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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

<table>
<thead>
<tr>
<th>Lesson characteristics</th>
<th>Intended outcomes</th>
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<tbody>
<tr>
<td>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)</td>
<td>A Students’ prior knowledge is activated.</td>
</tr>
<tr>
<td>2 The context is a concrete situation from students’ life worlds or from professional or scientific practices (C, D,E,F,G)</td>
<td>B Students feel involved and focused.</td>
</tr>
<tr>
<td>3 Within the context multiple biological concepts from different biological domains come together (G)</td>
<td>C Students feel motivated to learn biology.</td>
</tr>
<tr>
<td>4 The teaching unit has a guiding question, which provides a clearly focused problem orientation (H,I)</td>
<td>D The concepts have relevance within the context.</td>
</tr>
<tr>
<td>5 The student activities match the context and guiding question (F,I)</td>
<td>E The concepts derive their meaning from the context; students learn to understand the importance of biological knowledge within this particular context.</td>
</tr>
<tr>
<td>6 Students learn to use key concepts of biology (J)</td>
<td>F Students learn to develop specific biological skills.</td>
</tr>
<tr>
<td>7 Students are stimulated to reflect upon their learning process, their understanding of the biological concepts and the relation between the concepts (G,J)</td>
<td>G Students learn to understand how different biological concepts are related.</td>
</tr>
<tr>
<td>8 Students are presented with multiple contexts in which the same concepts are used (E,J)</td>
<td>H Students feel a “need-to-know”.</td>
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<tr>
<td></td>
<td>I The teaching unit is coherent.</td>
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<tr>
<td></td>
<td>J Students work on a thorough understanding of biological concepts and are able to use these concepts within a diversity of contexts.</td>
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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>
<thead>
<tr>
<th><strong>Table 5.3 Contents of the PD program and interviews</strong></th>
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</table>
| **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 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

<table>
<thead>
<tr>
<th>Box 5.2 Research questions and expectations</th>
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<tbody>
<tr>
<td><strong>1.</strong> What are characteristics of the innovative, context-based lessons the teachers design during the program?</td>
</tr>
<tr>
<td>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</td>
</tr>
<tr>
<td>1.b These lessons will meet an increasing number of reform criteria</td>
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<tr>
<td><strong>2.</strong> What changes in their regular teaching practice do the participating teachers report, as a result of the program?</td>
</tr>
<tr>
<td>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</td>
</tr>
<tr>
<td>2.b After the program, the teachers will apply the context-based approach more often and with more ease than before the program</td>
</tr>
<tr>
<td><strong>3.</strong> How could one in such a PD program build effectively upon teachers’ existing goals and concerns?</td>
</tr>
<tr>
<td>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</td>
</tr>
<tr>
<td>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</td>
</tr>
<tr>
<td><strong>4.</strong> 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?</td>
</tr>
<tr>
<td>4.a The teachers will use elements of the design tool when designing their lessons</td>
</tr>
<tr>
<td>4.b The teachers will reflect upon their students’ learning from the lessons they designed and use this information in subsequent designs</td>
</tr>
<tr>
<td><strong>5.</strong> How and to what extent might examples and modelling support teachers in their design of innovative context-based lessons for their own classroom practice?</td>
</tr>
<tr>
<td>5.a The teachers will use the model lessons as templates when designing their lessons</td>
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</tbody>
</table>
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 analyzed 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.

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

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 patient’s 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.