you think this goal system also applies to lessons about other topics in this class? And if so: why or why not?'; 'are certain goals more important than others?'; 'are certain goals easier to achieve than other goals?'; and also: 'what prevents you from reaching certain goals?'; 'do some goals contradict others and if so, how?' All in all, each interview lasted about one and a half hours. Afterwards the first author marked the central (multifinal and equifinal) goals in the system. Core goals were defined as goals linked to two or more other goals at a higher level (multifinal goals; Kruglanski et al. (2013)) or to two or more lower level goals (equifinal goals; Kruglanski et al. (2011)).

To gain insight into the way in which each participating teacher understood and implemented the new curriculum their lesson plans, assignments and videos of their lessons were collected both during and after the professional development program. Teachers' discussions during meetings were taped and during the fourth session an audiotape was made of each teacher thinking aloud during the process of designing a lesson. Shortly after this meeting, teachers were approached by telephone for individual interviews. Four to five months after the end of the professional development program, each teacher received a school visit and final interview, to discuss changes in their thinking and teaching and to allow them to reflect on the professional development program, the new curriculum and their personal goal system.

All discussions, interviews and thinking-aloud protocols were literally transcribed and coded. Based on the research question, and prior to coding, the following categories were chosen: 1) lesson characteristics, 2) teachers' goals during lesson design and teaching, 3) changes in teaching and thinking about teaching, 4) knowledge about, and attitude towards, the new curriculum, 5) references to elements from the professional development program, and, finally, 6) concerns, dilemmas and challenges as experienced during the implementation of the new curriculum. Based on the results of the analysis, subcategories of these main

categories were defined during the coding process (Miles & Huberman, 1994). Using this coding system, we constructed characterisations of each teacher's thinking concerning their teaching practice in relation to the new curriculum as well as their development. We performed a member check by presenting these characterisations to the teachers during the final interview.

4.4. Results

The results from the three previously mentioned teachers, William, Marion and Nicoline, will be discussed as examples of how different teachers' goal systems relate to their interpretation of the new curriculum. For each teacher their usual practice, goal system, interpretation of the new curriculum and the changes they made to their regular teaching practice will be described and discussed.

4.4.1 William

Usual teaching practice and goal system

William usually started his lessons by discussing the homework and asking questions to recap the previous lesson. He then would go on to the main body of his lesson, an explanation of new concepts. Subsequently learners started working on assignments and tasks in the course book. William's main conception of his role as a teacher was that it is his job to explain the structure of the subject material, make connections, and to show learners the bigger picture. This, 'showing the bigger picture' was a main goal of his teaching, with which three lower level goals were linked (see figure 4.1). Of course, he had other goals too, such as preparing learners for their exams, and helping them to make connections within textbook texts. Because his school urged him to do so, he has tried out a few active work methods, but he took a negative view of these methods due to his conviction that learners need his explanation to see the bigger picture. A second reason for his dislike was that these activities disrupt classroom routine. Importantly, William saw himself as a storyteller. Telling stories was part of his identity as a teacher. 'I don't switch my routine too often… because in my experience it makes it all so inefficient…and basically, I am a storyteller. Students often say to me "you're good at telling stories but they're such long ones." Well, yes, that's true, but I consider it my responsibility to explain and provide examples, that's just what I'm good at and that's my job.' William stressed this point so strongly that we also consider this to be a main goal, even though it only has two links to higher-level goals.

William's interpretation of the new curriculum

During the professional development sessions devoted to lesson preparation, William

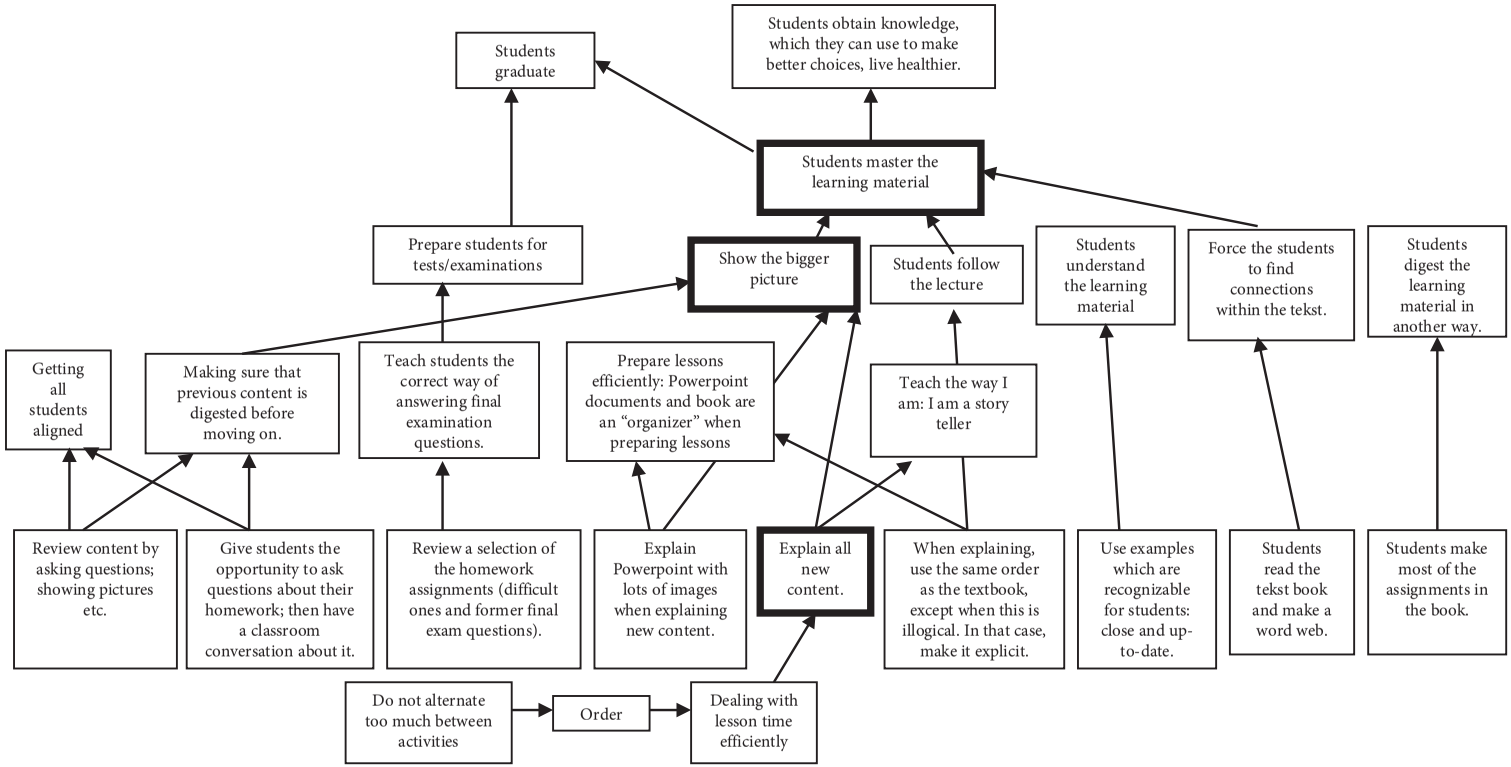


Figure 4.1 William's goal system. Core goals have bold outlines.

consistently stressed the importance of explaining the main story, and took this as his starting point for lesson development. During these lessons, his explanations to the whole class remained the core, although he did allow learners more time to work on his newly designed assignments. His choice of contexts was, in the first place, determined by what he assumed pupils to be able to relate to, the same way as in his usual lessons, where he provided many examples to allow pupils to make mental images of the content of the lesson. Secondly, he chose contexts that did not take the focus off the concepts he wanted to teach. He remained unconvinced about other elements of the new curriculum (see table 4.1) because he thought that contexts and context-specific meaning of concepts were over-rated. Also, he feared that allowing learners more time to make their own contributions to the class would detract from a clear understanding of the concepts at hand.

William's take on the new curriculum became even more clear when he discussed existing examples of context-based lessons, his own lessons or those of his fellow participants. He stated that he would choose to use some sections of the existing exemplar context-based lessons to allow learners to practice application, but only at the end of a lesson series. He stressed, however, that the context received too much attention, to the detriment of clear concepts. For example, Concerning Nicoline's lesson series, in which learners took on roles in an ecological advisory company, William said: 'Yes, I tried that out once when we were working on the topic of humans and the environment, but .. well, after giving learners three lessons of preparation time, they did the presentations but they just stuck to the text in the book and did not make connections.' When he talked about his own lesson about a tree surgeon, for example, William was clearly uneasy about the way in which a too-dominant context can take the focus off concepts and thus lead to learners who do not clearly understand these concepts. He was wary of letting learners take on roles as participants in a context and said: 'I ask – "what is that tree surgeon doing, and why does he do that?" , instead of asking "well, I am a tree-surgeon and I am going to prune a tree and what should I take into consideration?" …. Yes, but I think that allows me to stay closer to the final answer …and I think that gives me more control and, I think, faster results.' Later he said about a lesson series made by *Norbert 'that is really a challenging context. Which means that I wonder if, for learners, this can be a useful context because you can link so much into it, that I think it will be too difficult for them to see the wood for the trees.'*

Williams first "innovative" lesson started with a news headline about car manufacturer Saab that was heading for a bankruptcy. From here followed the (fictitious) question, how many cars could be made from the current stock of wheels, steering wheels and doors. Thus, the Saab parts were an analogy for the concept of "limiting factors" in the process of photosynthesis. The flow of activities in this lesson was still quite traditional: first, William talked his students through the analogy, then the students practiced with exercises in the textbook. In a later lesson, William changed the order of the activities: initially, the students

worked more independently: they read a newspaper article about a prohibition to cart manure and answered questions about the nitrogen cycle. A teacher-centred explanation followed later in the lesson. In a third lesson, William used demonstration practicals and three contexts (a tree surgeon caring for pruning wounds; a florist cutting flower stalks and a lab assistant using test tubes) to help students understand how water transport in plants takes place. We analysed the thinking aloud protocol of William's design of this last lesson. This showed how William, during his design, deliberated about the order and manner in which he will present the concepts in the lesson: 'So, I will show root pressure [with a picture or movie showing a blooding plant, later he comes up with the idea of the tree surgeon], next, I will get a flower and show that it sucks the water from a vase, how can it suck water without roots,… that they need to find out that the leaves do that and than a practical in which leaves cannot be used by covering them,… Or a branch without leaves. And compare.' [etcetera] It is remarkable that William tells his students that pruning wounds are covered in order to prevent water lose, while in reality this is done to prevent infection. "Poetic licence", William called it, which he felt is needed to present a coherent explanation of the concepts. Williams lesson designs show that he is prepared to let off aspects of his regular teaching practice (the lowest order goals), as long as he makes sure that he can present the biological concepts in a clear and structured manner.

During his final interview William explained that he had not changed his usual way of teaching very much. 'I was already doing this…I always linked the information to something that the learners can relate to. What I did do was make more conscious use of things like newspaper articles or movies, by using these as focus points for what I tell them.' To conclude, William said that by teaching his way he met the criteria of the new curriculum (teaching relevant, modern biology) and that he did not need to implement any changes, except to precede his explanation more often by a recent newspaper article or movie.

4.4.2 Marion

Usual teaching practice and goal system

In contrast to other teachers, Marion's goal system did not clearly follow the build-up of one of her usual lessons, but of a series of lessons. She often designed these in one sitting in which she focussed on a main theme – she called it the umbrella- and a variety of corresponding activities. Marion aimed to use a wide range of assignments and media such as practicals, computer work, films, explanations, etc. She had already given the new curriculum a lot of thought, and this had led to her idea of a main theme, which you could call a "context". In her opinion, the use of such a theme had obvious merits. For example, it works well to, prior to discussing certain concepts, watch a movie which clarifies these concepts. Another advantage is that lessons are unified by the theme, and thus Marion found it easier to free

herself from the schoolbook. She did, however, find it quite difficult to bring a whole series of lessons together under this one umbrella theme, and so her lesson preparation was very time-consuming. This brought us to another, yet implicit goal: to prepare lessons efficiently.

Marion's goal system (figure 4.2) shows a number of core goals at different levels, which is notably different from William's. Her system also clearly demonstrates how a goal system is influenced by the characteristics of a specific group of students. She said 'normally I would use many more worksheets in this form, but this specific group of learners really likes to react and to hold class discussions, so teaching by classroom conversations well with them.' The core goals which Marion emphasized most were "to activate and motivate students" and "use a variety of activities and methods". From her experience as a mentor of new teachers, which includes visiting lots of lessons, she knew how boring school can be for learners. Her hope was that by providing a lot of variety, she would not only motivate and activate learners, but also cater for different learning styles at the same time as presenting the theory in multiple ways. Her other core goals were "to help learners understand concepts and how they are interrelated"; "to teach learners to think logically"; and "to get good exam results".

Marion's interpretation of the new curriculum.

For the purpose of this professional development program, Marion made a multitude of new lessons. We will discuss a sub-selection of three lessons here. The first one started with some short practicals: students hold their hands in salt water, shake some salt onto snails and to expose cut flowers to a vase of salt water. She asked learners to explain their observations and she then incorporated what learners have said into her explanation about osmosis[3]. Next, students were asked to use their new knowledge in a new context, which was described on paper: a hospital patient is accidentally given an infusion of distilled water, the patient dies, explain why?

In Marion's second lesson learners worked with more or less authentic sources: they were given images of blood samples taken at a fertility clinic in order to determine the cause of a couple's infertility. To answer this, learners needed to delve into anatomy and hormones. Her third lesson featured three short films about the heart; in the first how a transplant heart is transported, the second showed a heart beating outside of the body, and the final film was about a soccer player who has a fatal heart attack on the playing field. During the accompanying classroom conversation Marion explained how the heart is regulated and how an ECG is made.

Marion's goal system helps us to understand the impact of the professional development program on her teaching practice. There is a strong relationship between her core goals and her interpretation of the new curriculum. She even literally interprets the new curriculum in

[3] Osmosis is diffusion of water through a semi-permeable membrane.

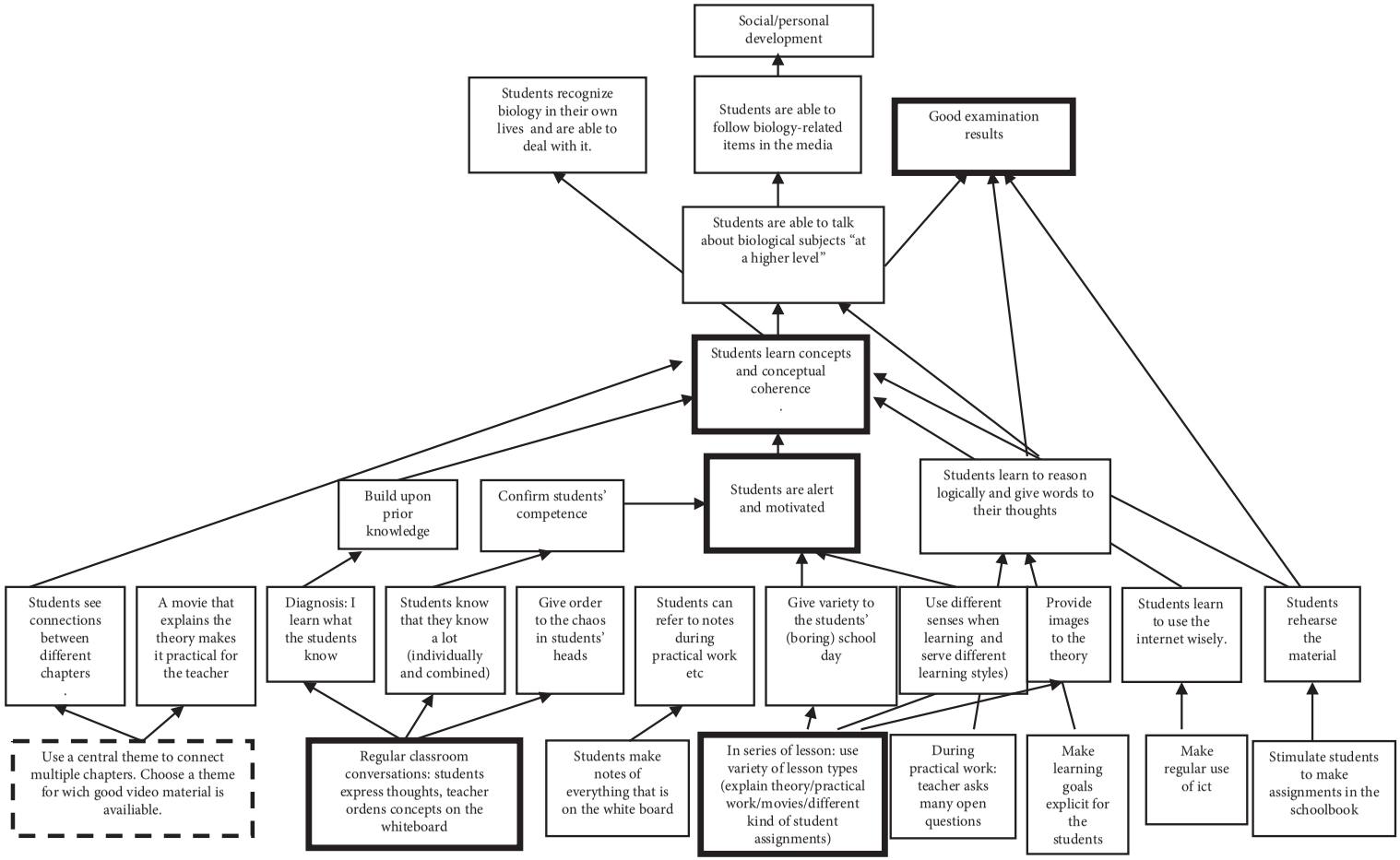


Figure 4.2 Marion's goal system. Core goals have bold outlines. The goal that has a dotted outline is a goal Marion is less satisfied about.

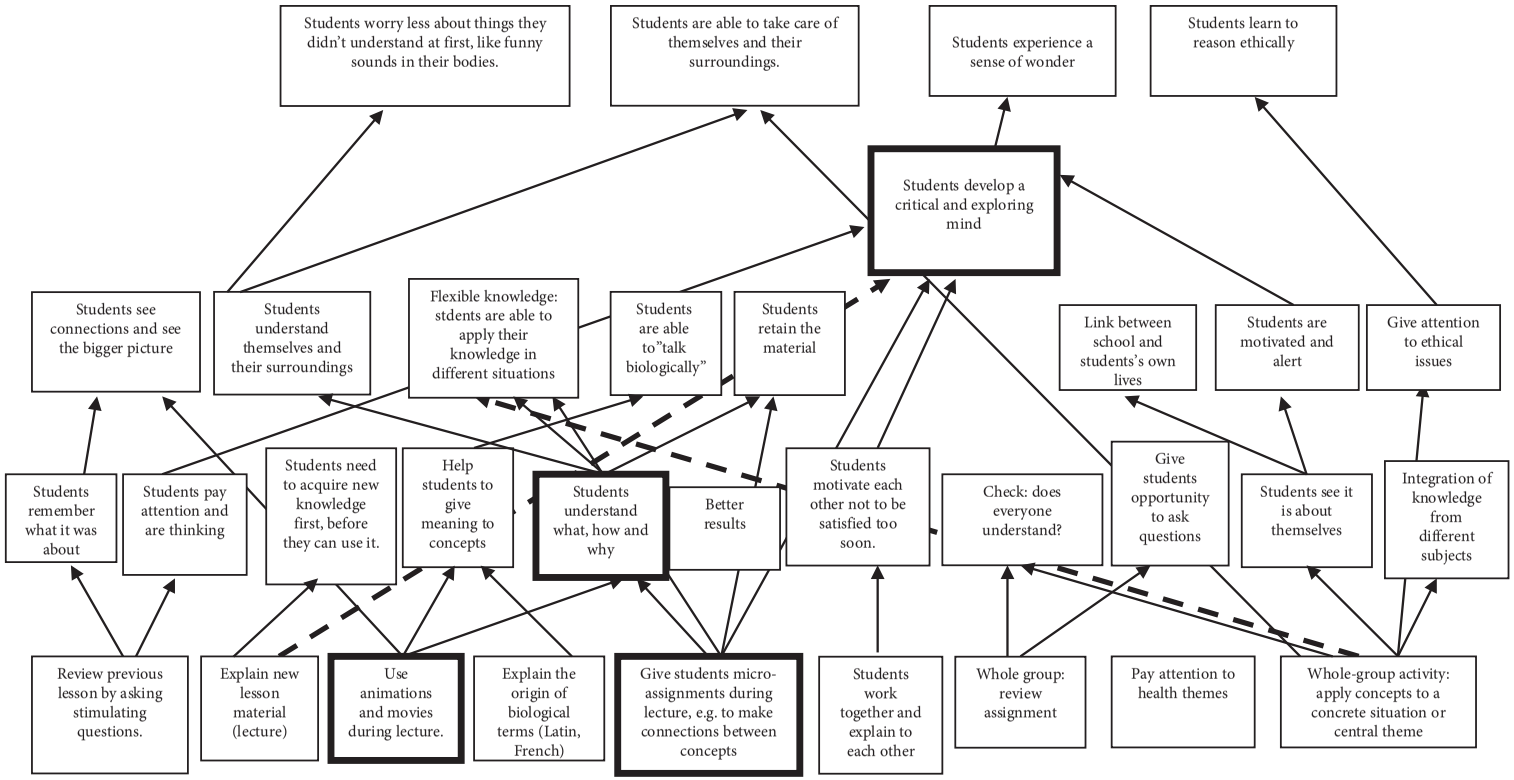
terms of her own goals. During her final interview she stated that the main issue of the new context- based curriculum '[the most important goal] is to get pupils actively involved… To relate the theory to learners' daily lives. Teaching should use activities which require something from learners…. It's more the teacher as a coach for active learners.' Later on, she said 'in retrospect, this has always been my main focus….so actually what I was doing before, matches the intention of the new curriculum.' The influence of other core goals is also clearly visible in the lessons she designed, e.g. motivating learners, asking learners to formulate their thinking and the important role of classroom conversation in her teaching. During the final interview it became clear that her goal system had also influenced her implementation of the new curriculum in a different way. Up until then, Marion had been preoccupied with finding a central theme to cover a number of lessons, and this had taken up a lot of her time, whereas her goal system did not show this as one of her main goals. Consequently, it was not hard for her to let go of this idea and to discover that an innovative series of lessons could also be compact, and thus fit easily into her curriculum. 'This has made me think more positively about the new curriculum, and I am able to implement it more easily'. After the professional development program, Marion continued making new lessons based on new, current contexts.

4.4.3 Nicoline

Usual teaching practice and goal system

Nicoline chose to study her upper forms, advanced level for this program. She usually started their lessons by asking questions about the previous lesson to refresh their memories. Her usual follow-up was an explanation of new content, illustrated by animations and film fragments. She liked to use short assignments during her explanation to get students thinking and to help them to think through things, because in this way they would retain and understand the content better. She stimulated cooperation between learners during assignments. Towards the end of a lesson she often presented a unifying theme or context, for example a medical case study, to which she returned during a number of lessons to link the concepts which have been studied.

During the interview Nicoline talked a great deal about her goals: she wanted to teach critical thinking, to show how concepts are interlinked, to help learners take sensible steps in their lives without worrying too much, she wanted to stimulate ethical thinking skills and she hoped to engender amazement. Nicoline regarded her own teaching very critically, and asked herself if her actions really tally with her goals. She was one of the few teachers who, during the laddering interview, also explicitly made negative links between goals in the system (see figure 4.3, these negative links are marked by the dotted arrow). For example, she had the impression that explaining to the whole class was negatively linked to her goal of teaching learners to think critically, because lecturing leads to passive learners. But, she



Figuur 4.3 Nicoline's goal system. Core goals have bold outlines. The dotted lines represent "negative links".
Note: the original goal system was more comprehensive. Because of space limitations, we chose to omit a cluster of goals around the social interactions between teacher and students. Those goals did not appear to have an influence on the decisions Nicoline took during lesson design.

said, 'I find it very difficult to stop doing this (lecturing).' She also thought that the way in which she presented the context at the end of a lesson, could make it harder for learners to develop flexible understanding because focussing on aspects of the context can draw their attention away from the concepts.

How Nicoline interpreted the new curriculum

Nicoline had many and varied goals she wanted to meet during the professional development. She aimed to trigger learners by touching their emotions and making them more enthusiastic, make them think more deeply, leave off the lecturing, have learners cooperate more, build better a relationship with them, become more creative herself, and design lessons in which learners think ecologically. During the program, Nicoline started off by designing ambitious lessons and she did not shy away from changing her routine. Her lesson about sports doping started with a video clip and a lively text about a Tour de France cyclist who admits to using doping, which she followed-up with a series of questions about the effects of doping and the roles of different components of the blood. In her extended lesson series about ecology, learners first worked on authentic tasks in small groups and shared their findings at a later stage. Her osmosis lesson required learners to explain what happens to different kinds of organisms when exposed to a saltier or more watery environment. Nicoline often said that her own high standards of work hinder her: 'because of this (my high standards) it always takes up so much of my time; I'm never happy with my work and I force myself to improve this, work on that.' At the same time, she was positive about her newly designed lessons for this professional development program, she rated her osmosis lesson highly: 'learners were very enthusiastic and really triggered'. Her lesson about doping also made her happy: 'learners were into the context'.

During her final interview, Nicoline turned out to have been stimulated to think about her teaching by the professional development program. Although she was not the only one of the participants to have changed her daily routines, she was one of the few who didn't say: I was already doing this. In contrast, Nicoline said 'I'm starting to think the other way around. What I always used to do is, well, we've discussed this and that and now it would be nice to show them how to apply these concepts, have they ever thought of this example? But now I try to move this to the start of my lessons …so I look for illustrations – and you can really find horrifying ones – and I ask them, look here, how is this possible? So they start to think …. , and yes, this has become sort of automatic with me, I try to fit the concept into something ….in which situations could it be recognizable to learners?' According to Nicoline, designing context-based lessons has become easier because 'at first I had the idea that it all had to be something really big…, now I think more like it can be bits and pieces.' This resulted in Nicoline feeling less of a gap between what she did during lessons and what she wanted to achieve - even with this group of learners who are difficult to motivate.

When, during the final interview, she revisited her goal system, she said it needed revision in order to reflect her current thoughts and actions. Also, an additional goal at the most concrete level needed to be inserted: begin the lesson with an lively introduction and a motivating question, with the aim of activating learners. She did not wish to change her idea about the larger context or theme which she brings up at the end of the lessons because, as she said, 'I really like connections'. Other parts of her goal system also remained unchanged.

The relationship between Nicoline's goal system and her interpretation and implementation of the new curriculum was fundamentally different from what we have seen in William's or Marion's case. For them, their goal system acted as a lens or filter for those aspects of the new curriculum which supported their existing core goals; whereas Nicoline used the new curriculum to alleviate existing frictions within her goal system.

In the above, we have chosen to limit our discussion of the results to the development of three participants. However, all twelve teachers demonstrated clear relationships between their core goals and their choices about how to implement the new curriculum – although their core goals were all different. We have shown how much difference it makes if someone interprets the new curriculum from the vantage point of teaching as lecturing and explaining the main issues or from the point of teaching as providing activating work methods for learners and/or stimulating learners to think critically and on their own. Some teachers were focussed on supporting learners individual learning styles by adopting a flexible way of teaching (Oliver); others focussed on developing learners' understanding and their own professional development (Jacqueline) or on stimulating emotional involvement (Ben), etc. In each case the core goals at the end of the program remained unchanged, while at the same time the majority had integrated aspects of the new curriculum into their practice – that is to say, those elements of the new curriculum that were compatible with their existing core goals.

4.5 Conclusion, discussion and implication

The aim of this study was to research how goals systems can be used to make sense of how teachers who took part in the previously described professional development program, interpret the new biology curriculum and integrate it into their teaching. We were especially interested in the role that core goals in a goal system play, and how negative links between goals play out. The goal system of each participant was mapped out during a laddering interview; in each goal system core goals could be identified. Core goals were defined as those goals which have two or more links to goals at higher or lower ranks. These core goals turned out to be very well conserved during the program, at the end of the program each participant had retained their core goals. Also, we found a very strong

relationship between a teachers' core goals and their interpretation and implementation of the new curriculum because teachers were easily able to implement those aspects of the new curriculum that were congruent with their own core goals. In contrast, non-core goals were easily dismissed or replaced by elements from the new curriculum. Those goals which teachers had described as being 'more important than other goals' were, in the majority of cases, the same as the multifinal and equifinal goals we identified (Kruglanski, et al., 2013; Kruglanski, et al., 2011).

Before starting the program, we had surmised that existing goals with negative links to higher goals would have a strong influence on the way the teacher interpreted the new curriculum. Such negative links mean that goals hinder each other, for example in the case of Nicoline when she experiences that lecturing impacts negatively on active thinking by learners. However, Nicoline picked out elements from the new curriculum that allowed her to meet her own higher-level goals (activate learners, stimulate critical thinking skills) especially where she had had negative links before. This points to the idea that negative links can provide targets for the integration of a new curriculum into teaching practice. On the other hand, it is rare for teachers themselves to point out negative links during a laddering interview, even when specifically asked to do so. This raises the question whether negative links do not exist in other teachers' goal system or if this could be due to the method of elucidating their goal system by a laddering interview. Our feeling is that for other teachers, negative links play a much smaller role. For example, in William's case you would expect a negative link when he says during the intake interview that he should do less talking, but his lecturing habit does not negatively link to any other goal in his system. This could explain why William, although he had made a resolution to have learners become more active, did not implement this resolution later.

This raises the broader question of the validity of the method and of the resulting goal system. A goal system is a useful construct insofar as it has *predictive validity*, which is to say that it describes goals which in practice drive lesson design and implementation (Grunert & Grunert, 1995; Yin, 2008). With this in mind, we have paid attention to predictive validity by designing the goal system together with teachers and by using the exact wording that teachers themselves used, i.e. without further categorisation. Secondly, we presented our conclusions about the relationships between goal system and teaching practice to individual teachers and requested their comments. Despite this, a few issues concerning validity still need to be addressed.

The aim of the laddering interview is to chart goals which influence the design and teaching of lessons for a certain group or form of learners. But how to be sure that the goal system contains *all* the goals which play a role? This research points to some answers. Firstly, each individual teachers' goal system was robustly linked to their considerations and choices during the design process. Secondly, additional support for the goals as mentioned

in the goal system was found during our other interviews with the participating teachers. However, in three out of twelve cases, goals which were not present in their goal system did, in fact, play a role during the actual design process. This was the case with the following three goals: prepare lessons efficiently, use lesson time and resources efficiently, and, finally, maintain order. These three goals were, for whatever reason, not mentioned during the laddering interview. An explanation for this oversight might be that, because these goals are so deeply ingrained in experienced teachers that they do not even think to mention them when preparing lessons 'as usual'; but these goals do come to mind when teachers are challenged to design innovative lessons. Such 'hidden' goals were only found in a few of the teachers, but even then, they were not core goals and were only linked to one or two non-central other goals within the personal system. To ameliorate this situation in the future, we recommend that the scope of the laddering interview be enlarged in such a way as to bring such hidden goals and links to light. One way of doing so, could be to ask teachers to comment and criticise an innovative sample lesson, and ask them to explain which element they would or they wouldn't adopt themselves. During our research we did try to discover such hidden goals by asking teachers to give their written feedback on a sample lesson, but because there was no opportunity to probe their answers more deeply or to ask for their reasoning, we could not use this information to complete the goal system more fully.

Another, related, aspect concerns the influence of the researcher on the results of the laddering interview. Following a profound reflection upon laddering interview criteria, Grunert and Grunert (1995) give directions on how to conduct a laddering interview in such a way that is has sufficient predictive validity. We have followed their directions in this study, for example, the interviewer/researcher was a biology teacher and as such well versed in the domain under study; she also used the so-called 'soft laddering' technique which means that participants are given as much freedom as possible to speak naturally and to follow their own train of thought, skipping from goal to goal, without interventions aimed at first 'finishing off' one goal before moving to the next. Of course, it still remains a subjective decision as to when to terminate follow-up questioning about the why of a specific goal. In this research, the cut-off point was when a participant no longer answered directly or easily. Because in this research none of the core goals were of the highest level of abstraction, this cut-off point was not an essential to our conclusions. At the highest level of abstraction, the goals of very many teachers coincide (prepare learners for their final exams, prepare learners for their future role in society, etc.).

The predictive validity of a teacher's goal system is context-dependant. We know that there is a strong relationship between the specific goals which teachers aim to achieve, the routines they develop, and both the subject matter content and the forms or levels they teach (Van Driel, Beijaard, & Verloop, 2001). We have addressed this issue by asking the participating teachers to focus on one specific class during the course of the research, and

to design lessons and answer our interview questions with this class in mind. This also means that the validity of their goal system has only been researched for this class. Marion's case is a clear example of the situatedness of her goal system, as in the group she focused on this study she often uses interactive classroom conversations, which contrasts with her teaching in other forms in which she tends to allow pupils to work independently with work-sheets. On the other hand some teachers, e.g. William, state that it does not make a difference which class they have in mind; and their descriptions of lessons in other forms do indeed match with their statements. According to the participating teachers there were no strong links between the subject content being taught and their goal system, but an excerpt from Nicoline's interview shows that the topic influences the teacher's type of goal: *osmosis is like a concept which I think they just need to have encountered so they have it in their minds…. Ecology has a different goal. You teach them a way of thinking. That's what I think is important.*

Not only the choice of form and topic, but other aspects of the context can impact a teacher's goal system too (Boekaerts, de Koning, & Vedder, 2006; Shah & Kruglanski, 2008). For example, school culture will influence teaching at a very concrete level, and will also determine whether certain actions will contribute or counteract the attainment of certain goals. Practical constraints, such as surplus or lack of IT facilities can lead to lessons being more or less enlivened by online videos, by online practical activities, by giving learners a chance to judge the quality of online information, etc. In some schools, use of IT is notorious for disrupting the flow of lessons because of network breakdowns, clearly an important practical constraint. However, because we set out to discover the predictive validity of a goal system within the context of a teacher's job, we consider it to be more of an advantage than a disadvantage that the whole of a school's specific culture is integrated into the goal system. Further research could bring more to light about the relationship between the goal system and school culture, and, for example, how colleagues can influence an individual teacher's goal system.

Another aspect that future research could look into might be the effect that a professional development course has on goal systems. In this study we have seen some evidence of such effects, for example in the cases of Nicoline and Marion. But on the whole the situation described here contained too many confounders to be able to unpack these effects, for example some teachers had already integrated elements of the new curriculum into their daily practice, and so also in their goal system, while others, during the year in which the PD program took place, foremost focused on the design of innovative project-like lessons while keeping their 'regular' lessons and goal system unchanged. These teachers might have formed a (temporary) goal system that was exclusively linked to these innovative lessons. The implications of such choices are as yet unknown and we cannot draw any conclusions from our research; perhaps the 'new' goal system will be integrated with the existing one, or

maybe it will stay separate or even disappear altogether. Other avenues for further research are: does it make a difference that some teachers have a more elaborate goal system than others? Does the level at which teachers discuss their goal system have an impact? Do the goal systems of novice teachers differ from expert teachers, and if so, how?

We can conclude that the results of this research show that a goal system, developed with the help of a laddering interview, helps to make sense of the way that teachers interpret and implement a new curriculum. The two most important relationships we found were the influence of core goals and, to a lesser extent, the influence of negative links between goals. This has implications for research on the relationship between teachers' goals and their teaching practice; the merit of the goal system is that it gives us a representation of an important part of teachers' cognitive structure (Kruglanski & Kopetz, 2009). The goal system acts as a lens, which the teacher uses – knowingly or unknowingly – to rate, chose, and adapt elements from a new curriculum. We have shown that in some cases teachers try to align their teaching with the new curriculum, in other cases they cherry-pick those elements from the innovation that fit easily into their existing goal system.

We consider goal systems to form a worthwhile addition to other common methods to chart teachers' goals and practice (Friedrichsen & Dana, 2005; Kang & Wallace, 2004; Schoenfeld, 2010). Firstly, a goal system shows which goals come into play during a teacher's daily practice, while other interview methods can produce goals that the teacher considers to be worthwhile but do not really impact his/her daily decisions (Kang & Wallace, 2004). Secondly, a goal system allows for integration of important contextual factors and also relates to larger series of lessons, that is, not just the one lesson. Finally, goal systems are very practical to construct because they can be made during the course of one laddering interview, without the necessity of interpreting and coding large amounts of data. Large scale charting of goal systems can give us invaluable insights into the way that goals play a role in the development of lessons and into how goals impact the actual teaching of lessons. If made at the onset of a professional development course, individual goal systems can allow teacher educators to tailor the course more closely to the needs of the participating teachers (Janssen et al, 2013). Finally, as participants in this study have confirmed, a goal system is a worthwhile instrument for personal reflection on teaching.

Chapter 5

A professional development strategy for biology teachers who design context-based lessons for their classroom practice

Abstract

The purpose of the present study is to develop and evaluate a professional development strategy to support biology teachers in their design of innovative context-based lessons for their own classroom practice. We propose that such a professional development program would need to have the following characteristics: (1) knowing that teachers' own goals and rules-of-thumb largely determine their interpretation of a reform, the program should build upon teachers' existing systems of rules and goals. Also, knowing that designing context-based lessons is complex, the program should offer (2) specific support in the form of design tools and heuristics, combined with (3) examples and modelling activities to help teachers to envision reform practices. The study was carried out parallel to the study that was reported in chapter 4, and was situated within the same professional development program, in which twelve biology teachers participated. All teachers designed several (series of) context-based lessons. Design support in the form of heuristics was productive, especially when these heuristics were modelled by teacher educators, or used during personal coaching. Another effective approach was offering reform elements to bring solutions to problems of practice during moments of individual coaching, while attending to the teachers' own goals. The highest impact, however, had the examples of context-based lessons that were used, either during modelling activities or during group discussions. We therefore recommend researchers and teacher educators to develop and use prototypical lessons that capture valued educational principles, such as the ones prescribed by the context-based reform, combined with the heuristics that are needed to design such lessons.

5.1 Introduction

Recently, Dutch secondary school science curricula have been updated. This reform was inspired by a context-based approach (Boersma et al., 2007). This means that teachers are expected to integrate real-world contexts in their teaching in order to make the curriculum more relevant, more up-to-date and more coherent. The (re)design of curriculum materials is an important element of the implementation of educational reform, especially in the case of context-based education, where teachers are expected to keep the curriculum up-to-date and relevant for their own students. However, designing context-based teaching materials is a complicated task (Wieringa, Janssen, & Van Driel, 2011) and teachers will need support to perform this task within their demanding school contexts, for instance in the form of professional development activities.

Professional development projects (PDPs) can have substantial impact on teaching practices (Kennedy, 2002; Luft & Hewson, 2014). However, whereas we have well-developed theories about student learning, such theories about teacher learning are largely lacking (Kennedy, 2016a). There seems to be a consensus about what PD features, *in general*, are correlated with the effectivity of PDPs (Borko, Jacobs, & Koellner, 2010), such as approaching teachers as active learners and facilitating cooperation among teachers. However, more specific theories are needed to effectively guide the design of PD projects in specific contexts. Wayne et al (2008) and Kennedy (2016b) argue that any reform-based PD strategy needs to be informed by two separate, but related theories. The first, the *theory of instruction*, explains the "links between the specific kinds of teacher knowledge and instruction emphasized in the PD and the expected changes in student achievement" (Wayne et al., 2008, p. 472). The second theory, the *theory of teacher change* (Wayne et al., 2008) or *theory of action* (Kennedy, 2016a) explains how specific features of the PDP are expected to help teachers to enact those new ideas within their own practice. The theory of instruction in the current study was based upon the specific characteristics of context-based teaching and learning as can be found in literature. The purpose of this study is to develop and evaluate a related theory of action to support biology teachers in their design of such innovative context-based lessons for their own classroom practice.

5.2 Theory of instruction: context-based teaching and learning

During the last decades, context-based education has been propagated in different parts of the world, in slightly different forms and with different purposes, often in response to alleged failures of the traditional science curriculum (Aikenhead, 2007; Gilbert, 2006). Likewise, in the Netherlands, context-based education is thought to bring a solution to

Box 5.1 Example of a context-based lesson: Malaria

The following example was used during the PD program:

- Students watch a short (1 min) video clip which shows the host of a travel program chatting with a taxi driver about malaria. The man has had malaria several times in his life. When he is asked how one can get malaria, he answers "from mosquitos, from food, from water, it is everywhere".
- Students are invited to think of their own central questions for the lesson. Examples are:
  - How is it possible to get malaria over and again, without getting immune?
  - How is it that some people survive better in malaria areas then others, without medicine?
  - How do you get infected? What does the life cycle of the malaria parasite look like?
- Using information provided by the teacher, students make a product, such as a leaflet, poster or theatre play, in which their questions are answered.
- In a follow-up lesson, the concepts of immunity and parasitic life cycles are rehearsed (decontextualisation), after which students answer questions about another context, which is Lyme disease, caused by Borrelia bacteria (recontextualisation), and think about the consequences the presence of these bacteria in their own direct surroundings has for their own lives.

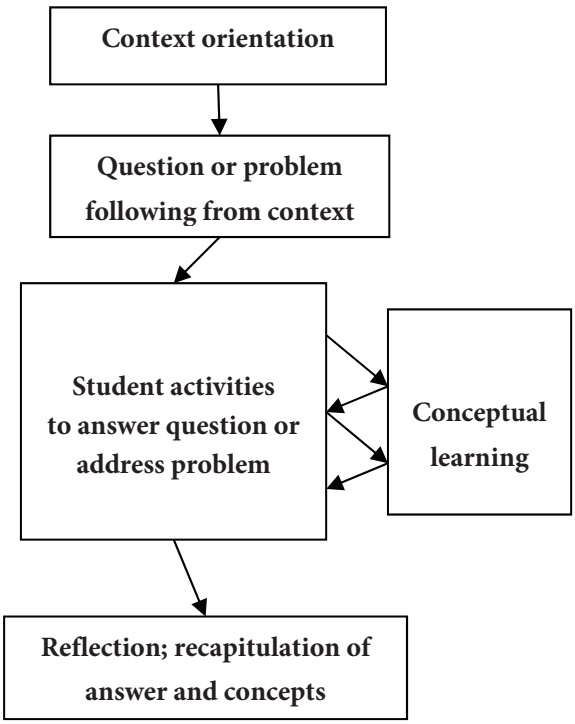


Figure 5.1 Basic structure of a context-based lesson or series of lessons

problems facing the biology curriculum at secondary schools, making the curriculum more relevant, more coherent and more up-to-date. For this reason, the examination standards for students have been adjusted, stating that students are expected to be able to apply biological concepts within relevant contexts. A context has been defined as an authentic professional, scientific or daily life practice, in which people perform activities in order to reach certain goals. Examples are managing a nature reserve, producing food, taking care of pets or doing forensic research (Boersma et al., 2010). In order to develop the theory of instruction that is one of the pillars of our PD project, we studied a diversity of publications about the aims and pedagogy of context-based science education (Bennett et al., 2007; Bulte et al., 2006; Gilbert, 2006; Krajcik et al., 2008; Merrill, 2002; Pilot & Bulte, 2006; Scott et al., 2007; Sevian et al.,

Table 5.1 Characteristics and objectives of context-based lessons

Lesson characteristics	Intended outcomes
1 Start with a vivid introduction on the context that ensures students imagine themselves being part of the context and that activates prior knowledge (A,B,C)	A Students' prior knowledge is activated.
2 The context is a concrete situation from students' life worlds or from professional or scientific practices (C, D,E,F,G)	B Students feel involved and focused.
3 Within the context multiple biological concepts from different biological domains come together (G)	C Students feel motivated to learn biology.
4 The teaching unit has a guiding question, which provides a clearly focused problem orientation (H,I)	D The concepts have relevance within the context.
5 The student activities match the context and guiding question (F,I)	E The concepts derive their meaning from the context; students learn to understand the importance of biological knowledge within this particular context.
6 Students learn to use key concepts of biology (J)	F Students learn to develop specific biological skills.
7 Students are stimulated to reflect upon their learning process, their understanding of the biological concepts and the relation between the concepts (G,J)	G Students learn to understand how different biological concepts are related.
8 Students are presented with multiple contexts in which the same concepts are used (E,J)	H Students feel a "need-to-know".
	I The teaching unit is coherent.
	J Students work on a thorough understanding of biological concepts and are able to use these concepts within a diversity of contexts.

Note The objectives as they have been defined in the right column are in most cases not only objectives, but also means towards higher goals such as conceptual understanding (J). In the PD program, a chart was used in which the hierarchical relationships between these means and goals had been visualized.

2018; Wierdsma, 2012), as well as official Dutch policy documents (Boersma et al., 2010). We also took into account the experiences of teachers in experimental development groups (Kamp, 2010; Wieringa, 2011). This resulted into the following theory of instruction (table 5.1 and figure 5.1). Starting a (series of) lesson(s) with a vivid introduction to a meaningful context is expected to help students to feel involved and motivated (Bennett et al., 2007) and to activate students' prior knowledge. By choosing a relevant context, the relevance of the biological concepts to be studied will be enhanced (Gilbert, 2006). Also, such a context helps students to learn how these biological concepts are used within real-life contexts, and to develop specific skills related to the subject of biology and science in general, such as doing research (Krajcik et al., 2008), designing, modelling, moral reasoning and decision-making (Van Der Zande, Waarlo, Brekelmans, Akkerman, & Vermunt, 2011). When using contexts, it is recommended to choose a strong guiding question or problem as a starting point for learning, in order to stimulate students to feel a "need-to-know" more about biology (Bulte et al., 2006). Using real questions or problems from real contexts is also expected to help students build a more coherent understanding of biology, because biological knowledge from different biological domains is used simultaneously, while it brings coherence to the lessons (Gilbert, 2006). It is important that the lesson focuses on key concepts of biology rather than on the details (Schwartz, Sadler, Sonnert, & Tai, 2009) and that students and teacher explicitly reflect upon the learning process, structuring and summarizing the concepts learned (decontextualisation). Also, ideally, multiple contexts should be used in order to teach students to build a thorough understanding of the biological concepts and to apply those concepts in a diversity of contexts (recontextualisation) (Wierdsma, 2012).

5.3 Theory of action: a strategy to support the development of biology teachers as innovative lesson designers

As was explained in Chapter 1, the decisions teachers take while designing their lessons to a large extent determine the outcomes of curriculum reform (Davis et al., 2016; Fullan, 1991, 2007; Randi & Corno, 1997) and can either lead to a weakening or a strengthening of the reform ideas (George & Lubben, 2002; Van Berkel, 2005; Wallace & Priestley, 2017). Lesson design, in this study, is defined as all activities teachers undertake when planning and preparing their lessons, which can include adaptation of existing materials and/or the development of new teaching and learning materials from scratch. Research shows that teachers, when designing context-based lessons, find themselves confronted with several recurring challenges, tensions and dilemmas. Teachers consider it difficult to familiarize themselves with the context, to translate a context into meaningful learning materials, to guide students' learning processes and to be aware of the need for recontextualisation (De Putter-Smits, 2012; Stolk et al., 2009). They worry that using contexts will take up more

of their classroom time, of which they already feel short. Also, they feel students might be confused when confronted with the different meanings concepts have in different contexts and some teachers fear that the use of contexts will reduce rather than stimulate students' motivation, when they feel a chosen context is not relevant for them (Wieringa et al., 2011). The work of Krajcik et al (2008) shows that even for experienced educational designers, who have substantially more time available for the design of curriculum materials than the average science teacher, the design of context-based lessons is problematic, especially when it comes to the alignment of curriculum standards, learning activities and central questions within the contexts.

In order for PD activities to be effective, these will need to support teachers when they find their own answers to all of these challenges summarized above, within their own classroom contexts. The explicit focus of PD activities should be on teachers' own lesson practice, for it is only during the design and enactment of lessons that teachers will really appreciate what it means to put novel ideas into practice (Deketelaere & Kelchtermans, 1996; Hashweh, 2005; Sanchez & Valcarcel, 1999). In this study, we choose for a format in which teachers go through several cycles of lesson design, enactment and reflection, because teachers as innovative lesson designers are, like other designers, expected to build up their knowledge in a cumulative fashion, developing knowledge in one design episode and carrying it over to the next (Schön, 1988). During this process, we will use a support strategy that consists of three main pillars: (1) activities to help teachers to become aware of and build upon their own goals, while simultaneously keeping reform goals in mind; (2) offering support in the form of design tools and heuristics; and (3) providing examples and modelling design processes

5.3.1 Building upon teachers' own goals

We know that teachers' own knowledge and goals strongly shape teachers' interpretation of reform ideas (Davis et al., 2016; Van Driel et al., 2001). Often, teachers will only implement those ideas that align with their own rules and goals (Doyle & Ponder, 1977; Janssen et al., 2013; Wieringa et al., 2011) while simultaneously reframing their teaching in terms of the reform (Knight-Bardsley & McNeill, 2016; Wieringa et al., 2011). From the (experienced) teachers' point of view, this is perfectly reasonable. During their years of practice, they have found solutions, in the form of routines, rules- of –thumb, that are practical within the challenging contexts they work in, having many different goals in mind. Teachers' goals do not only relate to student learning, but also to maintaining positive teacher/student relationships, having fun, having clear procedures, etcetera (Janssen et al., 2013; Kennedy, 2002; Wieringa et al., 2011). In her recent review of PD programs, Kennedy (2016a) shows that prescribing a new way of teaching is not effective and can even have negative effects on student learning, whereas a more fruitful approach is to help teachers to use reform ideas to

find solutions for problems they experience in their lessons, or to better reach their existing goals. Therefore, PD activities should enable participating teachers to become aware of their own goals, concerns and practical knowledge and find solutions that do justice to both their own local theories of practice and reform ideals.

5.3.2 Design tools and heuristics

In this study, we were specifically interested to learn how and to what extent design tools can support biology teachers when they learn to design innovative context-based lessons for their own classroom practice. Research has repeatedly shown that teachers, during the design of their lessons, very rarely use general normative design models, in which they are advised to start by specifying learning goals, proceed to develop learning activities, selecting media, etcetera, and end by assessing learning (Clark & Peterson, 1986; Gagne, Briggs, & Wager, 1992; Visscher-Voerman et al., 1999). These models seem to lack the specificity teachers need, and do not do justice to the cyclical nature of lesson design (Yinger & Hendricks-Lee, 1994). When combined with specific heuristics, however, design tools can be very effective, as has been demonstrated by Janssen et al. (2014), who developed a heuristic model to support prospective teachers' design of inquiry lessons, and Janssen and Van Berkel (2015), who show how a similar heuristic model helps teachers to design lessons that are challenging for all students. Gigerenzer and Gaissmaier (2011) define heuristics as strategies that ignore part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods. Birds effectively use such heuristics to find nest sites or mates (Hutchinson & Gigerenzer, 2005), sales managers to classify customers as active or inactive (Gigerenzer & Gaissmaier, 2011). In our study, a heuristic context-based (HCB) lesson design tool was developed to support teachers to design lessons that align with the reform framework (table 5.1) and that offers support in the form of heuristics and roadmaps to facilitate the design of those aspects of context-based teaching that teachers are known to find difficult, such as finding meaningful contexts or integrating context-based learning with textbook activities. The tool was based upon both the Tyler educational design model (Tyler, 1950) and the Backward design model (Wiggins & McTighe, 2005), which were specifically adapted for the design of context-based lessons using the Theory of Instruction which we described above, and enriched with specific heuristics such as the Reverse Heuristic, which will be described more in depth in the Methods section.

5.3.3 Examples and modelling

Teachers not only need frameworks and tools when implementing new lessons, they will also need examples to enable them to understand new ideas and to inspire their design. Shulman, in 1986, proposed to categorize teacher knowledge into knowledge of propositions (design rules) and cases: "case knowledge is knowledge of specific, well-documented, and

richly described events. … [Cases] exemplify, illustrate and bring alive the theoretical propositions that are potentially the most powerful a teacher has (Shulman, 1986b, pp. 11,12). And, more recently, Hashweh (2013) explained how the knowledge of teachers is often stored in a story-based manner. During the last decades, the use of cases or examples in teacher education and the professional development of teaching has become widespread (Doyle & Carter, 2003; Grossman et al., 2009). The use of cases is often combined with modelling: the demonstration of the design and/or enactment of (elements of) lessons. The recent movement around "core practices", for instance, attaches great importance to modelling preferred practices (Forzani, 2014; McDonald et al., 2013a). In our PD project, we will provide teachers with examples in the form of reform-based teaching materials, we will stimulate teachers to share their designs and teaching experiences during group sessions, and we will model the design and enactment of context-based lessons.

5.3.4 Research questions

The main research question in this study is:

What are characteristics of an effective professional development program to support biology teachers' design of context-based lessons for their own classroom practice? And in particular:

1. What are characteristics of the innovative, context-based lessons the teachers design during the program?
2. What changes in their regular teaching practice do the participating teachers report, as a result of the program?
3. How could one in such a PD program build effectively upon teachers' existing goals and concerns?
4. How and to what extent might design tools and heuristics support teachers in their design of innovative context-based lessons for their own classroom practice?
5. How and to what extent might examples and modelling support teachers in their design of innovative context-based lessons for their own classroom practice?

5.4 Methods

5.4.1 Design research

In this study, a design research approach was used. The aim of design research is to design, develop, and evaluate an intervention, such as a PD program, "as a solution to a complex educational problem as well as to advance our knowledge about the characteristics of these interventions and the processes to design and develop them" (Plomp, 2013, p. 9). In our case, this means that we designed a PD program with the aims of (1) offering a practical

solution to the complex problems of teachers and teacher educators who try to make sense of the context-based innovation, in their design of lessons, and (2) learning more about the relation between elements of the PD program and teachers' lesson designs.

5.4.2 Participants and setting

The program took place during the course of one school year and was conducted by two biology teacher educators, the second and fourth authors. Both had many years of experience working with both pre-service and in-service teachers. The fourth author had also been an active member of the Dutch curriculum reform committee. Fifteen biology teachers from five different schools participated. They had all responded to an advert in a national journal for biology teachers or to an email sent to a large number of secondary schools in the region of the teacher education institute, South Holland, in which we invited biology departments to participate. Three teachers discontinued the program for personal reasons and have been discounted in this research. Table 4.2 provided an overview of details of the participating 12 teachers.

5.4.3 Contents of the PD

The PD program consisted of five group sessions of three hours each Besides, with every participant, an intake, mid-term and final interview was held (table 5.3). The intake interview took place in the teachers' own school environment, or, if that was not possible, in the teacher education institute. Between meetings, the participants had the opportunity to ask the first author for feedback and support via email. Between meeting four and five, the first author telephoned every participant for a mid-term interview. Four to five months after the final session, each participant was visited at school for the final interview, in which we discussed changes in their thinking and in their practice and asked the teachers to reflect on the professional development program and the new curriculum.

The design of the PD project was based upon the Theory of Action we introduced before. It had a strong focus on teachers' own classroom practice. Teachers were asked to use the reform ideas to design a minimum of two (series of) innovative lessons between every two meetings for their own students, implement them and reflect on them, using student evaluation data they gathered themselves. Time during the meetings was made available for lesson design while support by teacher educators was on hand. Several strategies were used to **link up with teachers' own goals and concerns**. One of the main themes during the intake interview was the teacher's own knowledge about the context-based reform, as well as their concerns and reasons for participating in the course. Also, the laddering interview technique (Fransella, 2005) was used to map out the goal systems that underlie the decisions the teachers take when preparing and teaching lessons. In a laddering interview, teachers

Table 5.3 Contents of the PD program and interviews	
Intake interview (September)	Knowledge about context-based education Regular teaching practice & concerns Goal system Intentions for the program
Session 1 (September)	Information on context-based education Demonstration of exemplar innovative curriculum materials and assessments Participants analyse /assess curriculum materials Reflection and evaluation of the session
	Home/school: Analysis & implementation of exemplar curriculum materials
Session 2 (October)	Reflection on homework Demonstration reverse heuristic, combined with some short model lessons by teacher educator with a focus on context-based lesson structure, lesson introduction and central questions Participants design one lesson or lesson sequence using the design tool Reflection and evaluation of the session
	Home/school: *Design/enact/reflect on context-based lessons*
Session 3 (November)	Model lessons by participants, based upon their classroom experiences Reflection in groups: rules of thumb and difficulties Demonstration design tool with a focus on find authentic materials and not choosing a direction too soon + short model lessons by teacher educator Design one lesson or lesson sequence using design tool Reflection and evaluation of the session
	Home/school: *Design/enact/reflect on context-based lessons*
Session 4 (November)	Model lessons by participants Reflection on individual and reform goals Demonstration using design tool with a focus on activities to activate students + short model lessons by teacher educator; focus on student activities Participants design lesson while thinking aloud Reflection and evaluation of the session
	Home/school: *Design/enact/reflect on context-based lessons*
Mid-term interview	Reflection on lesson design process, lesson implementation and results Feedback on PD program; requests for final session
Session 5 (January)	Demonstration using design tool + short model lessons by teacher educator; focus on the use of newspaper articles Design contest & presentations Final evaluation
Final interview (May-June)	Knowledge about context-based biology education Changes in teaching practice and goal systems Opinion about elements of PD program

are first asked to describe a recent lesson that is representative for their teaching practice for a particular group of students. After that, the participant is continually asked the following two types of questions: 'why do you do that?', and 'why do you think that that is important?' on the one hand, and 'how do you do that exactly?' on the other (the merits and use of this technique to elucidate teachers' goals systems has been described in detail by Janssen et al. (2013); see also chapter 4). As can be expected that such goals and concerns are specifically valid for certain groups of students, teachers were asked to focus on one particular group of students during the PD program. Moreover, a range of activities was carried out during the meetings to make teachers' own goals and concerns explicit and to discuss them with their colleagues and with the teacher educators and to compare them to the reform goals. For instance, the teachers were asked to formulate concrete intentions before designing new lessons, and base their intentions on their goal systems. Also, we asked them to evaluate their own lessons using the reform goals, which were presented in the form of a goal system, and to evaluate exemplar innovative lessons and discuss their evaluations with their colleagues. The teacher educators were asked to work with the teachers on a need-to-know basis, bringing reform ideas forward when these offer a solution for their own concerns.

During the sessions, support was offered in the form of the HCB **lesson design tool**, the basis of which consisted of a ten step scheme containing all important aspects to consider when designing a context-based lesson:

1. Write down first ideas about subject/context
2. Analyse curriculum standards
3. Write down preliminary learning goals
4. Find and decide on context and central question
5. Design orientation phase: activity in which students imagine themselves being part of the context and prior knowledge is elicited
6. Break down the central question into sub questions
7. Design student activities that match the context and questions
8. Design activities for decontextualisation and reflection
9. Check for/add formative assessment activities
10. Use general effectiveness criteria to check and adapt the learning goals and lesson design

Participants were informed that these steps did not necessarily need to be followed in one given order and that it is part of a natural design process to return to certain aspects several times. For most aspects, extra support was available in the form of heuristics. The tool also included support in other formats, such as links to helpful websites and other information sources, tips and association tools to foster the creative process. At the start of the program, the use of the entire tool was demonstrated and illustrated by means of exemplar lessons.

During the remaining sessions, many of the individual heuristics were modelled, followed by periods of guided practice (see table 5.3). Also, parts of the tool were offered on a need-to-know-basis, while the teachers were designing their lessons. Because of its size, rendering the entire tool in this paper, including all heuristics, is not possible. Beneath, however, we will give an example which illustrates the use of one of the heuristics offered to facilitate step 4 to 7 in the HCB design tool, namely, the Reverse Heuristic.

Example: Reverse heuristic

The reverse heuristic (Janssen & Van Berkel, 2015) was one of the heuristics we offered as a part of the design tool. The reverse heuristic is a method to re-order lesson components that are already existent in many teachers' regular lessons. Traditionally, many teachers and textbooks start their lessons and chapters by explaining new concepts. Students then practice with some lower-order rehearsal questions, and then, when they think they understand the content, work on a more challenging (and motivating) assignment. When using the turn-around heuristic, one takes such a motivating and challenging task from the end to the beginning of the lesson. For example, when 7th grade students learn about the heart and circulation, they usually start by learning all the names of the different parts of the heart and blood vessels. In a biology textbook that is widely used in the Netherlands, at the end of the chapter about the heart, there is an assignment about a baby who is born with a VSD; a "hole in the heart". When starting the lesson with this assignment, the start of the lesson (step 4 & 5) could look like this:

> "This is Anna (picture/short video). When Anna was born, she made her parents very happy. Everything seemed to go very well. After six weeks, however, the doctor heard a heart murmur. She diagnosed Anna with a VSD: a ventricular septal defect. Anna's parents are alarmed, but during the first short conversation, there is not much time to ask questions. They do understand, however, that there is no immediate danger, there is no blood "leaking" from Anna's heart, but that she might experience problems later on.
> **Assignment 1**: Imagine you are Anna's father/mother/brother/sister. What questions would you have? Think of at least three good questions.
> **Assignment 2**: What knowledge do you need, before being able to answer these questions?
> **Assignment 3**: study the function and structures of the hearth and the main vessels of the body, or choose to listen to the teacher's explanation. Then, answer your and your classmate's questions. Below are the structures you will need to name in your solution (step 6).

In the remainder of the lesson, students can be guided through learning the structure and function of the hearth and the main blood vessels, and use this information to understand what might go wrong in Anna's case (step 7).

The program included the provision of many **examples** and exemplar materials, as well as **modelling** activities to help teachers to envision reform practices. The teacher educators modelled the implementation of reform ideas in a diversity of prototypical lessons, while at the same time demonstrating the use of the design tool. Sometimes, participants were asked to take the stance of students, sometimes they were critical colleagues. Participants were also asked to tell their colleagues about the lessons they designed and taught, and sometimes participants took the opportunity to demonstrate parts of the newly designed lessons to the group. The experiences teachers shared during group discussions could function as examples as well, as could visits to lessons taught by colleagues. Apart from the model lessons, we introduced the participants to exemplar reform-based curriculum materials without vivid modelling and asked them to analyse and if appropriate implement these materials.

5.4.4 Data collection and analysis

Audiotapes were made of the intake, midterm and final interviews and of all the group sessions, including the thinking aloud sessions. All audiotapes were literary transcribed. We collected the teachers' lesson plans and the materials they developed, such as student assignments, and, if available, videotapes of the lessons. In addition, we collected the following data sources: planning documents that were designed by the researcher and teacher educators using the design criteria, documents that were used during the sessions (presentations, assignments), evaluation forms filled in by the participants at the end of each session, notes taken during conversations between the teacher educators and researchers and an evaluation document that was drawn up by the teacher educators after the final session.

Design research is a research method which is very adequate to study a design within the complexity of reality, which we aimed to do in our study. It is, however, a method that is less suited to indisputably link certain effects to certain causes. Nonetheless, in design research, too, it is possible to optimize validation of the results as much as possible, which we did by triangulation of data sources and methods (video analysis, interviews, goal system analysis, thinking aloud protocols, document analysis, etcetera), by triangulation of researchers and by using member checks (Miles & Huberman, 1994).

The aim of the data collection and analysis process was to clarify the relationship between features of the PD program and the teachers' knowledge, goals, lesson design and classroom practice. As a first analysis step, we coded all data using categories we developed

on beforehand, based upon expectations we developed for each research question (box 5.2). For expectation 3.a, for instance, we formulated the categories "goals of context-based education", "characteristics of context-based education", "personal rule-of-thumb", "personal goal", "comments on goal system", "reference to own lesson", "opinion about context-based reform" and "dilemma". We left open the option to identify additional themes which appeared important during analysis. Emerging themes specifically related to tensions many teachers felt between their own goals and routines and reform ideas. This first cycle of coding enabled us to make summaries of each participant's thinking and practice during the program, which, as a member check, were discussed with the participants during the final interviews.

In order to be able to trace the participants' implementation of the context-based vision in their lesson plans and link this to what happened during the PD program, we needed to analyse the lesson plans the teachers designed. As it turned out, the number of innovative (series of) lessons each participant designed varied greatly, as did the number of lesson plans and other materials the participants handed in for feedback and analysis. We focused our analysis on those three (series of) lessons a participant chose to bring in during sessions 3, 4 and 5, so that we were able to draw conclusions about the progressions made in the

Box 5.2 Research questions and expectations

1. What are characteristics of the innovative, context-based lessons the teachers design during the program?
   - 1.a The participating teachers will, during the course of the program, design, implement and reflect on at least four to six new lessons or series of lessons
   - 1. b These lessons will meet an increasing number of reform criteria
2. What changes in their regular teaching practice do the participating teachers report, as a result of the program?
   - 2.a The teachers will, at the end, be able to summarize the general aims of the reform and give a brief description of characteristics of context-based lessons
   - 2. b After the program, the teachers will apply the context-based approach more often and with more ease than before the program
3. How could one in such a PD program build effectively upon teachers' existing goals and concerns?
   - 3.a The teachers will be able to explain how the reform related to their personal goals and rules-of-thumb for the target group of students
   - 3.b The teachers will use the reform to find solutions for the concerns or fulfil the intentions they stated at the beginning of the program
4. How and to what extent might design tools and heuristics support teachers in their design of innovative context-based lessons for their own classroom practice?
   - 4.a The teachers will use elements of the design tool when designing their lessons
   - 4.b The teachers will reflect upon their students' learning from the lessons they designed and use this information in subsequent designs
5. How and to what extent might examples and modelling support teachers in their design of innovative context-based lessons for their own classroom practice?
   - 5.a The teachers will use the model lessons as templates when designing their lessons

newly developed lessons, while maintaining some uniformity. For each of the selected lessons, the lesson plans and student materials the teachers designed during the program have been analysed by the first and third authors independently, using the reform lesson characteristics we presented earlier (table 5.1). For each of the 8 characteristics, a lesson plan could receive a score of 0 (not implemented), 0,5 (partly implemented) or 1 point (fully implemented). There were three minor disagreements between the two researchers, which were easily resolved through discussion. Twice there was a disagreement about whether a central question was present, when it was not made explicit in the learning materials, but when it could be easily referred from those materials. The other disagreement was about a lesson in which an orientation activity was present, but no attention was paid to the activation of prior knowledge.

To assess the extent to which the participants' daily lesson practice changed during and shortly after the program, we asked the teachers to describe their daily practice during the final interview, just like we did during the intake interview, to reflect on their own development during the program, and to give recent lesson examples to illustrate their accounts. Also, we asked them to reconsider their goal systems, and mark what had changed and in what way.

From the coded data, we selected all instances in which teachers' own goals and concerns played a role, whether it was during activities in which the participants explicitly reflected on their own goals and concerns, or when their goals played a role during group discussions or moments of individual coaching, or when participants referred to such instances and activities in their evaluation forms or during interviews. From this selection, we selected those moments in which building on teachers' own goals and concerns led to constructive lesson design, and also summarized the teachers' subjective opinion about the activities we offered.

In order to be able to evaluate the use and usefulness of the design tool, we looked for evidence of the participants' use of the design tool while they designed lessons, both in thinking-aloud protocols, interviews and group discussions. We also gathered evidence about the processes the participants went through when designing their lessons without use of the design tool, both by abstracting the design steps in the thinking aloud protocols and by directly asking them about their design processes during the interviews and discussion sessions. We summarized the procedures the teachers used when designing their lessons, and during one of the meetings in which the teacher educators and first author evaluated the program, we discussed how the design tool helped or could have helped to facilitate the design process and improve the lessons. The same question was asked to the participants themselves during the final interview.

The impact of examples and modelling was evaluated in much the same way: we specifically looked for references by the participants to specific examples and model lessons.

We also compared the lessons the participants designed to the exemplar materials and model lessons. When a lesson format resembled the format of a lesson that was modelled during a session, and did not resemble a teacher's regular lessons, we assumed that the model lesson was the source of inspiration, although we were aware of the fact that we could not always prove this to be true. After this last session, no lesson plans were handed in, therefore we were not able to judge the effects of this last session.

5.5 Findings

We will first describe the overall results of the program: characteristics of the newly designed lessons and impact of the program on teachers' everyday practice. After that, we will zoom in into the effects of the three most important types of support we offered: building on teachers' goals, offering design tools and heuristics and using examples and modelling.

5.5.1 Lesson plans and impact on daily practice (RQ 1 and 2)

All participating teachers designed several series of innovative lessons. As we described in the analysis section, every teacher selected three lessons or series of lessons to be discussed during the second, third and fourth meeting, successively. Those were the lessons we chose to use for our analyses. Table 5.4 shows to what extent those lessons incorporated the characteristics of context-based education, as we defined in the theoretical framework. Three examples illustrate the kind of lessons the teachers made, with their overall context-based score. As the table shows, most lessons centred around a context which was a concrete situation from students' life worlds or from professional or scientific practices, and most lessons focused on key concepts of biology, which are both core principles of context-based education. The table also shows that there was no upward trend: across all characteristics, lessons that were designed later in the program did not have a higher "context-based" score than lessons designed early in the program. This was somewhat unexpected, because we had thought that by paying attention to different aspects of context-based teaching during different meetings, we would help teachers to make lessons that were gradually more aligned with the context-based vision.

The fact that many of the newly designed lessons did not meet most of the reform criteria, could make one think that the lessons that were designed did not really contribute to the aim of the innovation. In general, however, an effective context-based lesson or lesson sequence does not necessarily need to include all criteria at once. For instance, most teachers started by experimenting with single lessons instead of lesson sequences, which makes it less necessary to pay attention to de- and recontextualisation. Also, it is important to not only

Table 5.4 Mean scores for the incorporation of each reform the characteristics of context-base education, as defined in the theory of instruction. Between brackets is the number of (series of) lessons that were handed in for analysis. This number does not equal 12, the total number of participants, because colleagues sometimes chose to work together when designing their lessons.

	Session 2 (8)	**Session 3 (11)**	**Session 4 (10)**
1 Start with a vivid introduction on the context that ensures students imagine themselves being part of the context and that activates prior knowledge	.50	.36	.65
2 The context is a concrete situation from students' life worlds or from professional or scientific practices	.50	.60	.75
3 Within the context multiple biological concepts from different biological domains come together	.38	.45	.20
4 The teaching unit has a guiding question, which provides a clearly focused problem orientation	.63	.36	.55
5 The student activities match the context and guiding question	.19	.41	.30
6 Students learn to use key concepts of biology	.75	.64	.90
7 Students are stimulated to reflect upon their learning process, their understanding of the biological concepts and the relation between the concepts	.25	.27	.25
8 Students are presented with multiple contexts in which the same concepts are used	.25	.36	.10

Examples:
My Sport (session 2; sum score=1,5)
During this lesson, Ingrid's first grade students work independently on an assignment in which they study images in which the muscles of the human body are drawn, and color the muscles they mostly use while practicing their favorite sport. The lesson is probably very effective in triggering preconceptions, linking the concepts to recognizable contexts and eliciting a motivation to learn more. The lesson was assigned a context-based score of 1,5, because it did not include authentic activities (the students do not perform any exercises in which they feel their muscles), it does not span different biological domains nor does it focus on key concepts, and there is no de- or recontextualisation (yet).

Geologist with green lungs (session 3; sum score=5)
This lesson about respiration normally features a demonstration practical with a candle in a jar, in which students observe condensation on the glass, only after the concepts of photosynthesis and respiration have been explained by the teacher. Steven adapted this format by starting the lesson with a short article about a man who locked himself in a closed greenhouse together with lots of plants for a long time. The students answer questions about the text such as "what is photosynthesis" and "what would happen if this man would start exercising on a home trainer: would more condensation occur on the greenhouse walls, or less?" After that, they do the classic practical work with candles in a jar, to see what happens in the processes of respiration and photosynthesis. This lesson did not meet all of the context-based criteria, but it had a much stronger "context-based quality" than Steven's regular lessons.

Osmosis (session 2; sum score=8)
In the first part of Marion's osmosis lesson, students go through a circuit of different short experiments: they sprinkle salt on snails, add too much plant nutrition powder to a vase of flowers and put their hands in salty water, while trying to answer the questions "what is happening here, and how can I explain it?". Then, during a classroom discussion, they learn to use biological concepts to explain the phenomena they experienced. Towards the end of the lesson, they read a story about somebody who by accident receives an infuse with pure water instead of saline solution, and using the concepts they learnt, try to predict what will happen within this' patients bloodstream. This lesson meets all context-based lesson characteristics.

consider how close a lesson design is to the formal innovation format, but also whether a design can be seen as an improvement of a teacher's regular teaching practice, both in terms of meeting a teacher's own goals and in terms of meeting the innovative goals, which was often the case, as the examples in table 5.4 illustrate.

Apart from analysing the data in table 5.4 on group level, we also considered the progression in lesson design on individual level. For most teachers, the emerging pattern was the same as the one that we saw on group level: there was no upward or downward trend. For three teachers, however, a different pattern appeared. For Jacqueline and Elizabeth, the "context-basedness" of their lessons did markedly increase during the program, as they learnt to make sense of the context-based approach, whereas for one teacher, Marion, there was a decrease in the average number of context-based characteristics she included in her lessons. Marion at first aimed at designing "perfect" context-based lessons, that complied with all of the criteria, which took her a lot of time. As we described in chapter 4, in the course of the program, Marion learned to lower her high aspirations in order to be able to apply the context-based approach more frequently and more easily in her lessons, which resulted into more frequent lesson with a lower average context-based score.

During the final interview, we asked the teachers how their daily practice had changed under influence of the program. If they reported changes, we asked them to illustrate this by using recent lesson examples. Jacqueline reported the most profound changes in her practice: "I really continued the work after the course indeed. There was a time that I thought… everything should be context-based from now on, but that was not realistic." Then, she gave a whole range of examples of recent lessons designed according to the context-based approach. Nicoline, Marion, William and Oliver reported small changes, such as designing more and shorter series of lessons (Marion), using newspaper articles as a starter more often (William, Oliver) and turning the lessons around, starting with the more interesting cases she had saved for the end of the lesson before (Nicoline). Steven and Elizabeth continued to develop project-like context-based lessons, and saved them in a school-based intranet environment. Ingrid, Norbert, Simone and Roger said they had not changed their teaching practice, apart from the continuous use of the lessons made during the PD. In the case of Roger, this was because he judged that the reform goals could be attained within his existing teaching practice and therefore he did not feel the need to change. The others stressed that they had wished to develop their practice more, but tight time constraints discouraged them. Many studies have shown that teachers need time, often years, to improve their practice, to give new ideas a durable place within their daily teaching routines (Kennedy, 2016a; Lundqvist & Lidar, 2017).

In summary, apart from Jacqueline, who profoundly changed her entire teaching practice, we see two types of results. Some teachers kept their regular practice unchanged, but kept enriching their repertoire by designing project-like extra context-based lessons. Others carried through small changes in their everyday lessons.

5.5.2 Build upon teachers' existing goals and concerns (RQ 3)

Chapter 4 of this thesis demonstrated how goal system analysis can be used to understand the interpretation and implementation of educational innovations by individual teachers, using the same data as in the current chapter. One conclusion was that the teachers who participated in this study tended to adopt those innovative goals that were congruent with central goals in their own goal system, while less central goals were more easily replaced by innovative goals. Chapter 4 showed for instance how William remained faithful to his central goal, to "show the big picture", which means he considered it his responsibility to guide the students through the main line of reasoning in the book and through the curriculum. He used examples to illustrate his story, and one influence of the program was that he used more up-to-date stories and examples, and gave students more time to think about questions he derived from a context, but in the end he always made sure to remain faithful to his main task: presenting the concepts in a clear, structured matter. For William, his personal goal to show the big picture, within one conceptual domain, conflicted with the reform goal to bring more coherence in the curriculum by having students work on context-based problems in which concepts from different conceptual domains come together. This was a goal conflict, or dilemma, many teachers recognized. Jacqueline said this could be resolved by organizing the curriculum differently, but, she says " in the upper grades the program has already been determined. It is possible to rearrange that, but to do so we will need a longer period of time." There were also other dilemmas that repeatedly showed up. One of them was whether to prepare students for tests and examination or for life. Students, when working on context-based problems, develop skills that should enable them to use biological concepts in real life, but they often feel less secure about what they need to learn for a test. A related dilemma is, where to find the balance between having the students perform *authentic activities*, such as formulating a diagnosis based upon blood charts, and *learning activities* such as making concept maps. Also, all teachers feel that using contexts takes more time because, like Elizabeth says, "The contexts need to be wider than just the concepts". A last dilemma was about giving freedom to the students to direct their own learning versus keeping control. While William felt that one should not give students too much room, because he was convinced they cannot make the important connections themselves, we have seen that Elizabeth tried to let loose control and give students more room, however difficult that was for her.

We had intended the PD to help the participating teachers to recognize those problems in teaching and learning for which the reform offers a solution, as a way to link up with teachers' own goals while simultaneously keeping the reform goals in mind. Many teachers used the opportunity to redesign lessons for specific topics, as we can hear when Roger starts one designing session by saying "What I am always struggling with, or … not really struggling, but what I can never arrange nicely is the lymphatic system". And

Marion said "One thing I have been unhappy with since years is that lesson about ECG's [electrocardiograms]" (third session). Also, the teachers really appreciated it when we tried to help them find solutions for their own concerns in the form of individual coaching. Nicoline's main concern was that her way of teaching did not stimulate students' critical thinking skills, but rather allowed them to remain in a "consumer mode". By using the reverse heuristic, bringing more stimulating contexts and questions to the beginning of the lesson, she succeeded in activating her students more. For Marion, reflection on her goal system helped her to let loose her very time-consuming design of large projects in order to make room for more frequent context-based activities. For Jacqueline, the project offered her the opportunity to find solutions for several issues she brought about during discussion sessions, such as how to make her students think more deeply and how to use newspaper article in class. The group activities in which participants were asked to reflect explicitly on their goal system and on their lessons, or to formulate concerns and intentions and relate them to the formal teaching format, were in general not perceived as being useful, if such an activity was not offered together with personal coaching. We can thus conclude that in this program, the most effective and rewarding way to build upon teachers' own goals was to bring teachers' goals forward during personal coaching and to support teachers to find solutions that match their own goals while they design lessons. Design tools and examples are helpful, as we will demonstrate in the following sections.

5.5.3 Use of the design tool and heuristics (RQ 4)

As we explained before, the idea behind the HCB design tool was that it could be used in several different ways. In its full version, the tool consisted of a comprehensive scheme, in which a teacher was reminded of all important aspects of the design of context-based lessons. For every aspect, such as designing a gripping introduction or structuring learning activities for students, heuristics were available to facilitate the process. In the beginning of the project, the tool was explained and each step was illustrated with examples. After that, the teachers were asked to follow all the steps in the scheme while designing their lessons. Most teachers, however, filled in the form after finishing their design rather than using it during their design. Later, the scheme was made available for reverence during the design sessions, few teachers revered to the design tool when designing their lessons. Using the tool in the form of filling in a form was considered a detour, and the teachers found it did not match their natural design process, in which they feel the need to envision the lesson immediately and build their design upon this initial picture. Simone says: "that's the way I do it: I can start off well, but find it difficult to develop it further… Then I need to … get that scheme that you gave me and then I think, how do I bring this together? Then out of convenience I start doing it like I always do it. I think it feels too artificial to use the tool." (mid-term interview). Only the picture that illustrated the tool, which showed the basic

context-based lesson structure (see figure 5.1) was considered helpful. As Marion said: "I keep that picture in the back of my head" (final interview).

A second and more effective way in which the tool was used was by offering elements during personal coaching, while giving feedback on teachers' lessons, or during their design of a new lesson. William, for example, said, during a conversation with the first author: "tips like you just said, that tree surgeon could have been done like this, and that lesson about those limiting factor, that ends with a question I should have posed at the beginning…well, I like such tips, that is very useful." During the mid-term interview, Jacqueline said she wished to do more with the news and socio-scientific issues, but that she didn't know how. She explains that she doesn't really like the traditional approach, in which students get to read the article and answer a whole list of questions about it; questions that are often meant to test their comprehension of the text. "One thing I would really want is do more with the daily news. That is difficult. I cut articles from the papers now and then, but … what next. You can come up with questions, but I would like to do something else with that." During the following session, Fred modelled a heuristic which helps to quickly make a lesson out of a headline. This was greatly appreciated by Jacqueline, and adopted as a new routine: "that's one thing I took from the course, that one can just show the headline and ask "what do you make of that?" … that it is not always necessary to make up a long list of questions". She gives an example from one of her recent lessons, in which she applied this heuristic: she showed the headline "new theory about origin of the moon", and simply asked the question how the students thought the moon originated. Several groups came up with one of the theories mentioned in the article, and all students were very curious to learn about the other theories. Another example shows how Jacqueline was not very satisfied with her first lesson, in which she gave students pictures showing people with different abnormalities caused by hormonal dysfunctions, and asked them to explain them. In his feedback, Fred referred to a heuristic from the design tool: "think how you would answer such a question yourself, and then reformulate that answer in sub questions for the students." Months later, in the final interview, Jacqueline demonstrates how this heuristic is being transformed into a new personal design rule, when she reminds herself that she should subdivide a central question into sub questions for her students, so that the students are forced to think about every aspect of an answer: "you should ask clear questions, because otherwise [the students] would be very quick to say, well, this is it. Those questions I ask them [while helping them], those questions should be there [pointing at the assignment paper]".

The third and most influential way of offering the tool and its heuristics was modelling its use during group sessions. Modelling sessions were experienced as inspirational, and when heuristics were modelled, most teachers started to apply the modelled aspects. The most valued and used heuristic was the easy-to-use reverse heuristic. For many teachers, this heuristic became part of their daily routine, as we could conclude from the final interviews.

Oliver, for instance, recalled how he went about designing a lesson about the eye: "There was a question in the book about glaucoma, that was the trigger…that is the Fred-method" [Fred, the second author, was the teacher educator who modelled the reverse heuristic] (Oliver, final interview). And Nicoline explained how she, as a result of the program, started to use this heuristic regularly: "now I often think, well, let's turn it around [and bring the context to the beginning of the lesson]" (final interview). Another example from the PD project was the heuristic "think of one central question which is important in biology and apply it to several appealing cases within one lesson". This heuristic was modelled using a lesson in which students were provided with pictures of a very large woman and a very small man, a bodybuilder, a person with an enlarged thyroid gland etc. For every case, students were given the same assignment, namely "explain in hormonal terms what goes wrong". This heuristic was applied by Jacqueline when she designed her hormone lesson, by Elizabeth for her lesson about chromosomal aberrations, and by Marion for her osmosis lesson.

One design advice that the teachers did not really pick up, despite repeated modelling, was the advice to keep multiple options open to see which option will work out best, before developing the lesson further. Often, a teacher would stick to the first idea that came to mind. Sometimes, this would work out fine, for instance because of the teacher's knowledge about a particular context or because a teacher already had valuable authentic materials (this was the case for Marion, who designed a successful lesson series about a couple's infertility problems, using authentic blood charts), but just as often it would have been advisable to choose a different path (for instance when Ingrid chose to design a lesson about a sport's doctor, although she couldn't find out what a sport's doctor actually does, and neither could her students).

In short, most of the heuristics from the design tool effectively helped the teachers in their design of context-based lessons, especially when modelled using rich examples, or when introduced to individual teachers at the right moment, offering solutions for design problems a teacher was struggling with in that very moment.

5.5.4 Examples and modelling (RQ 5)

Above, when we discussed the use of the design tool, we have illustrated the important role of modelling in the learning process. When the use of heuristics was modelled, this naturally involved the use of examples. Modelling, in this program, came in different forms. One of the teacher educators could give a demonstration lesson to demonstrate a certain pedagogical principle, a teacher educator could model the design of a lesson to demonstrate the use of design heuristics, or participants could share their lesson experiences and give demonstration lessons. We also provided exemplar curriculum materials as examples on paper, without modelling them. These materials had either been developed by a teacher

development group that was associated with the formal innovation committee or by the researchers or teacher educators themselves.

Both lessons modelled by teacher educators and by fellow participants were readily used as templates for new lesson designs. We have already shown how the model lesson about hormonal aberrations was used as a template by Jacqueline when designing her lesson about hormones, by Elizabeth for her lesson about chromosomes and probably also by Marion for her lesson about osmosis. Marion's osmosis lesson in turn inspired William to experiment with combinations of practical work and context-based questions, and Nicoline adapted this osmosis lesson by expunging the practical bit and enlarging the part in which students practice articulating their scientific explanations. Another lesson Marion designed, in which students performed authentic activities in a medical context (reading blood charts, coming up with a diagnosis and treatment plans), combined with a lesson the teacher educators introduced in which students think of answers to ask their doctor when confronted with a certain medical diagnosis, inspired others to have students enact authentic activities in medical contexts too (role playing in a conversation between doctor and patient; Elizabeth), or to introduce role playing in other contexts (e.g. advocates and opponents of zoos; Oliver). Also, many teachers repeatedly said they appreciated the model lessons, which made the teacher educators decide to change the contents of the last session, introduce more model lessons and discuss them.

The influence of formal exemplar materials without modelling was far less far-reaching. The reason for this was not that the teachers didn't study the materials. They did, and they handed in quite detailed reviews of those materials. They judged those materials as being too large, too ponderous, hard to fit into their own daily practice (Marion), they found difficult to see how those materials link to the textbook (Ingrid), they found that too many concepts from different biological topics come together which would, they feared, result in students losing the overview (William), etcetera. Some of the materials were evaluated more positively ("well structured", "nice activities", "up-to-date", "appealing"), and many teachers said they would use these materials after applying some adaptations. During the project, however, not one of the materials was used by the teachers, except for Jacqueline, who adopted an approach of copying and adapting lots of existing materials. Probably, only reading lesson descriptions and students' activities on paper was not sufficient for most teachers to enable them to imagine how those activities would take form in the classroom. This supports the results of previous studies that show that providing materials alone is not sufficient to ensure changes in teaching and learning (Penuel et al., 2011).

The effect of modelling can be brought to a higher level by using appropriate analytical frameworks. The second author introduced a typology of different context-based lessons using four different prototypical structures (direct instruction; master/apprentice; guided discovery; adaptive teaching), which helped some teachers to consciously chose one format

or another. William says, while thinking aloud: "I will use the same principle [as before]. Master/apprentice. I will give an example in one way, and then they need to apply it some other way." And Nicoline says "when Fred told there are different ways, that was really clarifying. Then I see I always take the same thing. … It helps me to think, if I want to do it differently I can also do it that other way."

In summary, modelling was probably the most effective strategy used in this PD project. Lessons modelled by teacher educators and fellow participants were an important source of inspiration for new lesson designs.

5.6 Discussion

In this study, we aimed at answering the question, what are characteristics of an effective professional development strategy for biology teachers who wish to design context-based lessons for their own classroom practice. During the program we developed, the participating teachers designed a range of context-based lessons, which in majority centred around a concrete situation from students' life worlds or from professional or scientific practices, and focused on key concepts of biology, two core reform principles. The impact of the program on the teachers' daily teaching practice varied substantially, with teachers who reported not to have altered their daily practice, apart from using the lessons they developed during the project, on one side, to a teacher who profoundly altered her entire curriculum on the other side.

The findings indicate what might be fruitful ways to **link up with teachers' core goals, concerns and knowledge** while supporting their professional development. The results underline the major influence of the teachers' existing goals on their interpretation of the reform. Many at first perceived the reform as unfit for their practice, because for instance, learning about contexts takes too much time and authentic activities take the place of existing successful activities. Explicit and repeated reflection on goals, intentions, and experiences did not turn out to be not very motivating nor effective, whereas offering reform elements to bring solutions to problems of practice during moments of individual coaching was more rewarding. Such moments of individual coaching, however, were rather scarce in the current set-up of the program. Participants who acted as very active owners of their own learning, like Jacqueline and Marion, used the opportunities during the sessions and interviews to bring forward their concerns and requests, and they benefited from the support they received as a result of that. For others, their concerns and difficulties seemed to come to light only during specific activities, for instance during a thinking aloud assignment, probably because teachers' knowledge and beliefs are largely tacit, and are closely linked to their actions. We would therefore like to adapt the PD strategy at this point

and recommend the inclusion of more opportunities for individual coaching as well as more formative assessment activities during the sessions.

The program offered **specific support in the form of design tools and heuristics**. Heuristics were particularly effective when offered on a need-to-know basis and when their use was modelled using vivid lesson examples. The most notable examples were the reverse heuristic and the headline heuristics. Such heuristics have two main advantages above other kinds of design help, such as the schemes that were meant to facilitate the formulation of lesson goals or the design of students' activities. Heuristics are very easy and fast ways to change the character of a lesson, using ingredients that are readily available. They often readily result into a complete new framework for a lesson and, as such, function as "gambits", the importance of which has since long been known in the field of design studies (Lawson, 2004). Furthermore, heuristics are congruent with the way people, in general, take decisions within the complexity of reality (Gigerenzer & Gaissmaier, 2011) and the way teachers think about teaching (Janssen et al., 2013; Westbroek, Van Rens, & Van den Berg, 2017), in which the vision of lessons as a succession of lesson segments plays an important role (Dam, 2014; Davis et al., 2016). Also, the reverse heuristic in particular offered a solution for one of the main problems the participants had, namely, how to design a context-based lesson within the limited time that is available for lesson preparation. For future research, the development and testing of design heuristics is recommended. The findings offer new evidence that teachers tend not to follow extensive prescriptive design models when designing (innovative) lessons, confirming the results of research on teacher planning from the 1980s and 1990s (Clark & Peterson, 1986; Young, Reiser, & Dick, 1998). This does not mean that we think that the design tool in the form of a comprehensive scheme is redundant; the tool was needed to be able to develop and bring coherence to the different heuristics that were used. In future projects, however, it would be recommendable not to ask participants to fill in such an entire tool while designing their lessons.

Examples and modelling the design and enactment of lessons using both the design tool and reform characteristics was a crucial element of the program, confirming the work of other scholars who advocate the use of modelling in professional development and teacher education (Grossman et al., 2009; Horn, 2010; McDonald, Kazemi, & Kavanagh, 2013b). Notably, for the teachers in our study, modelled lesson examples had a far larger effect than exemplar materials that were provided on paper. The importance influence of modelling is congruent with what we know about the practical knowledge of teachers and its relation to lesson design. Designing lessons is not a rational process. Teachers do not systematically go through lists and criteria when designing their lessons, considering all possibilities to come to an optimal solution. Instead, teachers bring into their memory cases of previous lessons, either taught by themselves or by others. Cases help a designer to "see" a situation "as" something familiar and to generate a general plan (Klein, 2008; Schön,

1988). They also enable the teacher to make mental images of the kind of lesson they will be designing (Kennedy, 2006). Modelled lesson examples presumably enable teachers to recognize problems and envision new designs more effortlessly as compared to examples, criteria or innovations objectives that are provided on paper.

As any research project, this study has its limitations. Most importantly, the research design consisted of only one larger cycle of development, implementation and evaluation, which consisted of separate sub-cycles in which each session was evaluated and conclusions were used to adapt the plan for the following session. Ideally, more cycles would be needed to test and develop the professional development strategy further. Also, in the current design, in which we chose to study the development and implementation of a professional development strategy in its entirety, it was impossible to make hard statements about the effects of the program or to indisputably ascribe certain effects to certain elements of the program, for which follow-up experimental studies would be needed.

5.7 Conclusion

PD effectiveness criteria, as described in literature, are often of a very general nature. Examples are recommendations to connect to teaching practice or to make sure a professional development program is ongoing and sustainable (Borko et al., 2010). In this study, we used a design research approach to develop a more specific theory of action underlying a professional development strategy to support biology teachers in their design of innovative context-based lessons. The study, again, confirms that teachers' own goals strongly determine their interpretation of a reform. Teachers seem to benefit most from instances of individual coaching, during which support is offered to find solutions to reach personal goals, or when the design of prototypical context-based lessons is modelled, including the use of smart heuristics. These types of design support align with the way teachers in natural circumstances take their decisions while designing lessons, knowing that this process is largely guided by these teachers' personal goals and their knowledge of specific cases. We therefore recommend researchers and teacher educators to work together in the development and evaluation of prototypical lessons that capture valued educational principles, such as the ones prescribed by the context-based reform, combined with the heuristics that are needed to design such lessons.

Chapter 6

Summary and Discussion

6.1 Summary and conclusions

The aim of this thesis was to clarify the relation between teacher knowledge and the decisions they make while designing innovative lessons, in order to be able to effectively support teacher professional development in the context of curriculum reform. The following two research questions were central to our studies:

1. What decisions do biology teachers make when designing context-based lessons for their own classroom practice, and how do these relate to their practical knowledge? (chapters 2, 3 and 4)
2. What are characteristics of an effective professional development strategy to support biology teachers when they design context-based lessons for their own classroom practice? (chapter 5)

In chapter two, we used a combination of thinking aloud protocols, interviews and classroom observations to gain a better understanding of the decisions biology teachers take when designing context-based lessons for their own classroom practice. We built on the idea that teachers, when designing lessons, use rules-of-thumb: notions of what a lesson should look like if certain classroom outcomes are to be reached. For the purposes of this study, we operationalised our first main research question into the following two more specific questions: (1) *What rules-of-thumb do biology teachers use when designing context-based lessons for their own educational practice?* And *(2) How do these personal rules-of-thumb relate to the formal innovative goals and lesson characteristics?* Six secondary school biology teachers with varying backgrounds were asked to design and implement lessons for their own classroom practice, while thinking aloud. We observed their lessons and interviewed the teachers prior to and after the lessons. Our results suggest teachers' personal rules-of-thumb do indeed guide the decisions teachers make. These rules-of-thumb were often strongly associated with intended lesson outcomes, such as having fun, having students understand the relevance of biological concepts, or triggering preconceptions. While all teachers said on beforehand they intended to faithfully apply the reform criteria in their design, it was only during the design of their lessons that the dominant role of teachers' personal rules-of-thumb came to light. Those personal rules-of-thumb appeared to have more impact on the lesson design than formal innovative goals and criteria. For instance, while according to the formal principles, the use of real-life situations (contexts) in class is thought to increase relevance, student understanding, coherence and student motivation, according to most teachers a context which was too specific and realistic would not motivate students to learn and would decrease the relevance of the curriculum in the eyes of the students. We propose that a teacher's personal rules-of-thumb can be viewed as that part of

the teacher's practical knowledge that has a direct effect on educational decision-making, and that they are equivalent to heuristics people in diverse settings are shown to use to find solutions in circumstances when time and means are constrained (Gigerenzer, 2008).

In chapter three, the relation between teacher's practical knowledge and their design decisions was further explored. This chapter was written in the form of a review of Donald Schön's *The Reflective Practitioner* (1983), and asked the question how Schön's concept of reflective practice could be used to relate a teacher's practical knowledge to his design decisions. Schön describes the process of reflection-in-action as essentially a design process in which knowledge-in-action is applied, tested, and developed. During the process, a practitioner's knowledge takes the form of *rules, types* (images of past situations, that help to recognize and understand the current situation), and *appreciative systems* (which determine how a practitioner assesses expected outcomes of design moves). We used these concepts to analyse the lesson design process of Richard, one of the teachers who took part in the study described in chapter two. Richard, an experienced biology teacher, designed a context-based lesson for his own students while thinking aloud. Richard's case showed how his knowledge-in-action became activated and transformed during reflection-in-action while preparing his lesson. Framing Richard's decision process as a process of reflection-in-action clarified the relation between his knowledge and his design of this lesson. This perspective helps to understand why teachers, in general, and Richard in particular, tend not to implement innovations in the exact way they were envisioned. We identified rules, types and appreciations, as active entities of Richard's knowledge. Types could be fragments of former lessons, for instance, a lesson in which he used an appealing example to explain a specific biological concept. Both rules and appreciations and rules and types appeared to be closely related. One rule ("the lesson should help students to experience the beauty of biology when their body works as it should"), for instance, steered Richard's appreciation of the idea to use a medical context. Further analysis also revealed that Richard's rules were hierarchically related, and that decision-making during the design of his lesson could be represented as a trajectory through his personal hierarchical system of rules and goals. Goals that are higher in the hierarchical system give a new meaning to Schön's concept of "appreciative systems", a concept which in Schön's book was rather vaguely defined. Therefore, we postulate that the use of hierarchical goal systems could add to Schön's understandings of reflective practice by understanding better how rules, types, and appreciations influence decision-making and are interrelated.

In chapter four we further elaborated on the use of hierarchical goal systems to understand teachers' interpretation and implementation of an innovative curriculum. A goal system is defined as a mental representation of the goals that are activated in a given context for a certain individual, including the hierarchical means-ends relations between the goals, with very general goals, such as "good examination results" giving rise to more

specific goals like "students develop their logical reasoning skills" and behaviours such as "ask many open questions during practical work". The study was situated in a professional development program for biology teachers who wished to learn to design context-based lessons for their own classroom practice. Twelve biology teachers participated. During an intake interview, each teacher's individual goal system was co-constructed by means of the laddering method. We used interview data, lesson plans and thinking aloud protocols to gain insight into teachers' interpretation and implementation of this educational innovation during the course of the program. We found that within a goal system, teachers' core goals – which are defined as goals with two or more links to either higher or lower ranking goals – were strongly related to teachers' interpretation and implementation of the reform ideas. To a slightly lesser extent, negative links – i.e. goals that obstruct or contradict each other- also appeared relevant and might be interesting targets for professional development activities. We conclude that goal systems form a valuable addition to existing instruments in the field as they seem to represent those parts of a teacher's knowledge that genuinely influence decision-making processes in the context of reform.

In summary, chapters two, three and four provided the following answers to the first research question: teachers base their design decisions to a large extent on personal rules-of-thumb, which are associated with personal goals. Teachers' personal rules and goals are hierarchically related, and can be represented in the form of a goal system. A goal system represents that part of a teacher's practical knowledge that is directly related to the decisions this teachers makes when planning for teaching.

Chapter five aimed to answer the second main research question. It reported on the development and evaluation of a professional development strategy that aimed at supporting biology teachers' design of innovative context-based lessons for their own students. We proposed that such a professional development program would need to have the following characteristics: (1) knowing that teachers' own goals and rules largely determine their interpretation of a reform, the program should build upon teachers' existing systems of rules and goals. Also, knowing that designing context-based lessons is complex, the program should offer (2) specific support in the form of design tools and heuristics, combined with (3) examples and modelling activities to help teachers to envision reform practices. The study was carried out parallel to the study that was reported in chapter 4, and was situated within the same professional development program, in which twelve biology teachers participated. All teachers designed several (series of) context-based lessons, the majority of which centred around a context which was a concrete situation from students' life worlds or from professional or scientific practices. Also, most lessons focused on key concepts of biology. The implementation of other reform criteria, such as using activities that match the context or including de- and recontextualisation activities,

varied considerably among the teachers and the individual lessons they designed. Activities that involved explicit reflection on goals or the formulation of intentions were not perceived as useful by most teachers, most probably because teachers' knowledge and beliefs are largely tacit, and are closely linked to their actions. The study supported findings by former studies that teachers do not use design tools in the form of fixed roadmaps or forms. Design tools in the form of heuristics, however, were readily adopted, especially when these were vividly modelled by teacher educators, or used during personal coaching. Another effective approach was offering reform elements to bring solutions to problems of practice during moments of individual coaching, while attending to the teachers' own goals. The highest impact, however, had the examples that were used, either during modelling activities or during group discussions. These types of design support align with the way teachers take their decisions while designing lessons, knowing that this process is largely guided by these teachers' personal goals and rules-of-thumb (chapters 2 and 4) and their knowledge of specific cases (chapter 3). We therefore recommend researchers and teacher educators to develop and use prototypical lessons that capture valued educational principles, such as the ones prescribed by the context-based reform, combined with the heuristics that are needed to design such lessons.

6.2 Discussion

In the introduction of this thesis, we sketched an overview of recent history and current thinking about teacher learning, teacher thinking, and the relations between teachers' personal practical knowledge and curriculum reform. Two main problems were identified. The first problem related to our lack of understanding about the relation between teachers' knowledge and their actions. The second was that although we have an idea of many general factors influencing teacher learning, we need better theories about how to support teachers when they develop their practical knowledge within the context of curriculum reform. Concerning the first main problem we decided to focus on the relation between teacher knowledge and the decisions they take when designing lessons. During our studies, we partly reverted to perspectives and research methods that were in vogue before the research of teaching turned to the role of knowledge in teaching in the 1980s, such as studying decision-making processes using thinking aloud protocols, and we combined this with insights from other research fields, such as goal system theory and design studies. The results show that goal systems enable one to efficiently and validly represent the relation between teachers' personal practical knowledge and the decisions they make while designing lessons. The professional development study (chapter five) indicates that in order to effectively support teachers in their design of innovative lessons, the types of design support that are offered

should be congruent with the nature of teachers' design processes and the manner in which their knowledge informs their design decisions. Below, we will discuss how the outcomes of our studies contribute both to current research into teachers' cognitions and their actions and to the development of effective professional development practices.

6.2.1 Goal systems help to understand teacher decision making while designing lessons

Although everybody would agree that there must be a connection between what teachers know and believe and what they do, many studies have found cognitions and actions to be poorly related. Fives and Buehl (2012) list a number of reasons for this incongruence between teachers' cognitions and actions, the most important of which is that many studies focus on higher order goals, but disregard other beliefs that more strongly guide the decisions teachers take, such as whether a teacher believes that he/she is able to successfully implement a given strategy within a given context with limited resources. Also, some studies suffer from methodological problems, for instance when they rely purely on teachers' self-reports, both when describing their cognitions and their practice. As we have seen in chapter 2 of this thesis, in interviews teachers might testify that they wish and intend to implement a certain educational idea, however, during the translation into action previously hidden but more powerful cognitions might redirect these intentions.

The study of teachers' decision-making processes while thinking aloud, which is reported in chapter 2, indicated the importance of rules-of-thumb as the steering entities of teachers' knowledge, that come into action while teachers design their lessons. During the process of lesson design, teachers' rules and goals, that are at other times largely tacit, become active, and when these conflict with reform goals, teachers' existing rules and goals typically determine the direction the design process takes. We were certainly not the first to identify the importance of rules in teachers' decision-making processes, nor to recognize the fact that rules are strongly linked to intended outcomes (Berliner, 1986; Elbaz, 1983; Feldman, 2000; Leinhardt & Greeno, 1986; Peters & Beijaard, 1983). Others have also found before that while educational reformers are often concerned with only one goal, promoting student learning, teachers have many additional concerns, such as maintaining lesson momentum, creating positive emotions, and meeting personal needs (Doyle & Ponder, 1977; Kennedy, 2002). So, what do the studies in this thesis add to those understandings?

First, the case-studies in chapter 2 thesis gave an impression of how teachers' rules and goals are hierarchically related. This idea was further developed in chapter 3, where Richard's case showed, for instance, how his rule to use an appealing context in which the body functions as it should, is linked to his intended outcome to have students understand the beauty of the complexity of the body when it functions normally, which in turn should lead to students having a positive image of biology. In chapter 4, we combined this understanding

of the importance of teachers' rules and goals with the insights from self-regulation theory and goal systems thinking (Carver & Scheier, 2001; Ford, 1992; Kruglanski et al., 2013; Shah & Kruglanski, 2008), and showed that teachers' rules and goals and their hierarchical relations can be efficiently and effectively elicited by means of a laddering interview. The findings demonstrated that each teacher's goals, and most notably teachers' core goals, define teachers' interpretation of reform ideas, and are closely connected to the decisions teachers make when designing lessons. The findings from this study have since then been confirmed by others. Westbroek, Janssen & Doyle (2017) demonstrated, for instance, how three highly qualified chemistry teachers' core goals determined their interpretation of a context-based chemistry approach.

Goal systems have important conceptual and methodological advantages as compared to other methods to elicit and represent teacher's cognitions. First, a goal system does not discriminate between different kinds of goals, and therefore it does not one-sidedly stress goals related to student learning while disregarding goals related to one of the other concerns teachers might have. Second, cognitions and contextual demands are integrated in one hierarchical conceptual system of rules and goals. A teacher's personal knowledge and beliefs, combined with contextual factors, determine which goals are selected and which means are available and will lead to the selected goals. Third, as already mentioned, goal systems make hierarchical relations between goals and means explicit instead of focusing on isolated teaching strategies or purposes for teaching. The strength of these hierarchical relations can be expressed in terms of a goal system's horizontal and vertical coherence (Sheldon & Kasser, 1995). A system is said to be *vertically coherent* when higher and lower goals are strongly related, that is, when a teacher has the means to achieve his or her valued higher goals. Also, when making decisions, teachers will generally strive for *horizontal coherence*, that is, they will choose activities that will lead to the achievement of various goals simultaneously. The fragment of the goal system of Marion (chapter 4), who in this particular class frequently held classroom conversations, shows how this central activity relates to the goals she has for this particular class (figure 6.1), while her entire goal system showed that she used multiple teaching strategies to activate and motivate her students, one of her core goals. From a methodological perspective, the main benefit of using goal systems is that a goal system only depicts those goals that are actually related to the decisions teachers take when designing lessons, whereas other methods may yield goals that teachers find important, but are not directly related to the decisions they make. Another important advantage is its practicality: a goal system can be constructed during a laddering interview of less than an hour, without the need of recording and analysing lots of lessons and interview data.

For all the reasons summarized above, goal systems thinking might be one of the keys to the development of better targeted support strategies for teachers, which is the topic of the next paragraph.

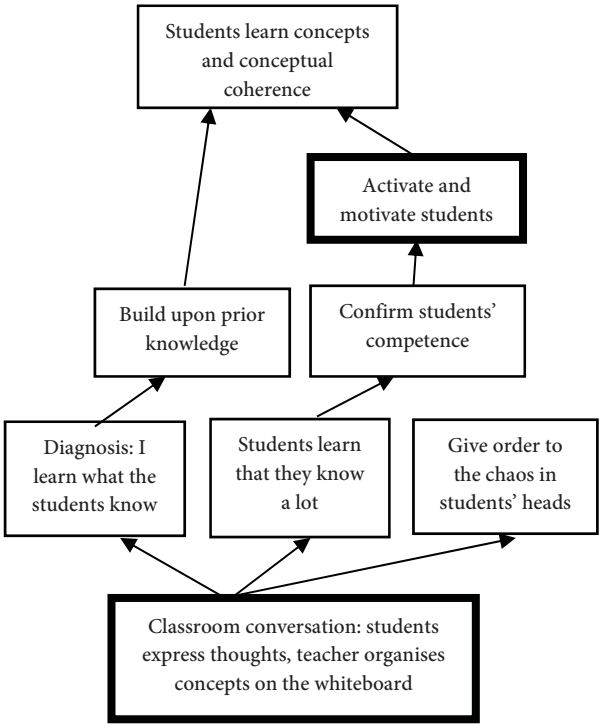


Figure 6.1 Fragment of Marion's goal system. For the complete system, see chapter 4.

6.2.2 Using goal systems, examples and heuristics to support innovative lesson design by teachers

As we explained in chapter 5, although we know that professional development activities occasionally have a substantial impact on teacher thinking and teaching practices, well-developed theories about teacher learning are lacking (Kennedy, 2016). In other words, sometimes PD projects are effective, sometimes they are not, and we do not know exactly how to explain that, apart from the influence of general features such as facilitating cooperation between teachers and making connections with classroom practices (Borko et al., 2010; Van Veen et al., 2010). There is a need for more specific guidelines how to support teachers when they integrate reform ideas in their existing practice.

A first step is the recognition that teachers' existing knowledge and beliefs will determine their response to reform proposals and professional development activities. Our studies showed that goal systems can be used to predict how teachers will respond to a reform proposal, by considering how such a proposal relates to a teacher's (core) goals. Next, the teacher should be supported in translating reform ideas into goals and teaching strategies that are practical and congruent with their perceptions of their own situations.

The findings in chapter five showed that examples, in particular when vividly modelled, and heuristics might be the most effective kinds of design support for teachers who design innovative lessons for their own classroom practice. Both heuristics and examples are congruent with the manner in which teachers' practical knowledge influences decision-making when designing lessons. First, we have seen that teachers' decisions are in important ways the result of the application of rules-of-thumb, many of which have heuristic value; a heuristic being defined as "a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods" (Gigerenzer & Gaissmaier, 2011). The rule, for example, for William to "use the same order as the book when explaining new content, except when this order is illogical" allows him to quickly decide on the structure of his teaching, just like the rule "use mini-assignments when explaining new content" allows Nicoline to activate students within a traditional lesson structure. The heuristics that were offered during the professional development program (chapter five), such as "use an existing stimulating context and move it from the end to the beginning of the lesson" and "show a newspaper heading and ask students an open question to discuss in groups" can have, in the teachers' minds, similar function as their existing rules or heuristics, while quickly resulting into lessons that are more aligned with the proposed context-based approach. Second, many studies that are performed under the umbrella of "naturalistic decision making" (e.g. Klein, 2008) and design studies (e.g. Schön, 1988) have shown that case-based reasoning seems to be the preferred method of reasoning for most people when planning for action. Likewise, when teachers design their lessons, cases or examples of former lessons, or lessons given by others, are essential to analyse given situations, generate new ideas (Schön, 1988; Shulman, 1986a) and to make mental images of the kind of lessons the teacher is designing (Kennedy, 2006). One explanation for the inspirational power of cases is, that cases, having proven their worth in real-world settings, offer solutions for many different problems simultaneously, such as maintaining lesson flow, engaging students and preparing the lesson with easily available materials, and that adapting a given example can be done easier and faster than designing an entire new one. Another explanation might be, that cases are stored as episodic memory, as opposed to more abstract criteria and design models, which are stored as semantic memory (Lawson, 2004). Therefore, cases are easily retrieved from memory and used during creative processes such as lesson design. This might also be the reason that, in our study, vividly modelling examples had a far larger effect than studying exemplar materials on paper.

Although heuristics and cases might now seem two separate entities, in reality, heuristics and cases are closely linked, especially when a heuristic leads to the basic outline of an entire lesson. One case that was designed and discussed by one of the teachers from chapter five, and that functioned as a source of inspiration for other teachers, for example, was a lesson in which students conducted several short experiments, asking themselves the same central

question over again. Such a lesson can be designed using the heuristic "provide students with a number of cases and one central question to apply to each case". In design studies, it has been described how the activation of a case in a designer's mind often automatically involves certain design moves that quickly lead to a first idea for the design, often implying the use of a heuristic (Boling, 2010). A second way in which cases and heuristics are related is when people use a heuristic to adapt existing cases, for instance, when a teacher applies the reverse heuristic to adapt an existing lesson.

6.3 Limitations

Inevitably, the studies reported in this thesis have their limitations, three of which are: (1) a somewhat unnatural approach of the design process, (2) a focus on lesson design, disregarding enactment and (3) limitations to the evaluation and redesign of the professional development strategy.

In the first study, the design process was approached as if the process happened in maximum one hour, and as if the lesson plan was the end product. In reality, the design process can be regarded as an ongoing cycle of planning, enactment, and reflection (Yinger & Hendricks-Lee, 1994). Many teachers are constantly aware of possible leads for a lesson. They collect newspaper articles and stories, they get new ideas during a walk through the woods or during discussion with colleagues. New lesson ideas are often tried out tentatively, and further developed over several lessons. Also, teachers often do not plan per lesson, but rather plan for longer periods of time ahead. The thinking aloud instrument does not seem to comply with this natural process of designing lessons. Still, the rules and goals the teachers used during their thinking aloud processes, were, according to the teachers themselves, representative for their regular way of thinking. Also, no large deviances were found between the lesson process, lesson plan and actual implementation of the lesson, which might mean that the thinking aloud task gave a good approximation of the thought processes that influence the teachers' decision-making under natural circumstances.

Another limitation was the disregard for lesson enactment. The studies were mainly focused on the lesson design processes, for all the reasons we summarized before, and less on lesson implementation and evaluation. When we studied the implementation of the lessons, we focused on content and order of the activities, while other aspects of the interactions between teachers and students were mainly left out of consideration. Also, although we asked and encouraged the teachers to measure the effects of their teaching, we did not measure the quality of the teaching and learning processes in terms of learning outcomes. We have demonstrated how the decisions teachers take are informed by their goal systems, and how this might differ from what teachers say in interviews. Follow-up

studies are needed to see whether and how goal systems are predictive of teachers' actions in class.

A third important limitation, specifically related to the development of the professional development strategy (chapter 5) was that while the separate ingredients of the professional development strategy were tested in several previous settings, including professional development projects and teacher education courses the entire professional development strategy was tested in only one cycle of development and evaluation. Ideally, more cycles of redesign and evaluation would follow, with new groups of participants. A related issue is, that the studies reported in chapters 4 and 5 were conducted simultaneously, using the same data. For that reason, it was not possible to benefit fully from the insights from chapter 4 when developing the professional development strategy.

6.4 Implications for teacher education, policy and further research

6.4.1 How can we link goal systems to other conceptualizations of teacher knowledge?

It was beyond the scope of this thesis to study possible links between goal systems and existing conceptualizations of the knowledge of teachers, such as Shulman's influential categorization of teacher knowledge into seven different types of knowledge (content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge (PCK), knowledge of learners and their characteristics, knowledge of educational contexts and knowledge of educational ends, purposes and values) (Shulman, 1987). The studies in this thesis, however, offer leads to bring together the goal system construct with such knowledge constructs. One might ask, for instance, what is the source of different goals within a goal system; whether a certain goal might be derived from experience, from scientific evidence or from reform ideals. Also, when studying the thinking-aloud protocols, we have seen that some teachers activate topic-specific knowledge about learning difficulties, curriculum standards and possible teaching strategies, which clearly links to their PCK, while others seem to have more general and topic-independent solution strategies. While in this thesis we only studied teachers' goal systems that are valid for their general teaching practice in one particular class, in reality, goal systems can be elicited at different levels of specificity.

The following example clarifies how such goal systems of varying specificity might relate to each other. Clara, one of the teachers who participated in the professional development program described in chapters 4 and 5, but who had to quit halfway because of personal circumstances, told us about a lesson in which she asked her students to draw a peanut. Figure 6.2 represents a small part of her goal system, in which she links her decision to use a peanut to several goals. As one can see, in this case, the higher one comes in the goal system, the more general her goals are. Many goals relate to her goal, to invoke a sense of wonder

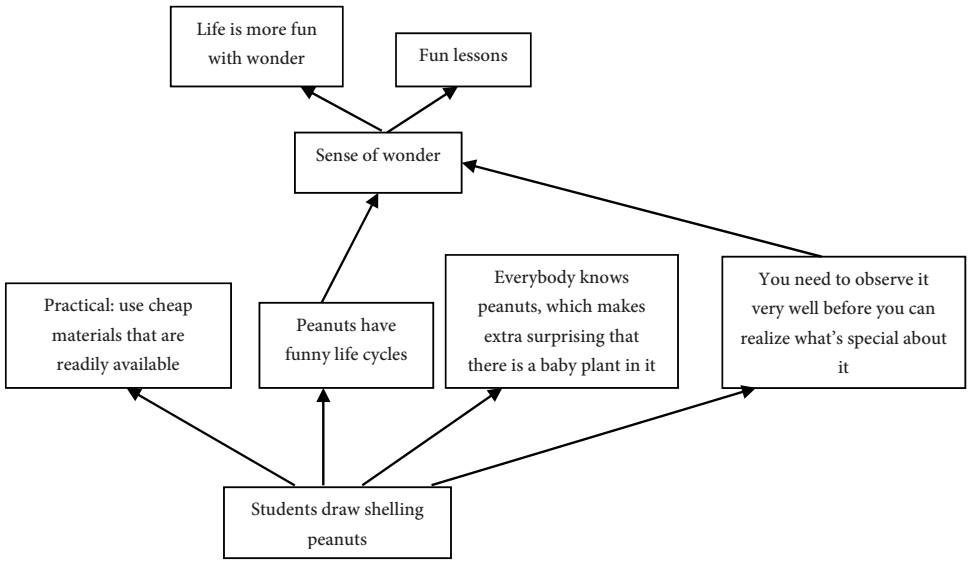


Figure 6.2 A fragment of Clara's goal system about her teaching strategy about plant life cycles, using peanuts

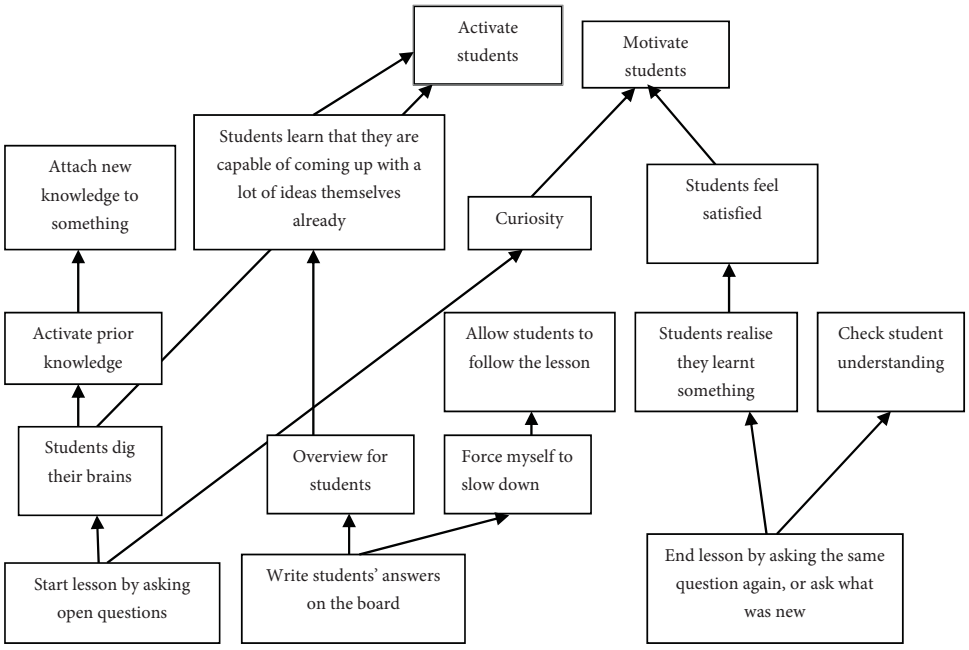


Figure 6.3 A goal system showing Clara's goals concerning the beginning and ending of lessons in grade 1

in her students. When asked for more examples, Clara will name more instances in which she uses recognizable objects in class to enhance students' sense of wonder, and bringing about this sense of wonder will prove to be a core goal in Clara's general practice. There are also instances, however, when both lower and higher goals are quite topic-specific. When a lesson is about sexuality, for example, a higher goal might be "students know how to set healthy relationship boundaries", while in a lesson about genetics, a goal might be "students can make informed decisions in contexts of genetic testing". In our studies, we have chosen to focus slightly more general goal systems that are topic-independent, but specifically valid for a certain group of students, because we wanted the goal system to be predictive of the decisions teachers take when designing lessons of all kinds of topics for this particular group of students. If one is interested in studying the relation between teachers' PCK and their actual teaching practice regarding specific topics, however, one might choose to make more topic-specific goal systems, such as Clara's plant life cycle goal system.

Instead of focusing on specific topics, one might also focus on more general teaching practices when constructing goal systems, as another example from Clara's will demonstrate. Figure 6.3 shows what Clara does when starting and ending lessons in grade 1 (age 12/13), and why she does it. These episodes are directed at motivating and activating her students through constructivist activities (figure 6.3). Such goal systems might be used in research and educational settings to clarify and demonstrate teachers' practical knowledge as related to common practices (often called "core practices"), such as starting and ending lessons, guiding classroom discussions, or explaining new content.

6.4.2 Using goal systems for research and practice in teacher education and professional development

The findings in chapter 5 show that for in-service teachers, goal system construction appears to be effective and predictive of future decision-making when designing lessons, while the teachers experienced it as a meaningful activity. These findings show the potential for goal systems as reflective and diagnostic instruments in teacher education and professional development settings. One's work satisfaction depends on the extent to which somebody succeeds in reaching one's goals, which can be related to student learning, but just as well to having fun, having a good relationship with students, developing oneself, etcetera. A goal system integrates all such goals, in so far as these are related to someone's actions, and might also include goals that are aspired, but are, according to the teacher, not yet satisfactorily met. Negative links between goals might also bring sources of frustration to the light, in that they show how some goals and actions might hinder the accomplishment of other goals.

In recent studies employing the so-called "bridging strategy" goal systems are used as a starting points for personal professional development trajectories (Janssen, Grossman, & Westbroek, 2015; Janssen et al., 2013) in which teachers are supported to step-wise alter

their practice in such a way that both their core goals and the reform goals are met. Janssen, Westbroek & Doyle (2014), for instance, successfully supported pre-service biology teachers to stepwise change their practice from performing cookbook labs to open inquiry by first analysing their goal systems and devising a support progression in which each step would mean an amelioration in the attention of teachers' own goals. Westbroek, Van Rens & Van den Berg (2017) used a similar approach to support experienced teachers when they introduce formative assessment strategies in their teaching.

Further research into the usefulness of using goal systems in teacher education courses and professional development projects would be recommended. Possible research questions could refer to the relation between a student teachers' goal system and the quality of their teaching practice, developments in the goal system during and after teacher education, the usefulness of combining goal system construction with learning new teaching strategies, etcetera. Preliminary results from our teacher education courses indicate that in general student teachers' goals and actions are less well-connected than those of more experienced teachers, which is consistent with earlier findings from lesson planning studies that novice teachers plan for similar actions as expert teachers, but do not as clearly link it to multiple goals to be reached. Berliner, for example, found that both novice and expert teachers plan to do homework checks, but while the novice teachers saw this merely as a means to correct students' answers, the expert teachers additionally considered it as an opportunity to collect student information on which to base further instruction (Berliner, 1986).

We would also be interested in developments in teachers' systems of goals over longer periods of time. While in our study we found goal systems to remain quite stable over the course of one school year (chapter 4), one might expect the systems to change over time, when the context or a teacher's knowledge, beliefs or ambitions change (Shah & Kruglanski, 2008). How does such a change process take place? Core goals would be expected be the most stable elements of the system, but based upon existing writings about self-regulation, one could additionally hypothesize that higher goals change only slowly, while lower goals trigger fast feedback and quick adaptations of behaviour or goals (Lord, Diefendorff, Schmidt, & Hall, 2010). This would mean that when a change in teaching practice has consequences for mid-level goals such as classroom order, or for the number of questions students ask in class, one would expect quick adaptation or continuation of the new behaviour, while it would take longer to develop higher level goals. Related questions are: what does it mean that some teachers have more complex goal systems than others? And what does it mean that some teachers tend to talk about their practice in higher level goals ("stimulate critical thinking"; "making learning visible") while others talk predominantly in terms of lower level goals ("use short instructions"; "give an overview over the lesson on the whiteboard")?

6.4.3 Developing and using a collection of examples and heuristics

Having learnt that the combination of examples, modelling and heuristics offer such powerful learning opportunities (chapter 5), we argue for building a collection of rich cases and heuristics. In literature, many inspirational cases can be found. Such examples, however, are not always readily available for teachers. The same goes for heuristics. Using heuristics in teacher education and professional development may give some the impression of downgrading theory, but the opposite is true: translating theory into heuristics means upgrading theory to enable it to be used in practice (Janssen et al., 2015). Apart from the more practical development of cases and heuristics, more research is needed into the actual use of cases and heuristics by teachers when designing their lessons. In our studies, it was not always possible to separate the effect of using examples and heuristics from the effect of modelling. Further study is needed to be able to compare the effects of vivid descriptions of someone's design process, for instance, with and without modelling.

Finally, in the same way as the language of design studies have enriched and stimulated our research into teacher thinking and lesson design, this language has the potential to enrich teacher education courses. The image of the teacher as a designer appears to be a fruitful metaphor for use in teacher education. Modelling the use of heuristics, using vivid examples, feeds beginning teachers' practical knowledge, just like a beginning architect would be both inspired and better equipped when experiencing many different buildings, combined with heuristics to create a similar effect as, say, a dome church or an English college library. In teacher education, we should inspire students to develop into adaptive experts, who simultaneously can recognize situations as familiar and use new situations as opportunities to experiment and develop their practical knowledge.

6.4.4 Implications for curriculum policy

Curriculum planners should not only recognize the fact that teachers have a multitude of goals to consider when planning their lessons, while their own innovation ideas are often focused on reaching one to a few overall goals. They could also go a step further and recognize the special wisdom that is enclosed in a teachers' goal system, that special wisdom that a policy maker, without working in the teachers' classroom context, could not have. This wisdom is largely implicit, and packaged in the form of rules, goals and cases instead of theories that can easily be transferred, but this does not mean that a teacher's practical wisdom is less developed, less valid or less "wise" than a curriculum developer's theory (van Driel et al., 2001). Instead of viewing reform ideas as packages of knowledge that should be implemented by teachers in order to innovate and improve teaching practices, it would be recommendable to strive for meaningful communication and mutual learning between teachers and policy makers, between teachers and researchers and between policy makers and researchers.

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Appendix 1: Kate's decision summary (chapter 2)

Decision	Reason
Use a context-based approach	Let the students understand what biology is really about. Create a good learning atmosphere.
Start at the students' level	They themselves are organisms too, otherwise they forget that. It is important they realize they are also part of it.
Use a well-structured assignment, with adequate control	Otherwise the students cannot find solutions; they will not reach a thorough understanding.
Students have to have learned the concepts from the book in advance	Otherwise they do not know in what direction to think, they need thinking tools and a conceptual framework. It is good to have the concepts reappear within different contexts, this enables transfer.
The situation does not need to be authentic	Such a situation is never really authentic. And what is real to them is tomorrow's test.
They need to use the book during the lesson	- If I give them a book but do not use it during the lessons, I think it will make students feel unsatisfied. - Students will feel reassured if they know how the lesson relates to the book.
The topic of the lesson will be biodiversity	That is really difficult.
Context taken into consideration, but rejected: holiday	Relation to biodiversity is too weak.
Context taken into consideration, but rejected: recreation	People like to recreate in areas where biodiversity is high, but 12-year-olds do not necessarily feel that way.
Context taken into consideration, but rejected: investigate soil specimens with many, and with few different animal species	This is not a context from students' daily lives.
Context taken into consideration, but not chosen: compost heap	This relates to nutrient cycles, we have already covered that.
Context taken into consideration, and chosen: students' own house	- Accords with the rule always to start at the level of students' lives - It fits the concept of "habitat" nicely
Student activity: draw your own house	This is a creative activity; creative activities have proven to be successful in the past.
The assignment is worked out on a worksheet	The worksheet coaches the students through their thinking processes, because the teacher cannot coach all students at the same time.
Second context chosen: the house of an animal	- Apply the concept "habitat" - Thinking from the perspective of the organism is in accordance with the biological way of thinking, which all revolves around the issue how animals manage to survive.

Students are assigned a specific organism, they cannot choose for themselves	- It would be fun to have them choose for themselves, but then they would choose their pets, who live in a house, instead of in a park. - Many different organisms are needed in order to end up with the concept of "biodiversity"
All animals chosen live in the park nearby school	Students know this park, and would be able to encounter these animals there, which would help them recognize the biology in the real world.
Students write the name of their animal on a note, and if possible stick it in their natural habitat on the map of a park	- Enables students to understand the link between the concept of habitat and the concept of biodiversity. - Motivates students to think about nature development.
A final assignment in which students practice the use of the concept of biodiversity	- Promotes further understanding of the concept of biodiversity.
Two lessons, instead of one	The lesson as designed does not fit in one session. Having two sessions has the additional advantage of making it more likely that students gain lasting knowledge.

Samenvatting

Wereldwijd is onderwijsinnovatie aan de orde van de dag. Ook het biologieonderwijs op Nederlandse middelbare scholen is in beweging. Enerzijds is dit ingegeven door de grote ontwikkelingen in de biologie als wetenschap, die een steeds belangrijkere rol spelen in de maatschappij, waarbij kwesties steeds ingewikkelder worden. Mag je erfelijke afwijkingen in het DNA van embryo's repareren? Moeten we de dieren in de Oostvaardersplassen bijvoeren, laten sterven of omzetten in blikjes wild? Van wie is een embryo wiens ouders plotseling zijn overleden? Is het genetisch modificeren van voedingsgewassen zodat ze meer mensen kunnen voeden duurzaam of juist niet? Daarom zijn burgers nodig die begrip hebben van de biologie achter deze kwesties en die op school hebben geoefend met het redeneren binnen actuele contexten. Ook scholen, docenten en leerlingen voelen al langere tijd de behoefte aan verandering, omdat het biologieprogramma als overladen wordt ervaren, en omdat er weinig samenhang wordt gezien binnen en tussen vakken. Om deze redenen werd in 2004 de Commissie voor de Vernieuwing van het Biologieonderwijs (CVBO) in het leven geroepen, die het advies uitbracht om het biologieonderwijs te vernieuwen en hierbij aan te sluiten bij de concept-contextbenadering, die in het binnen- en buitenland al wat langer furore maakte. Als leerlingen vaker zouden oefenen met het gebruik van biologische begrippen in actuele contexten[4], zo was het idee, zou de inhoud van het schoolvak vanzelf actueler en relevanter worden. Ook zouden leerlingen leren hoe verschillende concepten binnen en buiten de biologie met elkaar samenhangen, omdat echte contexten zich niet houden aan de strenge afbakening tussen hoofdstukken zoals die in de schoolboeken bestaat. In 2013 is het nieuwe examenprogramma ingevoerd, waarin contexten inderdaad een prominentere rol spelen. Docenten werden intussen vrij gelaten om hun eigen didactiek te kiezen en ontwikkelen, waarbij ze zich konden laten inspireren en begeleiden door publicaties, workshops en nascholingstrajecten.

Mij werd gevraagd om een nascholingstraject te ontwikkelen voor biologiedocenten die de concept-contextbenadering wilden vertalen naar hun eigen lespraktijk. Dit klinkt als een duidelijke opdracht. Er waren echter enkele belangrijke problemen. Ten eerste ontbreken duidelijke richtlijnen voor het ontwerp van zo'n nascholingstraject. We weten dat nascholing soms een grote invloed kan hebben op de lespraktijk van een docent, maar vaak ook helemaal niet, en we weten niet zo goed waar dat aan ligt, afgezien van enkele globale factoren zoals dat je aan moet sluiten bij de lespraktijk van de docent en dat het programma een zekere duur moeten hebben (hoewel er ook voorbeelden zijn van heel kortdurende

[4] Een context is door de CVBO gedefinieerd als een authentieke handelingspraktijk. Voorbeelden zijn het verzorgen van huisdieren (leefwereldcontext), het bakken van brood (beroepscontext) of het ontwikkelen van een medicijn tegen kanker (wetenschappelijke context).

programma's die toch een grote impact hadden). Wat we ook weten, is dat de bestaande praktijkkennis van docenten een bepalende rol speelt. Dat is logisch: wat zich heeft bewezen in de eigen klassenpraktijk wordt niet zomaar overboord gegooid. Hier doemt echter een nieuw probleem op: die praktijkkennis laat zich maar moeilijk onderzoeken. Deze kennis is nauw verbonden aan het handelen in een bepaalde context, en aan bepaalde onderwerpen, en stuurt het handelen op een grotendeels impliciete manier. Met andere woorden: docenten weten vaak niet wat ze weten, en als hun kennis en opvattingen toch middels interviews en vragenlijsten wordt bevraagd, blijkt wat ze zeggen vaak weinig voorspellend voor wat ze daadwerkelijk doen in de klas.

Op grond van een analyse van bovenstaande problemen, waarvan ik verslag doe in de inleiding in hoofdstuk 1, kwam ik tot de volgende probleemstelling: dit proefschrift heeft tot doel meer licht te werpen op de relatie tussen de praktijkkennis van docenten en hun handelen in de context van curriculumvernieuwing, om op grond daarvan aanbevelingen te kunnen doen voor het ontwerp van nascholing voor biologiedocenten die vernieuwende concept-contextlessen willen ontwerpen voor hun eigen lespraktijk. Ik besloot me in het onderzoek vooral te richten op de beslissingen die docenten nemen bij het voorbereiden van hun lessen. Ten eerste zijn de beslissingen die docenten nemen tijdens het voorbereiden van hun lessen bepalend voor de inhoud van die lessen. Ook is het ontwerpproces interessant vanuit zowel het onderzoeks- als het nascholingsperspectief. Tijdens het ontwerpen van lessen gebruiken docenten immers hun bestaande praktijkkennis, terwijl ze tegelijkertijd nieuwe kennis creëren, bijvoorbeeld als ze op zoek gaan naar manieren om de doelen die ze zich tijdens het ontwerpen stellen te verwezenlijken.

Het centrale doel is vertaald in de volgende twee onderzoeksvragen:

1. Welke beslissingen nemen docenten als zij vernieuwende concept-contextlessen ontwerpen voor hun eigen lespraktijk, en hoe zijn deze gerelateerd aan de praktijkkennis van deze docenten?
2. Hoe kunnen we biologiedocenten op een effectieve manier ondersteunen bij het ontwerpen van concept-contextlessen voor hun eigen lespraktijk?

Een eerste deelstudie (**hoofdstuk twee**) had tot doel in kaart te brengen wat biologiedocenten denken en doen als ze lessen ontwerpen voor hun eigen lespraktijk en zich daarbij laten inspireren door de concept-contextbenadering, zonder dat we ze hier begeleiding bij boden. We vroegen zes docenten, die waren geselecteerd vanwege verschillen in leservaring (1 tot 22 jaar), schooltype (vmbo/havo/vwo) en ervaring met de concept-contextbenadering om hardopdenkend concept-contextlessen te ontwerpen. Ook analyseerden we het ontworpen lesmateriaal, observeerden we de lessen, en interviewden we de docenten na afloop van de gegeven lessen. Bij het analyseren van de hardopdenkprotocollen bleek dat de docenten zich bij het ontwerpen lieten leiden door vuistregels als "vertel persoonlijke verhalen"

en "gebruik de concepten in meerdere situaties", die sterk waren verbonden met doelen zoals "plezier hebben in de klas", "voorkennis activeren" en "leerlingen verwonderen". Als vernieuwingsregels en -doelen conflicteerden met bestaande vuistregels en doelen van de deelnemende docenten kregen de bestaande doelen in de regel voorrang boven de vernieuwingsdoelen, ook al hadden alle docenten aangegeven bij deze gelegenheid vooral te proberen de vernieuwingsdoelen te implementeren. Ook bleken de docenten in sommige gevallen niet te verwachten dat de voorgestelde vernieuwingskenmerken tot de beoogde vernieuwingsdoelen zouden leiden. Zo hadden sommige docenten de verwachting dat het gebruik van authentieke contexten ertoe zou leiden dat leerling de leerstof als *minder* motiverend zouden ervaren, omdat concepten dan misschien wel relevant zijn voor deelnemers aan die context, maar niet voor hen, leerlingen die willen weten wat ze moeten kennen voor de toets. Deze studie wijst op het belang van persoonlijke vuistregels als dat deel van de praktijkkennis dat het beslisproces tijdens de lesvoorbereiding stuurt. Bij nadere beschouwing rees bovendien het vermoeden dat de regels en doelen van de docenten op een hiërarchische manier met elkaar samenhangen. Dit vermoeden werd in de volgende hoofdstukken verder onderzocht.

Wij waren niet de eersten die wezen op de belangrijke rol die vuistregels spelen voor mensen die in (beroeps)praktijken beslissingen nemen. Vuistregels spelen bijvoorbeeld een belangrijke rol in het werk van Donald Schön. Schön bracht in 1973 het grote belang van de praktijkkennis van professionals onder de aandacht; professionals die door de beslissingen die ze nemen bepalen hoe de wereld eruit ziet. Schön zette zijn belangrijkste ideeën uiteen in zijn boek *The reflective practitioner*[5] (1983). In **hoofdstuk drie** stelden we ons de vraag in hoeverre Schöns perspectief van "reflective practice" zou kunnen helpen om beter te begrijpen hoe praktijkkennis het beslisproces van docenten beïnvloedt tijdens het ontwerpen van lessen. Schöns inzichten zijn in het onderwijsonderzoek veelvuldig gebruikt om het belang van reflecteren op leservaringen te onderstrepen ("reflection on action"). Een belangrijk deel van Schöns werk gaat echter over het reflecteren *tijdens* het handelen (reflection-in-action). Elk proces van reflectie-in-actie, zegt hij, is in essentie een ontwerpproces. Tijdens het handelen gebruiken mensen, in een "gesprek met de situatie" (*conversation with the situation*) hun kennis terwijl ze tegelijkertijd nieuwe kennis creëren. Deze praktijkkennis bestaat, volgens Schön, naast de bekende vuistregels, uit *types* (voorbeelden of prototypes; beelden van eerdere situaties) en *appreciations* (waarderingen van verwachte uitkomsten van beslissingen). Wij gebruikten het perspectief van Schön om het ontwerpproces van een van de docenten uit de eerste deelstudie opnieuw te analyseren. Richard, een ervaren biologiedocent, ontwierp hardopdenkend een concept-contextles voor

[5] Het woord "practitioner" is niet zo gemakkelijk te vertalen. Het betekent zoiets als "beoefenaar", "iemand die handelt".

zijn 4 havo-leerlingen. Tijdens het ontwerpen werd Richards praktijkkennis geactiveerd en veranderden zijn opvattingen over de concept-context-vernieuwing. Het bleek mogelijk om *rules*, *types*, en *appreciations* als actieve onderdelen van Richards praktijkkennis te identificeren. Een voorbeeld van een *type* was een leservaring die Richard in herinnering bracht, waarin hij een aansprekend voorbeeld had gebruikt (een leeuw die tijdens een safaritrip plotseling tevoorschijn springt) om een bepaald concept te verduidelijken. Zowel *rules* en *appreciations* als *rules* en *types* bleken sterk aan elkaar gerelateerd te zijn. De regel "de les moet leerlingen laten ervaren hoe mooi het is als hun lichaam precies zo werkt als zou moeten" bepaalde bijvoorbeeld hoe Richard een eerder idee, om een medische context te gebruiken, waardeerde, en waarom hij dit idee vervolgens verwierp. Verdere analyse liet zien dat er hiërarchische relaties bestonden tussen Richards vuistregels, en dat zijn beslisproces kon worden weergegeven als een traject door zijn persoonlijk hiërarchisch systeem van regels; regels die in de psychologie, met name als het gaat over zelfregulatie, doorgaans *doelen* worden genoemd. Hogere doelen in het systeem, zoals het hiervoor genoemde voorbeeld "de les moet leerlingen laten ervaren hoe mooi het is als hun lichaam precies zo werkt als zou moeten", geven een nieuwe betekenis aan het begrip "appreciations", dat door Schön nog vrij vaag was gedefinieerd. Wij verwachtten daarom dat het gebruik van hiërarchische doelsystemen een waardevolle aanvulling zou zijn op Schöns inzichten. Door doelsystemen te gebruiken, zouden we beter zichtbaar kunnen maken hoe *rules*, *types* en *appreciations* onderling verbonden zijn en samen bepalen welke beslissingen docenten nemen.

De vermoedens die in hoofdstuk 2 en 3 al oprezen, dat doelsystemen een waardevolle aanvulling zouden kunnen zijn op bestaande methoden om de relatie tussen praktijkkennis en handelen zichtbaar te maken, is in een volgende studie meer systematisch onderzocht (**hoofdstuk 4**). Een doelsysteem is gedefinieerd als een mentale representatie van de doelen die in een bepaalde context voor een bepaald individu actief zijn, inclusief de hiërarchische doel/middel-relaties tussen de doelen. Heel algemene doelen, zoals "goede examenresultaten" zijn verbonden met meer specifieke doelen als "leerlingen ontwikkelen hun logisch redeneer-vaardigheden", die weer verbonden zijn aan concreet gedrag in de klas zoals "stel veel open vragen tijdens practica". Van twaalf docenten, die deelnamen aan een professionaliseringstraject, is het doelsysteem geconstrueerd. We deden dit met behulp van de veelbeproefde *ladderingtechniek*. In het kort houdt dit in, dat we de docenten vroegen een gemiddelde les in de betreffende klas te beschrijven, waarna we op elk genoemd aspect, zoals het uitleggen van nieuwe stof, doorvroegen *hoe* het aspect precies werd vormgegeven in de klas, en *waarom* op deze manier. De genoemde doelen werden direct tijdens het interview grafisch, in relatie tot elkaar, weergegeven. Op elk genoemd doel werd opnieuw doorgevraagd waarom de docent dit belangrijk vond, totdat het punt bereikt werd dat deze vraag geen nieuwe relevante informatie opleverde. Met behulp van aanvullende interviews,

lesplannen, lesopnames en hardopdenkprotocollen werd vervolgens in kaart gebracht hoe de twaalf docenten de vernieuwing implementeerden in hun lespraktijk. De resultaten wezen uit dat zogenaamde *centrale doelen* (*core goals*), gedefinieerd als die doelen binnen het doelsysteem die verbonden waren met twee of meer doelen op een hoger of lager niveau, sterk voorspellend waren voor de manier waarop de docenten de vernieuwing waardeerden en implementeerden in hun lespraktijk. Ook negatieve verbindingen - doelen die elkaar tegenwerken of tegenstrijdig zijn - bleken van belang. Doelsystemen lijken dus zowel op een efficiënte als effectieve manier dat deel van de praktijkkennis van docenten weer te geven dat daadwerkelijk sturend is voor het beslisproces tijdens het ontwerpen van lessen.

In **hoofdstuk 5** wordt aandacht besteed aan de tweede hoofdvraag van dit proefschrift, hoe docenten op een effectieve manier kunnen worden ondersteund bij het ontwerpen van vernieuwend onderwijs. Het doet verslag van de ontwikkeling en evaluatie van een professionaliseringsprogramma dat tot doel had om biologiedocenten te ondersteunen bij het ontwerpen van vernieuwende concept-contextlessen voor hun eigen lespraktijk. De volgende drie kenmerken stonden centraal: (1) het programma moet voortbouwen op de bestaande doelen van docenten. Deze bestaande doelen zullen immers bepalend zijn voor de manier waarop zij een vernieuwing interpreteren. (2) Het programma moet docenten ondersteunen met specifiek voor deze vernieuwing ontworpen ontwerpgereedschap en heuristieken, en (3) het programma moet deelnemende docenten in staat stellen te ervaren hoe concept-contextlessen ontworpen en uitgevoerd kunnen worden. Dit laatste kan worden gerealiseerd door het organiseren van modelleersessies waarin zowel de opleiders, die de leiding hadden over het professionaliseringsprogramma, als de deelnemende docenten zelf, voordoen hoe zij dergelijke lessen ontwerpen en uitvoeren. De studie liep parallel aan de studie waarvan we verslag deden in hoofdstuk 4, en vond plaats binnen hetzelfde professionaliseringsprogramma, waaraan 12 biologiedocenten deelnamen. Alle docenten ontwierpen in het kader van het programma meerdere vernieuwende lessen(series). In het merendeel daarvan stond een concrete situatie uit de leefwereld van leerlingen of uit een beroeps- of wetenschappelijke praktijk centraal. Ook waren de meeste lessen gericht op het aanleren van kernconcepten uit de biologie. Er waren echter aanzienlijke verschillen tussen de docenten in de manier waarop en de mate waarin andere vernieuwingskenmerken, zoals het gebruik van authentieke activiteiten en van de- en recontextualisatie, in de lessen werden verwerkt. De resultaten lieten zien dat de docenten het weinig zinvol vonden om het complete ontwerpgereedschap te gebruiken tijdens het ontwerpen van hun lessen, iets dat ook uit eerdere studies bekend was, terwijl de afzonderlijke heuristieken juist veelvuldig werden gebruikt, met name als deze waren gemodelleerd door de opleiders of gebruikt tijdens momenten van individuele coaching. Zulke momenten van individuele coaching waren extra zinvol als hierbij door de coach werd aangesloten bij de bestaande doelen van docenten. De meest toegepaste heuristiek was de zogenaamde *omdraaiheuristiek*, die er in

het kort op neerkomt dat een docent een uitdagende opdracht, die normaliter aan het eind van een les gebruikt wordt, verplaatst naar het begin van een les, waarna de benodigde hulp in de vorm van uitleg en deelopdrachten aangepast wordt aan de behoeften van leerlingen. De meeste invloed, echter, hadden de voorbeelden van concept-contextlessen die tijdens modelleersessies tot leven werden gebracht, hetzij door de opleiders, hetzij door de docenten zelf.

In **hoofdstuk 6** wordt teruggegrepen op de problemen die we bespraken in hoofdstuk 1, en wordt gereflecteerd op de antwoorden die dit proefschrift heeft opgeleverd. De twee belangrijkste problemen, die centraal stonden in dit proefschrift, waren (1) het gebrek aan inzicht in de relatie tussen de praktijkkennis van docenten en hun handelen en (2) de behoefte aan betere richtlijnen als we docenten willen ondersteunen bij het ontwikkelen van hun praktijkkennis in de context van onderwijsvernieuwing. Bij het beantwoorden van de onderzoeksvragen grepen we deels terug op perspectieven en onderzoeksmethoden die in zwang waren voor de jaren 80 van de vorige eeuw, zoals het bestuderen van beslisprocessen in hardopdenkstudies, en we combineerden deze methoden met inzichten uit andere vakgebieden, zoals doelsysteemdenken en ontwerpstudies. De resultaten laten ten eerste zien dat het mogelijk is om in een doelsysteem op een efficiënte en valide manier de relatie tussen praktijkkennis en lesontwerp van docenten weer te geven. Ten tweede laat het proefschrift zien dat om docenten effectief te ondersteunen als zij innovatief onderwijs ontwerpen het aan te raden is om aan te sluiten bij de manier waarop docenten normaal gesproken onderwijs ontwerpen, en de manier waarop zij zich hierdoor laten sturen door hun praktijkkennis. Op beide aspecten gaan we wat dieper in.

Wij waren zeker niet de eersten die wezen op het belang van vuistregels voor de beslissingen die docenten nemen, en ook werden vuistregels in andere studies vaker verbonden aan doelen die docenten hebben. Ook hebben anderen gewezen op het feit dat terwijl onderwijsvernieuwingen vaak gericht zijn op het bereiken van een doel, namelijk het bevorderen van leren van leerlingen, docenten veel doelen tegelijkertijd moeten zien te bereiken, zoals het creëren van flow tijdens een les, zorgen voor een goede relatie met leerlingen, en tegemoet komen aan persoonlijke behoeften. De belangrijkste toevoeging aan deze inzichten is het gebruik van doelsystemen om regels en doelen van docenten in kaart te brengen, waarbij, zoals hoofdstuk 4 laat zien, de *centrale doelen* van een docent een bijzondere rol innemen. Het weergeven van regels en doelen van docenten in de vorm van een doelsysteem heeft enkele belangrijke voordelen. Ten eerste maakt een doelsysteem geen onderscheid tussen verschillende typen doelen, en legt daardoor niet eenzijdig de nadruk op het leren van leerlingen. Een tweede voordeel is, dat cognities en contextfactoren worden geïntegreerd in één systeem. Verder maken doelsystemen hiërarchische relaties tussen doelen en middelen expliciet, in plaats van dat, zoals vaak gebeurt, alleen onderwijsstrategieën of doelen in kaart gebracht worden. Het belangrijkste

methodologische voordeel van het gebruik van doelsystemen is dat alleen die doelen in kaart worden gebracht, die daadwerkelijk sturend zijn voor de beslissingen die docenten nemen, terwijl andere methoden doelen naar boven kunnen brengen die weliswaar gewaardeerd worden door de betreffende docent, maar die niet altijd verbonden zijn met de lespraktijk. Een ander voordeel is, dat een doelsysteem binnen een tijdsbestek van minder dan een uur geconstrueerd kan worden.

Dit proefschrift levert verder nieuwe aanwijzingen op hoe docenten op een effectieve manier ondersteund kunnen worden bij het ontwerpen van vernieuwende lessen. Zoals hoofdstuk 5 liet zien, lijken vooral voorbeelden en heuristieken docenten te helpen bij het ontwerpen van hun lessen. Zowel voorbeelden als heuristieken sluiten aan bij de manier waarop de praktijkkennis van docenten hun lesontwerp stuurt. Ten eerste hebben we gezien dat docenten zich sterk laten sturen door vuistregels, waarbij deze vuistregels vaak een heuristische functie hebben. Als William bijvoorbeeld de regel toepast "gebruik, bij het uitleggen van nieuwe lesstof, dezelfde volgorde als het boek, tenzij dit een onlogische volgorde is" (hoofdstuk 4), stelt dit William in staat om op een efficiënte manier zijn uitleg voor te bereiden, net zoals Nicolines regel "gebruik mini-opdrachtjes tijdens het uitleggen van nieuwe stof" haar in staat stelt om leerlingen te activeren binnen een traditionele lesstructuur. De heuristieken die tijdens het in dit proefschrift beschreven professionaliseringsprogramma werden aangeboden kunnen, in het denken van de docenten, een zelfde functie vervullen, terwijl ze snel resulteren in een lesopzet die meer aansluit bij de concept-contextbenadering. Ten tweede hebben veel eerdere studies uitgewezen dat voorbeelden een grote rol spelen als mensen plannen maken en beslissingen nemen. Dit geldt ook voor docenten die lessen ontwerpen: voorbeelden van lessen zijn belangrijk bij de analyse van gegeven situaties en om nieuwe ideeën voor de toekomst te genereren. Goede voorbeelden, die zich in realistische situaties hebben bewezen, bieden vaak een oplossing voor meerdere problemen tegelijkertijd, zoals een les ontwerpen waarin leerlingen gemotiveerd en actief aan het werk blijven, binnen de beschikbare tijd, met materialen die voorhanden zijn. Bovendien is het voor docenten gemakkelijker zich levendige voorbeelden voor de geest te halen als zij lessen gaan ontwerpen, dan meer abstracte informatie zoals op de vernieuwing gebaseerde ontwerpcriteria. Hoewel heuristieken en voorbeelden nu als twee losse concepten worden besproken, zijn ze in werkelijkheid sterk aan elkaar verbonden, vooral wanneer een heuristiek, zoals de omdraaiheuristiek, leidt tot een ontwerp van een gehele les. In de praktijk van het professionaliseringstraject werden, tijdens modelleersessies, heuristieken en voorbeelden doorgaans samen aangeboden. Tot slot worden in hoofdstuk 6 implicaties besproken voor de opleiding van docenten, voor vervolgonderzoek en voor onderwijsbeleid.

Curriculum vitae

Nienke Wieringa was born on 16 September 1978 in Voorburg. She completed her secondary education in 1996 at Zandvlietcollege in The Hague, after which she went to Utrecht to study social geography (propaedeuse *cum laude*) and biology (propaedeuse *cum laude*; M.Sc.). She specialized in tropical ecology, for which she did her fieldwork in the tropical rainforest surrounding Riberalta, Bolivia. Nienke started her teaching career in 2004, when she worked for an environmental awareness institute, taking primary school children to the forest to experience nature. After that, she graduated from ICLON Graduate School of Teaching and worked as a biology teacher for 10 years at her own secondary school, currently called Christelijk Lyceum Zandvliet. After her first year as a teacher, Nienke started her PhD research at ICLON. As of 2013, Nienke has been a teacher educator and school subject specialist at ICLON.

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